Lean Production and Operational Performance: The Influence of Organizational Culture

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Abstract - The use of lean production methods to drive sustainable competitive advantage has been a cornerstone of worldwide manufacturing strategy since the early 1980's. Unfortunately, success from using lean has been mixed. Some researchers suggest that contextual variables play a central role in explaining the inconsistent results. This study evaluates the role of one critical contextual variable, organizational culture, in realizing operational improvements from lean. We investigate the influence of four distinct organizational cultures, as well as a hybrid culture and a firm's ability to be culturally ambidextrous, on the relationship between lean and operational performance, as measured by cost, quality, delivery and flexibility. We find that lean is able to maximize cost reduction in any organizational culture setting, but requires a supportive organizational culture to maximize quality, delivery, and flexibility improvements. Further, realizing quality improvements from lean is particularly sensitive to organizational culture. We also find that a developmental culture is the most supportive of lean; it outperforms all other individual cultures and performs as well as more complex cultural arrangements, such as a hybrid culture or a firm's ability to be culturally ambidextrous. Since a developmental culture is characterized by flexibility and an ability to embrace change, we propose that these organizational attributes unleash an advanced deployment of lean which results in superior operational performance.

Keywords – lean, operational performance, organizational culture, quality

1. Introduction

Lean production ("lean") can be defined as "an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability" (Shah & Ward, 2007). American consumers first experienced the value of lean in the 1970's, as Japanese auto manufacturers gained significant traction in U.S. markets following the 1973 oil crisis. The consumers did not know why Japanese imports were superior, only that the quality and price of Japanese vehicles were clearly superior to their American counterparts. It took until the 1980s for U.S. automakers to understand that the competitive landscape had changed and begin to study lean. Investigative study soon followed and continues to this day[1]. Over the past many years, researchers have earnestly attempted to understand the identifying technical and social characteristics behind lean and replicate it around the globe. However, the ability to consistently realize superior operational performance from lean has been elusive[2]. While many successes have been achieved, inconsistent operational results from lean have led researchers to consider contextual elements and interactions. One contextual variable of considerable interest is organizational culture.

[1] For a detailed timeline for the development of lean production, see Holweg 2007. For a detailed discussion of academic research on lean production, see Shah & Ward 2007.

[2] Pay, R. 2008. Everybody's Jumping on the Lean Bandwagon, but Many Are Being Taken for a Ride. Industry Week, March 1, 2008.

While researchers and practitioners have long known that organizational culture plays a key role in lean's ability to improve operational performance (ex. Nahm et al., 2004; Sakakibara et al., 1997), only recently have researchers begun to unpack this complex relationship (Bortolotti et al., 2015; Iyer et al., 2019; Losonci et al., 2017; Pakdil & Leonard, 2015; Tortorella et al., 2019; Wiengarten et al., 2015). For example, they have identified unique human resource practices that support lean, such as team players, flexible workers, workers who embrace change, small-group problem solving, and decentralized decision making (Challis et al., 2005; Sakakibara et al., 1997). They have also shown that an organizational culture which nurtures learning, communication, and knowledge sharing best supports lean (Iyer et al., 2019; Nahm et al., 2004; Tortorella et al., 2019). Finally, they show that organizational cultural attributes such as collectivism, future orientation, a humane orientation, and a lower level of assertiveness, positively moderate the relationship between lean and operational performance (Bortolotti et al., 2015; Naor et al., 2008; Wiengarten et al., 2015).

However, while much is known, several questions remain unanswered which will collectively extend our understanding of the complex and nuanced role organizational cultural plays in maximizing operational value from the use of lean. First, which specific organizational culture best exemplifies the cultural attributes, and nurtures development of the human resource practices, researchers have identified as critical to lean implementation success? We use the competing values framework (Quinn & Rohrbaugh, 1983) and the four organizational cultures types it develops (i.e.,hierarchical, group, rational, and developmental) to identify which organizational culture maximizes lean performance. Second, does lean require a supportive organizational culture to realize all types of operational performance, e.g., cost, quality, flexibility, and delivery? For example, researchers have shown that lean is particularly adept at reducing cost by eliminating waste (Achanga et al., 2006; Bicheno, 2004). As such, lean may not require a supportive organizational culture to maximize cost improvements. Similarly, lean's ability to maximize other types of operational improvement may not require a supportive organizational culture. Third, does lean require a complex organizational culture, such as a hybrid culture or the ability to shift between different cultures (ambidexterity), to maximize operational improvement? Successful lean implementation seems to require firms to manage competing organizational requirements, such as the need to be flexible, yet maintain a level of control; to look internal, but also external; and to value the individual worker, while also valuing the customer. It is possible that managing these contradictory requirements requires a complex organizational culture.

To evaluate these research questions, we use data gathered from 266 manufacturing plants and 9 industrialized countries. The results substantiate previous findings linking lean and operational performance. However, they also show that the magnitude of operational improvement is contingent on the type of organizational culture in place and the type of operational performance desired. We find that lean can maximize cost reduction in any organizational culture setting, but a developmental organizational culture is required maximize quality, delivery, and flexibility improvements from using lean. We also find that a developmental culture is the most supportive of lean, outperforming all other individual cultures and performing as well as a hybrid culture or a firm's ability to be culturally ambidextrous. The combined results provide a deeper understanding of the relationship between lean production, organizational culture, and operational performance, with implications for both practitioners and researchers. For practitioners, understanding how organizational culture impacts lean implementation better prepares them to use lean in the realization of business and operational goals. In particular, since lean's impact on cost performance is robust to organizational culture, using lean to reduce costs would seem to be an effective strategy, especially for those just beginning to use lean. Further, since complex organizational culture arrangements are unnecessary to realize full value from lean, a firm can focus on implementing a developmental organizational culture. This should be less complicated than implementing a hybrid culture or developing cultural ambidexterity. For researchers, we extend an understanding of the complex relationship between organizational culture and lean, and provide evidence that lean delivers differential value to operational performance. In the process, we demonstrate the organizational culture explains some portion of the inconsistent relationship between lean and operational performance observed in prior studies.

The remainder of this article is structured as follows. Section 2 provides a literature review and articulates testable research hypotheses. Section 3 discusses the data and the approach used to measure each variable. Section 4 describes the methods used to conduct the analyses and the analytical results. Section 5 discusses the essential findings. Finally, Section 6 discusses contributions from the study, as well as limitations and future research opportunities.

2. Literature Review and Research Hypotheses

Lean research has been on-going throughout its genealogical progression from the Toyota Production System (TPS), to Just-In-Time (JIT), and ultimately to lean (Holweg, 2007). Moreover, research related to lean production has been conducted using different terms (Shah & Ward, 2007).

We use the term 'lean' in this literature review to refer to research streams on TPS, JIT and lean. However, when referring to unique research projects, we use the specific term used by the author of the project.

2.1 Lean and operational performance

The relationship between lean and operational performance has been studied extensively. Testing the relationship in the current study serves two purposes. First, it provides an opportunity to validate prior studies using alternate data and measures. Researchers have long emphasized the importance of conducting replication studies (Hubbard & Vetter, 1996; Pagell, 2020). Second, it is a necessary prerequisite to evaluate the moderating role of organizational culture, the primary focus of the study. Most studies evaluating lean observe that it has a positive and significant impact on various measures of operational performance (Chavez et al., 2013; Fullerton & McWatters, 2001; Iyer et al., 2019; Mackelprang & Nair, 2010; Onofrei et al., 2019; Swink et al., 2005; Wiengarten et al., 2015). However, some authors find that only certain lean practices (Flynn et al., 1995; Matsui, 2007; McKone et al., 2001) positively influence operational performance. Notably, a small group of studies find no relationship between lean and operational performance (Dean Jr & Snell, 1996; Flynn et al., 1995; Snell, 1998; Swink et al., 2005). Researchers believe the inconsistent results may be explained by contextual and contingency factors. Contextual factors investigated include plant/firm characteristics such as size (Lawrence & Hottenstein, 1995; Shah & Ward, 2003; White et al., 1999), union status (Shah & Ward, 2003), type of production process (Lawrence & Hottenstein, 1995), employee development (Challis et al., 2005; Fawcett & Myers, 2001) and organizational culture (Bortolotti et al., 2015; Iyer et al., 2019; Losonci et al., 2017; Pakdil & Leonard, 2015; Tortorella et al., 2019; Wiengarten et al., 2015). Others have examined strategic and broader industry characteristics such as strategy integration (Swink et al. 2005), technology investment (Challis et al., 2005; Ward & Zhou, 2006), industry type (Lawrence & Hottenstein, 1995) and industry clock speed (Chavez et al., 2013). Finally, a handful of studies evaluate the role of national culture in realizing operational improvements from lean (Kull et al., 2014; Netland, 2016). Given the overwhelming evidence of a significant and positive relationship between lean and all types of operational performance, we propose:

