Organizational Tools and Cultural Change in the Success of Lean Transformations: Delving into Sequence and Rhythm

ABSTRACT

Even if the original seminal authors developed the tools used in Lean Manufacturing (LM) as inherently culture-dependent, western companies have found a variety of alternatives to implement them. We can simplify them by theoretically identifying two different extreme approaches that in real life are normally combined with diverse intensities: one emphasizes the intrinsically efficient nature of lean tools (lean-toolbox perspective), whereas the other stresses the cultural side (lean-culture perspective). The inappropriate interaction between both approaches has been put at the root of the low success rate of LM in non-Japanese firms. On the one hand, there is no agreement on which sequence to follow regarding managerial tools and cultural change during lean transformation processes. On the other hand, there are also different views on what the correct rhythm should be, since the pace at which organizational tools and cultural transformation occur can also determine the synergies that both can generate. This article synthesizes and compares empirically the different perspectives and tests them in a wide dataset of 1,692 North American manufacturing firms. Results suggest that cultural change does not moderate or precede lean transformations, but instead totally mediates the relation between the deployment of tools and enhanced plant performance. These findings not only offer managers a tentative sequence and rhythm in the deployment of lean tools and values, but also offer a relevant theoretical byproduct: the integration of Western and Japanese approaches.

Keywords: Lean transformations, lean culture, lean toolbox, rhythm, sequence, moderation, mediation.

1. INTRODUCTION

Although many studies support the positive impact of Lean Manufacturing (LM) on operational indicators such as reductions in cycle time, changeover time, or quality defects (Camacho-Miñano et al., 2013), parallel evidence shows that the expected outcomes have not always materialized (Yang et al., 2011). Even today, after more than 40 years since the basics of LM were first translated into English (Sugimori, 1977), the success rate of LM transformations (programs that find and eliminate unproductive activities while increasing value creation) has achieved very low figures in non-Japanese firms (Netland and Ferdows, 2014). Some authors suggest, in fact, that only 10% of companies accomplish a successful lean implementation, reaching the stipulated goals within the established deadlines and costs (Baker, 2002; O'Corrbui and Corboy, 1999). In addition, among the firms that were originally successful, the benefits that have been reported dissipate often over time because of the difficulties to sustain the new routines in the long term (Netland and Ferdows, 2014). Overall, while a negative return on investment is a concern in itself, plant managers fear that failures raise workers' skepticism on lean transformations and, therefore, make subsequent efforts more difficult (Netland, 2016).

Many reasons exist for this high failure rate indeed, but the literature seems to show a degree of consensus on the root of the problem: the scarce connection often found between lean tools and lean culture in transformation processes (e.g., Yadav et al., 2017). To be sure, these perspectives reproduce a simplified representation of lean transformations that could be reflected by a lean tools-lean culture continuum showing how managers emphasize one or the other in different organizations. Managerial philosophy on how operational excellence takes place situate them somewhere closer or further to these two extremes. Thus, while the lean toolbox approach perceives LM as an integrated system of interrelated socio–technical practices and tools (Shah and Ward, 2003, 2007; Camacho-Miñano et al., 2013), the lean culture approach, which is mainly associated with Japanese roots, tends to focus attention on the cultural transformation (Liker, 2004; Bhasin and Burcher, 2006; Naor et al., 2008).

Whereas the distinction between the two philosophical perspectives is rather clear in the literature, therefore, two issues that are more related to implementation than to theoretical conceptions seem still underdeveloped: the sequence and the rhythm with which managers need to deploy tools and stimulate values in order to make lean journeys feasible. On the one hand, there is no agreement on which sequence to follow when it comes to prioritize lean tools vs. lean culture perspectives; that is, whether tools or values should go first (Camacho-Miñano et al., 2013; Netland, 2016; Yadav et al., 2017). On the other hand, it is not clear either what the correct rhythm should be; i.e., the pace at which all reforms should be deployed (Snyder et al., 2016).