> **Hypothesis 1 (H1) –** *The implementation and use of lean production is positively associated with firm operational performance, as measured by cost, quality, flexibility, and delivery.*

2.2 The moderating role of organizational culture

Practitioners and researchers have long understood that organizational culture plays a critical role in successfully implementing lean (ex. Nahm et al., 2004; Sakakibara et al., 1997). However, additional research unpacking this complex relationship has recently gained momentum (ex. Iyer et al., 2019; Losonci et al., 2017; Tortorella et al., 2019). What we know is that an organizational culture which encourages communication and knowledge sharing is positively associated with the implementation of lean (Nahm et al., 2004). Combining lean with human resource practices that may be associated with organizational culture, such as leadership, planning, HR management, training, and an ability to change, positively influences manufacturing performance (Challis et al., 2005). It is found that infrastructure quality practices, some of which touch upon aspects of lean production, are realized only within a hybrid organizational culture with high levels of group, developmental, and rational cultures, and low levels of hierarchical culture (Naor et al., 2008). Cultural collectivism at the national and organizational level is also found to have a significant impact on the efficacy of lean practices (Wiengarten et al., 2015). Successful lean plants have a specific organizational culture profile, i.e.,higher institutional collectivism, future orientation, a humane orientation, and a lower level of assertiveness (Bortolotti et al., 2015). Successful lean plants are also found to differ in the number of 'soft' practices they use, not the number of 'hard' tools they deploy. Soft practices are concerned with people and relations, such as small group problem solving, employees' training to perform multiple tasks, supplier partnerships, customer involvement, and continuous improvement (Bortolotti et al., 2015). Finally, characteristics reflecting a learning organization are highly correlated with the implementation of certain lean practices (Iyer et al., 2019; Tortorella et al., 2019).

2.2.1 Cultural alignment and successful lean implementation

Schein (1992, p. 12) defines organizational culture as "a pattern of basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and that, therefore, is taught to new members as the correct way to perceive, think, and feel in relation to those problems." Organizational culture is a group property which forms over time. Once formed, it is difficult to change. This study measures several different organizational cultures in order to identify which support, or hinder, successful

lean implementation. Prior studies have shown that cultural alignment leads to the successful implementation of management practices (Bortolotti et al., 2015; Detert et al., 2000; Gimenez-Espin et al., 2013; Green, 2012; Losonci et al., 2017; Naor et al., 2008; Zu et al., 2010). For example, Naor et al. (2008) find that an organizational culture with high levels of group, developmental, and rational cultures, and low levels of hierarchical culture, best supports the implementation of several management practices which overlap with lean. Bortolotti et al., (2015) find that successful lean plants have a specific culture profile, i.e., higher institutional collectivism, future orientation, a humane orientation, and a lower level of assertiveness. Finally, Losonci et al. (2017) find that flexibility-oriented culture types positively influence lean implementation.

2.2.2 Measuring organizational culture – The Competing Values Framework (CVF)

A large body of research begins with the assumption that culture is a measurable characteristic of an organization (O'Reilly & Chatman, 1996; Sorensen, 2002). In fact, many prominent studies in operations management are based on this assumption (ex. (Khazanchi et al., 2007; McDermott & Stock, 1999; Nahm et al., 2004; Naor et al., 2008). Several measurement systems exist to measure an organization's culture, including the Organizational Culture Inventory (Klein et al., 1995), Double S Cute (Goffee & Jones, 1998), and Competing Values Framework (Quinn & Rohrbaugh, 1983)[3]. The Competing Values Framework (CVF) is used in this study because it is well-established in research and practice and has been used extensively in OM research (Cameron & Quinn, 2005; Khazanchi et al., 2007; Losonci et al., 2017; McDermott & Stock, 1999; Naor et al., 2008, 2010, 2014; Pakdil & Leonard, 2015; Paro & Gerolamo, 2017).

The Competing Values Framework measures four distinct cultures, hierarchical, group, rational, and developmental, which reflect an organization's behavioral preferences regarding three value dilemmas, i.e., competing values; (1) focus on internal harmony/stability vs. focus on external competitiveness, (2) preference for stability/control vs. flexibility/change, and (3) concern for 'the end' vs. concern for the 'means' as an avenue to the end. The *hierarchical* culture type has an internal focus and stresses control. It emphasizes information management and communication as means to achieve stability and control. It has values and norms associated with bureaucracy, such as control, internal efficiency, and coordination. Motivational factors include stability, security, procedures, rules, and regulations. The *group* culture has an internal focus and values flexibility. It emphasizes cohesion and morale as means to achieve human resource development.

[3] See Detert and Schroeder (2000) for a literature review of other frameworks used to measure organizational culture.

It has values and norms associated with affiliation, teamwork, and participation. Organizations that adopt the group culture focus on achieving collective good through teamwork. Motivational factors include cohesiveness, attachment, and membership. The *rational* culture type has an external focus and is control oriented. It emphasizes planning, goal setting, and evaluation as a means to achieve productivity and efficiency. Organizations with a rational culture tend to focus on the pursuit and attainment of specific objectives. Motivational factors include competitiveness and goal attainment. The *developmental* culture has an external orientation and emphasizes flexibility and readiness as means to achieve growth and resource acquisition. It has values and norms associated with creativity, risk-taking, innovation, and adaptation to the external environment. Motivational factors include creativity, growth, and variety (Quinn & Rohrbaugh, 1983). The CVF is summarized in Figure 1.

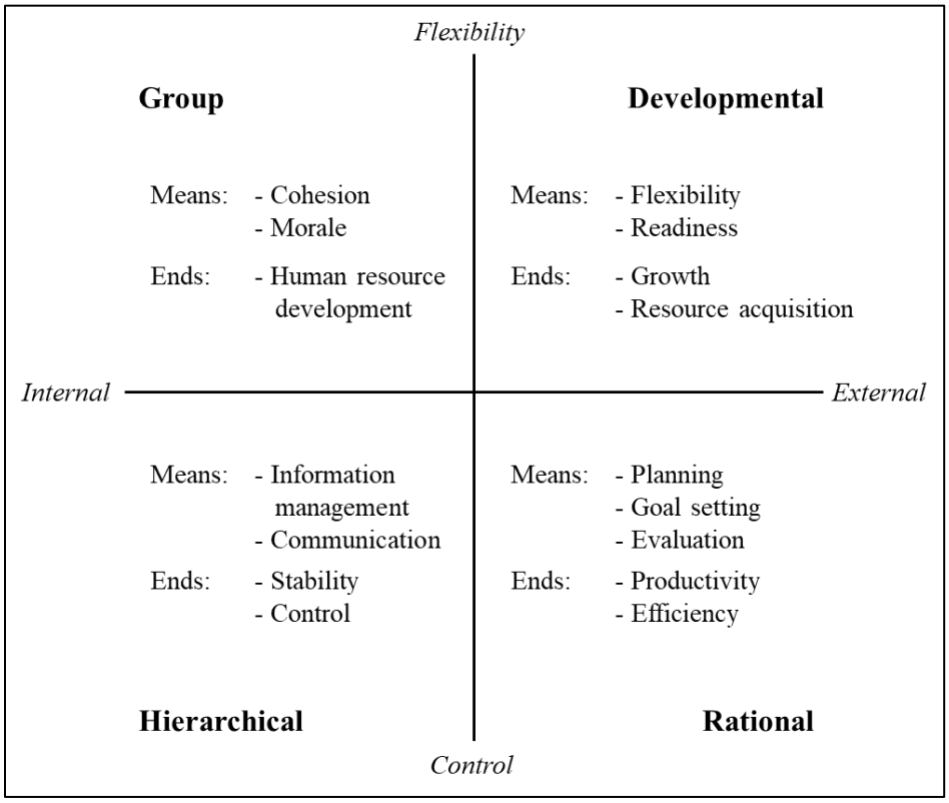

Figure 1. Competing Values Framework (adapted from Quinn & Rohrbaugh, 1983)

Notably, while the CVF identifies four distinct culture types, it does not mean that a firm can exhibit only one culture type. In practice, firms may exhibit a combination of various culture types (McDermott & Stock, 1999), even competing culture types (Buenger et al., 1996). This is consistent with Quinn & Rohrbaugh (1983) contention that competitive firms must be able to

handle conflicting and contradictory organizational requirements. Quinn and Rohrbaugh specifically note that while certain organizational cultures may be seemingly opposites (ex. developmental and hierarchical), they are not empirical opposites, i.e., mutually exclusive within a given organization. In fact, "an organization might be cohesive *and* productive or stable *and* flexible" (Quinn & Rohrbaugh, 1983, pg. 374). In sum, a single firm may exhibit multiple culture types, to varying degrees (Naor et al., 2014; Quinn & Rohrbaugh, 1983).

2.2.3 Lean's human resource system

Shah & Ward (2007) define lean as a 'socio-technical' system. While the technical tools are most visible when observing lean in practice, the social/human resource elements are equally important. Described as 'involved employees' by Shah and Ward, lean's human resource system departs significantly from the traditional practices used by other production systems. According to the literature, lean's human resource system includes 'respect-for-humanity' (which consists of group problem solving, employee accountability, and employee empowerment), incenting group performance over individual performance, frequent supervisor interaction with employees and the production process, multi-skilled employees, a focus on continuous improvement, and coordinated decision making across the organization (see Table 1 for details and references).

'**Respect-for-humanity**' - encourages active worker participation in problem solving and process improvement, elimination of wasted worker movement, consideration for worker safety, communication of management's respect and appreciation toward workers, and showing workers respect by entrusting them with greater responsibility and authority (de Treville & Antonakis, 2006; Hopp & Spearman, 1996; MacDuffie, 1995; Matsui, 2007; Mehra & Inman, 1992; Monden, 1983; Sakakibara et al., 1997; Sugimori et al., 1977; Womack et al., 1990) **- Group problem solving** - completing production tasks as individuals, but problem solving as a small group (de Treville & Antonakis, 2006; Matsui, 2007; Sakakibara et al., 1993, 1997) **- Employee accountability** – individual accountability for quality, equipment maintenance, and workplace discipline (Davy et al., 1992; de Treville & Antonakis, 2006) **- Employee empowerment** - supervisors relinquish control and provide employees tools, time, authority, and accountability for process and quality improvement (Collins et al., 1988; Davy et al., 1992; de Treville & Antonakis, 2006; Fawcett & Myers, 2001; Flynn et al., 1995; Kimura & Terada, 1981; Mehra & Inman, 1992). Called 'jidoka', employees are often empowered to stop the production line if they identify a quality issue.
Incentivizing group performance - incentivizing group performance, as opposed to individual performance (Matsui, 2007)
Frequent supervisor visits to the shop floor – called 'going to the *gemba*', the frequent visits ensure supervisors interact with employees and understand production challenges first-hand (Matsui, 2007)
Multi-skilled employees – lean tools, such as *production cells* and *job rotation*, require employees be able to perform multiple tasks (Curington et al., 1986; Davy et al., 1992; Matsui, 2007; Sakakibara et al., 1993). The compensation system in lean production often pays a premium for skill breadth (Luthans & Fox, 1989).

Continuous improvement - employee responsibility to look for ways to do their jobs more efficiently and involvement in process improvement, such as through *quality circles*, suggestion box or other (Davy et al., 1992)
Coordinated decision-making - coordination of decision making between various parts of the organization facilitates informed and efficient decisions to resolve problems as they arise (Hrebiniak & Joyce, 1985)

Table 1. Lean's human resource system

2.2.4 An organizational culture supportive of lean (as seen through the lens of the CVF)

To determine which cultures support or hinder operational performance, the lean human resource system described above is mapped against the three sets of competing values defined in the CVF. The result is a prediction for each culture type as to whether it supports, hinders, or is not expected to influence the realization of operational performance benefits from lean. Seen through the lens of the CVF, a 'lean' culture could be described as follows:

Focus (internal vs. external): An internal focus prioritizes the well-being of the individual, while an external focus prioritizes the well-being of the organization. Lean's 'respect-for-humanity' system emphasizes the importance and value of the individual, but as a means to achieve high levels of customer service. As such, lean focuses on the well-being of the individual, but only as a means to achieve well-being for the organization, as realized through superior customer satisfaction. We conclude that an organizational culture which emphasizes an external orientation (such as a developmental or rational culture) should better support the realization of operational benefits from lean.

Structure (control vs. flexibility): An organization that prioritizes control prefers stability and structure. An organization that prioritizes flexibility prefers individual and organizational adaptability. Lean values flexible individuals and a flexible production system. This is observed in its preference for a flexible worker able to do many jobs, significant decentralization of authority and worker empowerment (ex. Jidoka), the priority it places on small-group problem solving (ex. quality circles), and its preference for single-piece flow, i.e., making only what the customer wants when they want it (ex. JIT and cellular manufacturing). The combination of lean's social and technical elements results in a production system which is flexible and responsive to changing customer demands. As such, a culture that values individual and organizational flexibility (such as a group or developmental culture) should achieve greater operational benefits from lean.

Outcomes (ends and means): Lean's ultimate objective ('ends') is to achieve superior customer satisfaction, since superior customer satisfaction should result in organizational performance which

outpaces competition over time. Thus, a culture which values organizational growth (developmental) as an 'end' would seem to be a good fit with lean. However, even though a culture that strives for productivity and resource efficiency (rational) would seem to be a good fit with lean since lean emphasizes waste elimination (Shah & Ward, 2007), and a culture that values human resource development (group) would seem to be a good fit for reasons discussed previously, the relationship between these cultures and lean is unclear (from an 'ends' perspective). This is because the outcomes they seek would likely be 'means' to achieve customer satisfaction in a lean production environment, rather than organizational outcomes in themselves. Lastly, a culture which values stability and control (hierarchical) would seem to be a poor fit with lean because lean values the opposite, i.e.,flexibility and adaptability.

Lean achieves superior customer satisfaction through a variety of 'means'. One way is by developing employees and processes which are supremely adaptable, as discussed previously, i.e., produce exactly what customers want when they want it. Thus, a developmental culture which values flexibility and readiness should be a good with fit with lean. Similarly, because lean emphasizes employee respect, empowerment, and accountability ('respect-for-humanity'), a group culture which values cohesion and morale should be a good fit with lean. Finally, because lean emphasizes careful planning, goal setting, and evaluation, as evidenced through lean tools such as Hoshin Kanri (policy deployment) and Heijunka (level scheduling), a rational culture would seem to fit well with lean. However, it would seem that a hierarchical culture which values information and communication control would be a poor fit with lean, since lean's preference for decentralized decision-making and worker empowerment make such control unnecessary.

The preceding conversation is summarized in Table 2. At the bottom of Table 2, and presented in the hypotheses below, are our conclusions regarding the fit between each culture type and lean.