Bearing both issues in mind, this study aims at synthesizing the different formulae for interaction that the literature has established between lean culture and tools. Right from this literature, we develop two research hypotheses that we seek to test empirically: First, to determine the most adequate sequence (H1), and second, to delve into the rhythm with which that former tested sequence should be deployed (H2). A by-product of our results is the integration of Western and Japanese lean approaches (the former focuses more on tools and the latter on culture). Thus, even acknowledging that not all Japanese companies are lean, and that firms such as Toyota has successfully implemented lean thinking in their sites outside of Japan, our results should help to address the problems traditionally linked to the internationalization of lean practices and the low success rate of LM transformations in non-Japanese industries.

From an empirical point of view, this study also has two strengths. First, in contrast to frequent anecdotal evidence and surveys that are biased toward large firms or sectors with a strong lean tradition, our sample is comprised of plants from different industries (Table A1). It is precisely this focus on the manufacturing plant that gives us our second empirical strength. Although most studies focus on the firm as the unit for analysis, our dataset allows us to examine the adoption of tools and culture on the shop floor, therefore limiting the typical average answer in our data that in fact represents diverse establishments for one single firm with very different technological, product or human resource management characteristics.

The paper is structured as follows: Section 2 describes the lean culture and lean toolbox approaches to in order establish the research hypotheses. In the third section, we describe the sample of firms and variables. Section 4 covers the econometric analysis. Finally, Section 5 and discusses results and concludes with our main results, managerial implications and suggestions for future research.

2. THEORETICAL FRAMEWORK AND HYPOTHESES

2.1. Lean literature streams: Culture versus the Toolbox approach

It is conventional wisdom that the LM concept originated from the Toyota Production System (TPS). Since the first English article on the TPS (Sugimori, 1977) and especially since the publication of *The Machine that Changed the World* (Womack et al., 1990), LM has gradually spread to different sectors to the extent that today it is considered the reference in operations management (Yadav et al., 2017). However, despite the prevalence of LM philosophy and tools, no clear consensus exists about what "lean" entails in terms of practices involved and how they should be measured (Bhamu et al., 2014).

LM's eclectic nature and continuous evolution over time have thus given rise to a confusing collection of concepts (Womack et al., 1990; Shah and Ward, 2007), very often leading to the diffusion of numerous new labels for the same well-established concepts. This jungle of concepts and labels can be nevertheless organized into two main areas that, although with many intersections, reflect a different emphasis: the lean toolbox perspective, which focuses on the tools, and the lean culture approach, which stresses the philosophy of the paradigm (Bhamu et al., 2014).

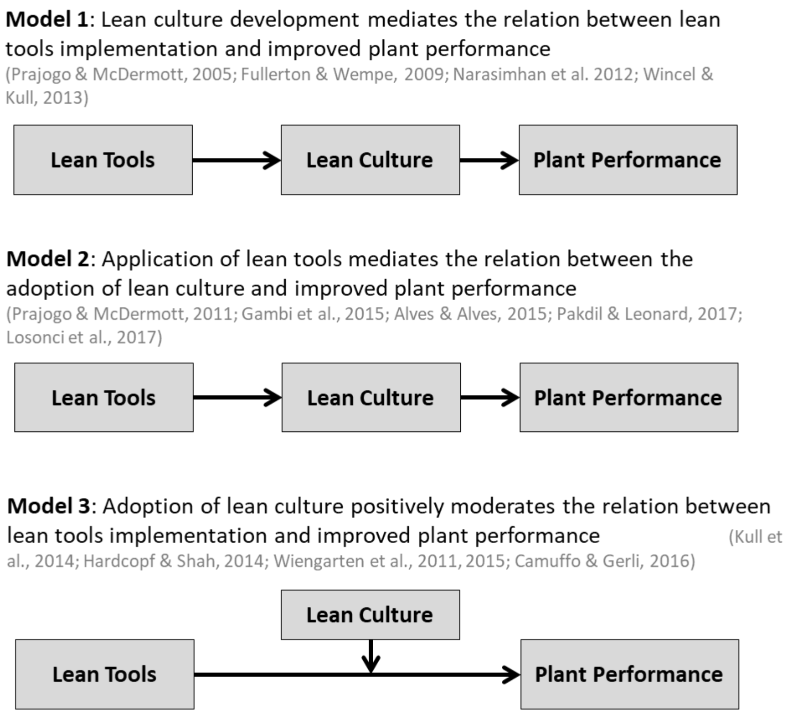
The lean toolbox approach emphasizes LM as a set of tools and techniques to reduce waste. Authors such as Shah and Ward (2003, 2007), for instance, highlight the application of waste elimination tools over the cultural aspects of organization. From this point of view, lean tools such as A3 problem solving, Value Stream Mapping (VSM) or Single Minute Exchange of Dies (SMED), among others, are considered drivers of change (Yadav et al., 2017). Mazur et al. (2008) highlighted especially the role of VSM and A3 as essential tools for an effective lean transformation. By contrast, the lean culture approach describes LM as a set of –often unconscious- values and principles determining the way people relate and work, as well as the organization's interaction with its environment (Pettersen, 2009). Overall, this approach emphasizes the relevance of a combination of values, beliefs, and underlying assumptions that organizational members share about appropriate behavior (Detert et al., 2000), therefore influencing crucially not only how lean-related strategies, tools or structures can be implemented, but also their very same effectiveness.