	Organizational Culture Type			
CVF Element	**Hierarchical**	**Group**	**Rational**	**Developmental**
Focus (internal vs. external)			✓	✓
Structure (control vs. flexibility)		✓		✓
Outcomes (ends)	✘	Maybe	Maybe	✓
Outcomes (means)	✘	✓	✓	✓
Cultural fit with lean	***Poor***	***Fair***	***Fair***	***Good***

Table 2. Fit between organizational culture and lean (as examined through the CVF)

Hypothesis 2a (H2a) – *A **hierarchical** culture will **negatively** moderate the relationship between lean and operational performance.*
Hypothesis 2b (H2b) *– A **group** culture will **not moderate** the effect of lean on operational performance.*
Hypothesis 2c (H2c) – *A **rational** culture will **not moderate** the effect of lean on operational performance.*
Hypothesis 2d (H2d) – *A **developmental** culture will **positively** moderate the relationship between lean and operational performance.*

2.2.5 The moderating impact of a hybrid culture and cultural ambidexterity

In addition to clarifying which organizational culture best supports lean, we desire to understand whether a singular organizational culture maximizes lean's ability to deliver all types of operational improvement or whether a more complex cultural arrangement is required, such as a hybrid culture or the ability to be culturally ambidextrous. Successful lean production seems to require firms to manage competing organizational requirements, such as the need to be flexible, yet maintain a level of control; to look internal, but also external; and to value the individual, while also valuing the customer. Thus, firms which better manage these apparent contradictions should achieve better operational performance from lean (Naor et al., 2014). According to the literature, a firm can better manage competing organizational requirements in at least two ways. The first is to possess a hybrid culture which embodies the most supportive elements of each individual culture (maximizing some, minimizing others). In support of this view, Gimenez-Espin et al. (2013) find that a hybrid culture made up of group and developmental cultures best facilitates the implementation of an operations management system. Also, Naor et al. (2008) find that a hybrid culture consisting of high group, developmental and rational cultures, but low hierarchical culture best facilitates the implementation of certain operations management practices. The second approach is to be culturally ambidextrous, i.e., develop the ability to flex between different cultures, as the situation requires. In support of this view, Quinn & Rohrbaugh (1983) note that "in the administrative world, an effective organization may need to perform well on all four sets of criteria. However, at any given time there are likely to be tradeoffs between the criteria". In sum, we expect that firms which pair lean with a hybrid culture or cultural ambidexterity will achieve greater operational performance than firms which have a dominant organizational culture, even if that culture is supportive of lean.

Hypothesis 3 (H3) – *Firms which possess a hybrid culture or demonstrate cultural ambidexterity will achieve better operational performance from lean than firms which possess a single, dominant organizational culture.*

3. Data and Measures

3.1 Sample

The data used in this study comes from the High-Performance Manufacturing (HPM) project. HPM is an international research project, data from which has been used extensively in academic research to study the connection between various firm practices and attributes (including lean and organizational culture) and manufacturing performance (ex. Bortolotti et al., 2015; Furlan et al., 2011; Hallgren & Olhager, 2009; Naor et al., 2014). Data was collected from 266 randomly selected manufacturing plants located in the United States, Finland, Sweden, Spain, Austria, Italy, Japan, Germany and South Korea. The countries were chosen as representative of the most industrialized nations, while also providing diverse national cultures and economic characteristics. The plants selected were a mixture of high-performing and traditional, from three manufacturing sectors: machinery, electronics and transportation equipment (SIC codes 35, 36 and 37 respectively). The industries selected included a mix of stable and rapidly changing competitive environments. Each plant had a minimum of 100 employees and all plants were from different parent organizations. Table 3 provides the number of responding plants by industry and country. Capturing data at the plant level is appropriate since both lean and culture impact firm performance at the plant level. It is also consistent with prior studies investigating the impact of lean production on operational performance (Mackelprang & Nair, 2010). Choosing a higher level of analysis has the risk of co-mingling effects from other organizational changes on operational performance. The industries and process types included in the study represent a significant portion of worldwide manufacturing capacity, improving the generalizability of the results.

	Industry			
Country	**Electronics**	**Machinery**	**Transportation**	**Total**
Finland	14	6	10	30
Sweden	7	10	7	24
Germany	9	13	19	41
Italy	10	10	7	27
Austria	10	7	4	21
Spain	9	9	10	28
Japan	10	12	13	35
South Korea	10	10	11	31
United States	9	11	9	29
Total	88	88	90	266

Table 3. Sample demographics (number of plants)

3.2 Survey instrument

Participating plants were randomly selected from a master list of production facilities in each country. A local member of the research team contacted the plant manager at each facility. In exchange for participation in the study, participating plants were provided a benchmarking report of their performance against other facilities in their own country, as well as against facilities in other countries included in the study. Each plant completed a battery of questionnaires, with each questionnaire completed by the people most qualified to respond. For example, the Production Control Manager answered questions related to production and the Quality Manager answered questions related to quality. Final scores for each question were the average response across all respondents for that question. Since surveys were also conducted in countries where English was not the first language, a careful process was followed to ensure correct translation of the questionnaires into the local language. The survey response rate was 65%.

3.3 Measures

3.3.1 Dependent variable

Operational performance: Measures for cost, quality, delivery and flexibility are developed using an existing measurement system developed for the HPM data by Naor et al. (2008, 2010, 2014). Each operational performance metric is measured as a first-order factor. The individual measurement items evaluate a respondent plant's performance relative to the competition, using a 5-point Likert-type scale (see Appendix A for measurement details). The plant manager was the primary respondent for each item.

3.3.2 Independent variable

Lean production: While various measurement systems for lean exist (ex. Mehra & Inman, 1992; Sakakibara et al., 1993), Shah & Ward (2007) were the first to develop a standardized measurement system. We leverage their approach and operationalize lean by including pull, flow, low setup and total productive maintenance (TPM). We focus on this subset of constructs for a number of reasons. First, since our study evaluates manufacturing plants, we focus only on lean practices which will be clearly evident within a plant. Shah and Ward describe these practices as 'internally related'. Second, given that our organizational culture variables capture elements of human behavior, we exclude another measure of human behavior, 'involved employees', to avoid endogeneity concerns. Finally, we exclude statistical process control to be consistent with the set

of tools and techniques deemed to comprise lean production (ex. Bhamu & Sangwan, 2014; Fullerton et al., 2014; Jasti & Kodali, 2015; Jayaram et al., 2008; Mackelprang & Nair, 2010). Lean is thus modeled as a second-order construct representing complementarities among the four first-order factors of Pull, Flow, Setup, and TPM (see Appendix A for measurement details).

3.3.3 Moderating variables

Organizational Culture: Measures of hierarchical, group, rational and developmental organizational cultures are developed using an existing measurement system developed for the HPM data by Naor et al. (2014). Each culture type is measured as a first-order factor. Unique items are measured using a 7-point Likert-type scale (see Appendix A for measurement details).

Hybrid culture: In developing Hypotheses 2a-2d, we proposed that a developmental culture would positively influence, a hierarchical culture would hinder, and group and rational cultures might positively influence performance from lean, but the relationship is uncertain (see Table 2). Taken together, we propose that a hybrid culture consisting of high levels of developmental, group, and rational cultures, and a low level of hierarchical culture will be the most supportive of lean. A hybrid culture variable is thus developed as the sum of developmental, group, and rational culture factor scores, minus the hierarchical culture factor score.

Cultural ambidexterity: Building on the prior conversation, an ambidextrous firm which can flex between developmental, group and rational cultures should realize better performance from lean. The variable is developed following the approach recommended by He & Wong (2004). They propose that a firm can be considered ambidextrous in a 'fit as moderating' strategic fit analysis if it scores high on all pertinent cultures. As such, ambidexterity is measured as the cross-product of each culture score. High levels of the cultural ambidexterity variable thus reflect plants with high developmental, group, and rational culture scores.

3.4 Measurement system validation

Common respondent bias is avoided in two ways. First, the independent and dependent variables are assessed by different respondents (Ketokivi & Schroeder, 2004). Second, a different response format is used for dependent and independent variables (Maruyama, 1997), i.e., operational performance items are measured on a 5-pt scale, while culture items are measured on a 7-pt scale. To minimize common method bias, the survey included a mix of item types and reverse scales (Crampton & Wagner III, 1994). In addition, we conducted Harman's one-factor test and did not

find a dominating factor that accounted for more than 50% of total variance. Finally, single-rater bias was avoided by asking multiple respondents to answer each question.

4. Methods and Results

4.1 Methods

Factor analysis is used to develop first- and second-order factors for each variable, excluding hybrid culture and cultural ambidexterity, and structural equation modeling (SEM) is used to evaluate research hypotheses. As compared to regression analysis, SEM analyzes all proposed relationships simultaneously. This results in more accurate measurement errors and subsequently, more accurate parameter estimates in research contexts such as ours (Hair et al., 2010). Finally, the fit between lean, operational performance, and organizational culture is modeled as 'fit as moderation' since the fit relationship includes only three variables, has a high degree of specificity, and anchors on a specific criterion variable, organizational performance (Venkatraman, 1989). Since we propose that lean's impact on operational performance differs across different cultural environments, i.e., high vs. low, fit as moderation is tested using subgroup analysis.

4.2 Results

4.2.1 Lean and operational performance

H1 posits that lean will have a significant and positive impact on operational performance. To test this hypothesis, a structural equation model is fit using the overall sample (Figure 2). The model fit indices are reported at the top of Table 4 and the regression coefficients with their significance are summarized at the top of Table 5. The results indicate that the model fits very well and lean has a significant and positive impact on all four measures of operational performance, including cost, quality, flexibility, and delivery. The results validate prior research and reinforce the significant positive impact of lean production on operational performance.

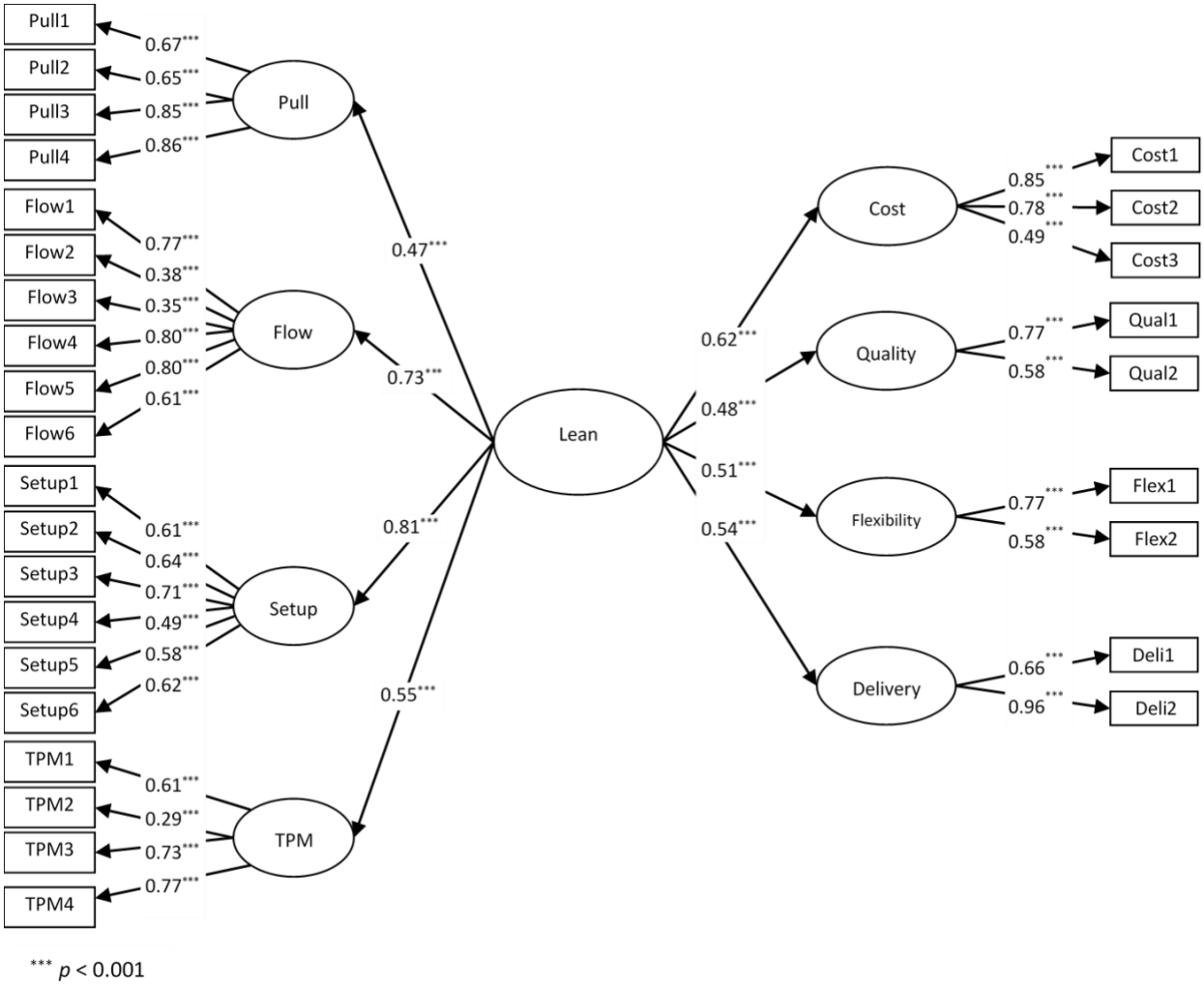

Figure 2. Structural model for the complete sample

4.2.2 The moderating impact of organizational culture

Factor analysis is used to develop culture scores for each plant. Since a plant can exhibit more than one type of organizational culture (see Section 2.2.2), four culture scores are developed for each plant. For each culture type, plant scores are split on the median to place plants into high and low groups of equal size. Finally, the same SEM model is fitted for each subgroup. Fit as moderation is signaled if there is statistical difference between the regression coefficients attached to the lean in the high and low groups using a standard t-test (Bruning & Kintz, 1987, pp. 226-228). Model fit indices are shown in Table 4 and results are shown in Table 5.

Model	χ^2	df	Normed χ^2	IFI	TLI	CFI	RMSEA
Overall	639.511	363	1.762	0.903	0.892	0.902	0.054
High hierarchical culture	558.981	363	1.540	0.881	0.863	0.878	0.064
Low hierarchical culture	518.973	363	1.430	0.887	0.869	0.883	0.057
High group culture	530.632	363	1.462	0.883	0.865	0.880	0.059
Low group culture	537.304	363	1.480	0.874	0.854	0.870	0.060
High rational culture	565.387	363	1.558	0.853	0.830	0.848	0.065
Low rational culture	500.398	363	1.379	0.888	0.870	0.884	0.054
High developmental culture	500.348	363	1.516	0.881	0.863	0.877	0.063
Low developmental culture	540.665	363	1.489	0.867	0.846	0.862	0.061
High hybrid culture 1	510.608	363	1.407	0.854	0.830	0.848	0.056
Low hybrid culture 1	618.875	363	1.705	0.872	0.854	0.869	0.073
High hybrid culture 2	529.073	363	1.458	0.893	0.877	0.890	0.059
Low hybrid culture 2	551.079	363	1.518	0.863	0.842	0.859	0.063
High ambidexterity 1	500.535	363	1.379	0.906	0.892	0.904	0.054
Low ambidexterity 1	514.527	363	1.417	0.890	0.873	0.887	0.056
High ambidexterity 2	515.543	363	1.420	0.906	0.892	0.903	0.056
Low ambidexterity 2	555.326	363	1.530	0.857	0.835	0.852	0.063
Western countries	558.015	363	1.537	0.899	0.885	0.897	0.052
Eastern countries	589.719	363	1.625	0.825	0.797	0.819	0.098

Table 4. Model fit indices

Hypothesis 2a posits that a hierarchical culture will *negatively* moderate the effect of lean on operational performance. Table 4 shows that fit indices from the two subgroups are similar. Table 5 shows that a hierarchical culture does not significantly moderate lean's impact on any of the four measures of operational performance. Thus, inconsistent with our hypothesis, a hierarchical culture does not seem to hinder or help lean deliver operational improvements.

Hypothesis 2b posits that a group culture will *not* moderate the effect of lean on operational performance. Table 4 shows that fit indices from the two subgroups are almost identical and Table 5 shows that a group culture does not significantly moderate lean's impact on cost, flexibility, and delivery. However, a group culture is found to negatively impact lean's ability to improve quality. Thus, we find only partial support for H2b.

Hypothesis 2c posits that a rational culture will *not* moderate the effect of lean on operational performance. The results support this hypothesis. Table 4 shows that fit indices from the two subgroups are similar and Table 5 shows that a rational culture does not moderate lean's impact on any of the four measures of operational performance.

	Cost	Quality	Flexibility	Delivery
Overall	0.25***	0.24***	0.35***	0.29***
Organizational Cultures				
High hierarchical	0.23***	0.32***	0.31***	0.30***
Low hierarchical	0.26***	0.19**	0.38***	0.27***
Difference (T & P-value)	-0.43	1.59^{+}	-0.74	0.25
High group	0.28***	0.13*	0.32***	0.23***
Low group	0.26***	0.36***	0.31***	0.35***
Difference (T & P-value)	0.20	**-2.59****	0.11	-1.09
High rational	0.26***	0.22***	0.31***	0.20**
Low rational	0.24***	0.20**	0.33***	0.36***
Difference (T & P-value)	0.19	0.26	-0.24	-1.38^{+}
High developmental	0.28***	0.33***	0.40***	0.40***
Low developmental	0.19***	0.12*	0.24***	0.20**
Difference (T & P-value)	1.08	**2.45****	**1.63***	**1.87***
Hybrid Culture				
High hybrid 1	0.25***	0.35***	0.44***	0.35***
Low hybrid 1	0.32***	0.14*	0.27***	0.23**
Difference (T & P-value)	-0.68	**2.39****	**1.69***	1.06
High hybrid 2	0.32***	0.31***	0.44***	0.39***
Low hybrid 2	0.17**	0.14*	0.21**	0.20**
Difference (T & P-value)	**1.73***	**1.92***	**2.30****	**1.73***
Ambidextrous Culture				
High ambidexterity 1	0.28***	0.34***	0.44***	0.44***
Low ambidexterity 1	0.22***	0.16**	0.29***	0.22**
Difference (T & P-value)	0.60	**2.04***	1.55^{+}	**2.04***
High ambidexterity 2	0.27***	0.26***	0.38***	0.26***
Low ambidexterity 2	0.21***	0.23***	0.28***	0.29***
Difference (T & P-value)	0.78	0.24	0.98	-0.33
Country Culture				
Western countries	0.25***	0.26***	0.33***	0.31***
Eastern countries	0.22**	0.19*	0.43***	0.24*
Difference (T & P-value)	0.34	0.77	-0.92	0.64

Significant at *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; + $p < 0.1$

Table 5. Lean's impact on operational performance

Hypothesis 2d posits that a developmental culture will *positively* moderate the effect of lean on operational performance. Table 4 shows that fit indices from the two subgroups are similar. Consistent with H2d, Table 5 indicates that plants with a high developmental culture outperform plants with a low developmental culture, with respect to quality, flexibility, and delivery performance. However, a developmental culture does not seem to moderate lean's impact on cost reduction. The composite results provide partial support for H2d. Further, a developmental culture appears to be the most supportive of lean.

The results yield also some valuable observations when viewed from the lens of operational improvement type. First, lean has a strong and positive influence on all types of operational performance, regardless of organizational culture. However, the magnitude of improvement can be enhanced (or diminished) by the presence of a supporting (or hindering) organizational culture. Second, lean maximizes cost reduction in any culture setting. In contrast, lean's ability to improve delivery, flexibility, and quality performance is only maximized when implemented within a developmental culture. Further, lean's ability to improve quality is extremely sensitive to organizational culture. It is enhanced within a developmental culture, but hindered within a group culture. Third, a developmental culture appears to be the most supportive of lean. We discuss valuable implications from these findings in Sections 5.1 and 5.2.

4.2.3 The moderating impact of a hybrid culture and cultural ambidexterity

To evaluate whether a hybrid culture or cultural ambidexterity outperforms a single organizational culture in its ability to deliver operational benefits from lean (H3), we test 'fit as moderation' as before. As discussed in Section 3.3.2, measures of hybrid culture and cultural ambidexterity were developed under the assumption that developmental, group, and rational cultures would be supportive of lean, while a hierarchical culture was expected to hinder lean's ability to deliver operational improvement. Results are provided in Tables 4 and 5 under the titles Hybrid 1 and Ambidexterity 1 respectively. The model fit indices in Table 4 suggest that all models fit the data well. We subsequently observe in Table 5 that a hybrid culture enhances lean's ability to improve quality and flexibility performance, while cultural ambidexterity enhances lean's ability to improve quality and delivery performance.

As a robustness check, we develop and evaluate revised measures for hybrid culture and cultural ambidexterity that incorporate the results from investigating H2a-d. Those analyses showed that a developmental culture was the most supportive of lean, a group culture was the least supportive, and rational and hierarchical cultures did not help nor hinder. Combining our original predictions (H2a-d) with the afore-mentioned results, we propose that a hybrid culture which consists of high levels of developmental and rational culture types and low levels of hierarchical and group culture types will best support lean performance. Extrapolating this prediction to cultural ambidexterity, we propose that a firm which can flex between developmental and rational cultures will best support lean. The results from this robustness check are provided in Tables 4 and 5, under the labels 'Hybrid 2' and 'Ambidexterity 2' respectively. As shown in Table 5, Hybrid 2

enhances lean's ability to improve operational performance of all types, but Ambidexterity 2 neither enhances or hinders lean's ability to improve operational performance of any type.

As a final step to evaluate H3, we compare the best performing hybrid culture (Hybrid 2) and best performing ambidexterity measure (Ambidexterity 1) against the most supportive single culture (developmental). T-tests show no differences, suggesting that a developmental culture performs as well as a hybrid culture or cultural ambidexterity in maximizing operational performance from lean. This is good news for practitioners since implementing a single organizational culture should be less complex than implementing a hybrid culture or cultural ambidexterity. In sum, the results do not provide support for H3.

4.3 Post hoc analysis - Western vs. Eastern countries

While individual plants possess unique organizational cultures, they operate in countries which have distinctly different characteristics, such as national cultures (Hofstede, 1984; House et al., 2004; Smith, 2006). For example, Hofstede (1984) finds that Western countries (ex. United States) focus more on individualism and strive to equalize power across members of society. In comparison, Eastern countries (ex. Japan) emphasize collectivism, restraint through strict social norms, and rigid codes of belief and behavior. These differences may impact how lean is deployed and the resulting operational benefits derived from lean. To address this possibility, we repeat H1 after splitting the plants in our sample into two country groups based on similar national cultures. We follow Naor et al. (2008, 2010, 2014) to create a group of 200 plants which operate in Western countries (Austria, Finland, Germany, Italy, Spain, Sweden and the United States) and a group of 66 plants which operate in Eastern countries (Japan, South Korea).

Results from this analysis are shown in Tables 4 and 5. The model fit indices in Table 4 suggest that models for both subsamples fit the data well. As to the comparative results in Table 5, we first notice that lean drives significant and substantial operational improvement in both Western and Eastern countries, across all measures of operational performance. We subsequently observe that there appears to be no significant difference across the two groups in the magnitude of operational benefits derived from lean, regardless of operational performance type. This suggests plants in both regions of the world realize significant and similar operational benefits from lean.

5. Discussion and Conclusions

The use of lean methods to drive sustainable competitive advantage has been a cornerstone of worldwide manufacturing strategy since the mid 1990's. Unfortunately, success from using lean

has been inconsistent. This study evaluates the critical role of organizational culture in realizing operational benefits from lean. In the first investigation, we identify a significant and positive relationship between lean and all types of operational performance, including cost, quality, delivery and flexibility. The result confirms findings from prior studies, albeit over a more comprehensive sample of plants and countries. The 266 plants in our sample come from 9 different industrialized countries and operate in both stable and rapidly changing competitive environments. Thus, lean production seems to be broadly applicable to different national, organizational, and operational contexts. Through a post hoc analysis, we find that lean delivers similar operational benefits across diverse country contexts (West vs. East). This might be surprising given the dramatic differences between Eastern and Western countries in attributes which could affect operational performance, such as national culture. However, the result is consistent with that obtained by Naor et al. (2010), who find that national culture does not enhance or hinder operational performance. While it is unclear whether or how a country's national culture influences a firm's organizational culture, we conclude from incorporating results from later analyses that firms from any country desiring to implement lean should focus on creating a developmental culture within their organization. This conclusion is especially salient in the current era of increased business globalization, where companies regularly relocate operations to other countries or work with suppliers from other countries to implement lean production

We next investigate the moderating role of organizational culture. The first observation is that lean's impact on cost performance is robust to organizational culture. This knowledge is important to practitioners who often look to lean as an avenue to obtain or maintain competitive manufacturing cost positions. While previous authors have shown a similar relationship (e.g., Narasimhan et al., 2006; Shah & Ward, 2003), the current finding is useful by showing the strength of the relationship. A subsequent finding is that lean's impact on quality performance is particularly sensitive to organizational culture. While lean delivers quality improvements in all organizational cultures, quality performance is enhanced within a developmental culture and diminished within a group culture. In fact, lean's impact on flexibility and delivery is also enhanced within a developmental culture. Thus, a developmental culture appears to be the most supportive of lean, enhancing quality, flexibility, and delivery performance. Finally, we find that a developmental culture supports the delivery of operational benefits from lean as well as a complex hybrid culture or the ability to be culturally ambidextrous. Assuming it is easier to

implement a single developmental culture than a hybrid culture or cultural ambidexterity, this knowledge should be valuable to practitioners.

5.1 Organizational culture and different types of operational performance

A key conclusion from the study is that lean's ability to reduce cost is robust to organizational culture. In contrast, lean's ability to maximize flexibility, delivery, and quality improvements is maximized only when lean is implemented within a developmental organizational culture. We believe an explanation for this result lies in examining the interplay between the 'hard' technical tools and the 'soft' human resource practices (see Table 1) that comprise lean's 'socio-technical' system (Bortolotti et al., 2015; Shah & Ward, 2007). Lean technical tools and human resource practices are implemented through a 5-stage process; (1) specify value from the perspective of the final customer, (2) define and improve the value stream, (3) create flow, (4) create pull, and (5) continuously improve (Womack & Jones, 1996). The lean tools used in the different phases vary significantly in technical complexity and employee skill requirements (Bortolotti et al., 2015; Tortorella et al., 2019). Foundational tools, such as value analysis, value stream mapping, process mapping, takt time analysis, process balancing, and setup reduction, are deployed in Phases 1-3. Other foundational tools, such as preventive maintenance and 5S, are deployed in Phase 5. Successful implementation of foundational tools reduces process waste, resulting in cheaper processes (George, 2004). Since foundational tools require limited training or changes to a firm's existing human resource practices (George et al., 2005), we propose they can be implemented successfully in any organizational culture setting. As such, lean can maximize cost reductions in any organizational culture setting. That is not to say that organizational culture doesn't matter, as a supportive culture might accelerate the pace of improvement, but that organizational culture does not moderate the relationship between lean implementation and process cost reductions.

More complex tools, such as Kanban and work cells, are required to create pull (Phase 4). These tools increase process speed and flexibility. However, in contrast to foundational tools, implementation of these tools requires extensive training, cross-departmental collaboration, and significant changes to existing human resource practices, such as creating multi-skilled employees, instilling individual accountability, and developing group problem solving skills (George et al., 2005). Since the worker skill requirements are unique and deviate significantly from traditional human resource practices, successful implementation may require an organizational culture which nurtures their development. Finally, tools such as root cause analysis (Ishikawa diagrams and 5-

whys) and mistake proofing (Poke Yoke) are essential for improving process quality. They are generally implemented in Phase 5. While not technically complex, they require that employees take accountability for process performance and change the way they approach process improvement. Since they require employees to work differently, implementation success may again require an organizational culture that supports and nurtures their use and development.

5.2 Taking lean from good to great, the role of a Developmental culture

The second major conclusion from the study is that a developmental culture uniquely supports lean's ability to deliver superior operational outcomes. A developmental culture has an exceptional capacity to be flexible and embrace change (Quinn & Rohrbaugh, 1983). It also has values and norms associated with creativity, risk-taking, innovation, and adaptation to the external environment. We propose that these unique organizational attributes nurture the deployment of advanced lean tools and human resource practices required to deliver superior quality, flexibility, and delivery performance (see Section 5.1). Support for our proposal can be found in the literature. Ward et al. (1996) identify an organizational configuration they label as 'lean competitor' which delivers superior operational results. A lean competitor thrives in an environment of high velocity and complexity, but requires an adaptive organizational structure. Tortorella et al. (2019) find that elements of a 'learning organization' are positively correlated with the implementation of more complex lean practices. In this context, a learning organization is defined as an organization where employees continuously increase their ability to generate desired results through the development of novel ways to think collectively, so that organizational members learn to learn together (Senge, 1990). In this sense, learning organization practices are elements of organizational culture. Onofrei et al. (2019) find that operational benefits from lean are significantly enhanced within an organization which has significant 'intellectual capital'. In this context, intellectual capital is "a system of knowledge-based resources" that includes human capital (expert employees), structural capital (well defined and documented processes), and social capital (broad problem solving and collaboration across employees and departments). Finally, Narasimhan et al. (2006) show that the implementation of advanced lean practices, such as close relationships with suppliers and JIT production techniques (pull systems and work cells), and highly developed employee work practices create a production environment which produces superior quality, delivery, and flexibility. Interestingly, they also find that cost improvements are similarly realized in both a basic and advanced (agile) lean implementation. These findings mirror our own, suggesting that the key

to advanced lean implementation and superior operational outcomes is the presence of a developmental organizational culture.

6. Contribution, Limitations and Future Research Opportunities

6.1 Contributions to practice and theory

The cumulative results provide a deeper understanding of the relationship between lean, organizational culture, and operational performance, with implications for both practitioners and researchers. For practitioners, the most significant contribution is the knowledge that a developmental culture uniquely maximizes lean's ability to improve operational performance. In fact, a developmental culture performs as well as a hybrid culture and a firm's ability to be culturally ambidextrous. While lean positively impacts operational performance of all types, regardless of organizational culture, a developmental culture is required to maximize quality, flexibility, and delivery benefits. We propose that the match between lean and a developmental culture unleashes an advanced application of lean which produces superior operational benefits. Since implementing a single culture should be less complex than developing a complex hybrid culture or the ability to be culturally ambidextrous, this finding is good news for practitioners.

A second valuable finding for practitioners is that lean has a positive and significant impact on cost reduction and the impact is robust to organizational culture. This is an important contribution because many practitioners pursue lean as a cost reduction strategy. Our results lend credibility to that strategy. The fact that cost reduction can be achieved in any cultural setting is advantageous to new users of lean because maximum value can be realized without adjusting a firm's organizational culture, a task which can be challenging. A final contribution for practitioners is the observation that lean delivers similar operational value in any country. This finding is particularly useful in the current era of expanding globalization. Firms increasingly relocate or outsource operations to other countries. Lean is frequently deployed in these international settings to drive operational improvements. Our findings suggest that firms can realize full value from international investments in lean without adjusting for unique attributes of the host country, such as national culture. Instead, they should focus their energy on developing a developmental organizational culture within their organization. Taken together, the results better prepare practitioners to maximize the use of lean in the realization of business and operational goals.

For researchers, the results validate conventional wisdom and previous empirical evidence that lean improves all measures of operational performance. However, the extent of improvement

depends on organizational culture. A developmental culture uniquely supports an advanced implementation of lean, maximizing operational performance. The results at least partially explain the inconsistent results observed in prior studies. They also suggest that future researchers should control for organizational culture when evaluating the impact of lean on operational performance. Further, although a hybrid culture and cultural ambidexterity have been found to be useful in achieving superior performance in other organizational improvement contexts, they are not needed to maximize operational improvement using lean. This suggests that researchers need to be cautious in unilaterally adopting concepts from other disciplines. Lastly, our multi-country, multi-industry and multi-plant analysis allows us to uncover universality in the relationship between lean and operational performance.

It is worth noting that while our research provides valuable new insights, we also evaluate important relationship which have been studied previously. For example, we use different data and measures to replicate the relationship between lean and operational performance. Such examinations address the "replication crisis" in operations management (Pagell, 2020). Replication studies help establish the "robustness and empirical generalizations of results, thus contributing to the growth of knowledge" (Hubbard & Vetter, 1996). Recently, researchers from management (Bamberger, 2019; Miller & Bamberger, 2016), strategy (Aguinis & Solarino, 2019; Bettis et al., 2016), economics (Duvendack et al., 2017), psychology (Maxwell et al., 2015) and operations management (Hubbard & Vetter, 1996; Pagell, 2020) have published editorial opinions and research articles to extoll the value of replication studies.

6.2 Limitations and future research

While offering important new insights regarding lean production, our study is not without limitations. One limitation is that the study does not evaluate whether lean influences a firm's culture, a firm's culture influences lean, or both. This is an important question because while cost reductions are maximized in any cultural setting, quality, flexibility and delivery improvements are maximized only within a developmental culture. If in fact lean develops and modifies culture, organizations desiring to implement lean need not worry about adjusting their existing culture to maximize all types of operational performance, as it will happen organically over time. On the other hand, if organizational culture is relatively unaffected by the implementation of lean, business leaders will need to make cultural adjustments to realize full value from lean. Note that

one research study finds that culture change happens in both directions, i.e., while lean influences culture, firms must be intentional in their efforts to achieve the desired culture (Shook, 2010).

A second possible limitation is that we use cross-sectional data to capture performance effects which occur over time. More specifically, firms generally increase the use of lean methods over time, resulting in greater operational benefit over time. Additionally, operational benefits may be slightly delayed after deploying lean. Thus, should a plant included in our study only begin deploying lean immediately prior to data collection, the operational benefits from that deployment may not be fully visible in the data. While gathering longitudinal data would be one way to resolve this concern, we believe it is unnecessary. First, lean has been in use since the early 1980's. Thus, at the time of data gathering most study respondents (plants) would have been using lean practices for many years and benefits from that implementation would be visible at the time of data collection. Second, the delay between lean deployment and benefits realization should be relatively minor, since lean process improvements should be visible rather quickly.

Beyond the research ideas mentioned previously, additional opportunities exist to extend and advance the current study. One idea would be to evaluate the connection between lean implementation and organizational culture over time. The implementation of process improvement methodologies, including lean, has had notoriously high failure rates. In fact, there are many examples of failure even after tremendous gains were achieved. This presents an interesting research opportunity aimed at better understanding these failures, such as examining whether the type of organizational culture at time of implementation predicts the ultimate adoption of lean. Another idea to potentially investigate is whether the best culture for lean is department specific, as opposed to firm specific. For example, one culture may be needed to maximize lean in R&D, a second may be needed to maximize lean in the back-office, and a third may be required to maximize lean in manufacturing. The culture which best supports lean execution may thus be a collection of cultures that are department specific. A final idea for investigation would be to determine how challenging it is to implement a developmental culture and how best to install it. It is possible that developmental culture is a particularly difficult or easy to implement. Knowing how to effectively and efficiently implement it would be of value to practitioners.

Despite these limitations, our results have critical implications for both theory and practicing managers. By identifying the organizational culture that best supports lean implementation and demonstrating the complex relationship between organizational culture and different types of

operational performance, our study helps clarify confusion around implementing lean and maximizing performance benefits from its use.

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Appendix A - Measurement Scales and Details

Survey items for Lean

All items are rated on a 1-7 Likert-type scale: 7 = strongly agree, 6 = agree, 5 = slightly agree, 4 = neutrality, 3 = slightly disagree, 2 = disagree, 1 = strongly disagree.

	Pull (Cronbach's alpha = 0.86)	**Mean**	**Std dev.**	**Loading**
Pull1	Suppliers fill our Kanban containers, rather than filling purchase orders	3.43	1.27	0.67
Pull2	Our suppliers deliver to us in Kanban containers, without the use of separate packaging	3.42	1.25	0.65
Pull3	We use a Kanban pull system for production control	3.87	1.38	0.84
Pull4	We use Kanban squares, containers or signals for production control	4.00	1.43	0.86
	Flow (Cronbach's alpha = 0.79)			
Flow1	We have laid out the shop floor so that processes and machines are in close proximity to each other	5.36	0.83	0.77
Flow2	We have organized our plant floor into manufacturing cells	5.06	1.19	0.38
Flow3	Our machines are grouped according to the product family to which they are dedicated	5.15	1.03	0.36
Flow4	The layout of our shop floor facilitates low inventories and fast throughput	4.97	0.97	0.80
Flow5	Our processes are located close together, so that material handling and part storage are minimized	5.08	0.92	0.80
Flow6	We have located our machines to support JIT production flow	4.70	1.00	0.61
	Setup (Cronbach's alpha = 0.82)			
Setup1	We are aggressively working to lower setup times in our plant	5.32	0.85	0.61
Setup2	We have converted most of our setup time to external time, while the machine is running	4.27	0.98	0.64
Setup3	We have low setup times of equipment in our plant	4.77	0.91	0.73
Setup4	Our crews practice setups, in order to reduce the time required	4.06	1.22	0.48
Setup5	Our workers are trained to reduce setup time	4.63	1.05	0.58
Setup6	Our setup times seem hopelessly long	5.20	0.98	0.62
	TPM (Cronbach's alpha = 0.69)			
TPM1	We upgrade inferior equipment, in order to prevent equipment problems	5.03	0.84	0.61
TPM2	In order to improve equipment performance, we sometimes redesign equipment	5.07	0.88	0.29
TPM3	We estimate the lifespan of our equipment, so that repair or replacement can be planned	4.74	1.03	0.73
TPM4	We use equipment diagnostic techniques to predict equipment lifespan	3.85	1.08	0.77

Survey items for Organizational Culture

All items are rated on a 1-7 Likert-type scale: 7 = strongly agree, 6 = agree, 5 = slightly agree, 4 = neutrality, 3 = slightly disagree, 2 = disagree, 1 = strongly disagree.

	Hierarchical culture (Cronbach's alpha = 0.85)	**Mean**	**Std dev.**	**Loading**
Hier1	Even small matters have to be referred to someone higher up for a final answer	3.27	0.94	0.88
Hier2	Any decision I make has to have my boss's approval	3.14	1.01	0.85
Hier3	There can be little action taken here until a supervisor approves a decision	3.60	0.96	0.76
Hier4	Our organization is very hierarchical	3.42	1.08	0.57
Hier5	There are many levels between the lowest level in the organizati and top management	3.59	1.25	0.47
	Group culture (Cronbach's alpha = 0.82)			
Group1	Our Supervisors encourage the persons who work for them to work as a team	5.40	0.71	0.81
Group2	Our Supervisors encourage people who work for them to exchange opinions and ideas	5.36	0.65	0.81
Group3	Our supervisors frequently hold group meetings together where the people who work for them can really discuss things together	4.91	0.85	0.70
Group4	Generally speaking, everyone in the plant works well together	5.44	0.76	0.65
Group5	Departments in the plant communicate frequently with each other	5.38	0.72	0.48
	Rational culture (Cronbach's alpha = 0.74)			
Ratio1	Our incentive system encourages us to vigorously pursue plant objectives	4.36	1.57	0.56
Ratio2	In our plant, goals, objectives and strategies are communicated to me	5.58	0.76	0.74
Ratio3	Our plant has a formal strategic planning process, which results in a written mission long-range goals and strategies for implementation	5.30	1.02	0.61
Ratio4	Plant management routinely reviews and updates a long-range strategic plan	5.30	0.94	0.46
Ratio5	We encourage employees to work together to achieve common goals, rather than encourage competition among individuals	5.84	0.57	0.56
	Developmental culture (Cronbach's alpha = 0.76)			
Dev1	Our plant stays on the leading edge of new technology in our industry	5.08	1.02	0.33
Dev2	Compared with our industry, we introduce new products more slowly	4.80	1.18	0.51
Dev3	We have reduced the time to introduce products by designing product and process together	4.98	1.15	0.43
Dev4	Introduction speed is our top priority in developing new products	4.74	1.14	0.61
Dev5	We achieve a competitive advantage by introducing new products more quickly than our competitors	4.81	1.08	0.78

Survey Items for Operational Performance

Please indicate your opinion about how your plant compares to its competition in your industry, on a global basis: 5 = superior; 4 = better than average; 3 = average, 2 = equivalent to competition; 1 = poor, low end of the industry.

		Mean	**Std dev.**	**Loading**
Cost (Cronbach's alpha = 0.68)				
Cost1	Inventory turnover	3.37	0.82	0.72
Cost2	Cycle time (from RM to delivery)	3.44	0.72	0.78
Cost3	Unit cost of manufacturing	3.22	0.85	0.49
Delivery (Cronbach's alpha = 0.77)				
Deli1	On-time delivery performance	3.85	0.83	0.96
Deli2	Fast delivery	3.74	0.82	0.66
Quality (Cronbach's alpha = 0.61)				
Qual1	Product capability and performance	3.89	0.72	0.58
Qual2	Conformance to product specifications	3.88	0.66	0.77
Flexibility (Cronbach's alpha = 0.72)				
Flex1	Flexibility to change product mix	3.88	0.71	0.62
Flex2	Flexibility to change volume	3.84	0.77	0.90