The authors who emphasize cultural principles argue that "lean is much more than just a toolbox" and defend the cultural component as the key element that unites and gives meaning to the lean transformation process. Following Liker (2004), we apply here the principles of the 4P model (Figure 3) to describe the primary elements of lean culture. This model, which is graphically represented with a pyramid, reflects an on-going drive toward perfection through four core values and beliefs that should permeate the work of any organization: long-term philosophy, total elimination of waste, respect for people, and continuous improvement (Camacho-Miñano et al., 2013).

2.2. Alternative models of lean transformation: Synthesis of perspectives to validate sequence.

Consistent with the above discussion, our literature review has identified a lack of consensus on how to implement LM. In fact, three alternative models reflect the most widespread perspectives on the relationship between the lean toolbox and lean culture approaches (Figure 1). The first (model 1) stems from authors who consider that the cultural component mediates between the adoption of lean tools and improved business results. The second (model 2) stems from authors who suggest that the tools play a mediating role between lean culture and improved plant performance. The third (model 3) emerges from authors who consider that culture moderates the impact of tools on improved plant performance. It is worth noting, therefore, that we do not aim at testing every possible interaction among these three variables, but just the ones that are theoretically supported by the literature. We follow a deductive methodology.

Figure 1. Alternative models in the literature reflecting sequence (Hypothesis 1)



Note: A variable mediates between two other variables X and Y when it explains how they are related, even determining the very existence of the relation. By contrast, a variable moderates the relation between two other variables X and Y when it influences the magnitude of the effect (increasing it or decreasing it) that X exerts over Y.

Model 1. A number of researchers argue that lean success is largely dependent on the attainment of a lean culture and have attempted to formalize a consistent theoretical framework that is conducive to superior plant performance (Liker, 2004; Wincel and Kull, 2013; Pakdil and Leonard, 2014, 2017). However, beyond these theoretical studies, hardly any empirical studies analyses the relationship between lean practices, culture and operational performance (Bortolotti et al., 2015). Those studies that are not theoretical usually focus on a narrow sub-group of lean practices (Mackelprang and Nair, 2010).

Fullerton and Wempe (2009), for instance, used a multiple case study to address how organizational culture partially mediates the relation between quality improvement practices and performance. Similarly, Prajogo and McDermott (2005) used the Malcolm Baldrige Quality Award to examine organizational culture as the impetus for several lean practices, which in turn were associated with improved competitiveness. Within this stream of research, Wincel and Kull (2013) asserted that culture is likely to evolve as lean tools and techniques are implemented and mastered by an organization. Other studies that could be included in this first group were conducted by Nahm et al. (2004) and Narasimhan et al. (2012), who discussed a mediating effect of organizational culture, respectively, between customer satisfaction and time-based manufacturing practices, and between time-based manufacturing practices and performance.

Model 2. A second major literature stream examined how culture characteristics can support the implementation of LM tools that lead to performance improvements. These studies, which are mostly conceptual (Camacho-Miñano et al., 2013), hinge on well-known cultural models and focus also on certain LM practices. Baird et al. (2011) and Gambi et al. (2015), for instance, analyzed the role of culture as an antecedent of certain TQM practices. Similarly, Losonci et al. (2017) examine the impact of shop floor culture assessed by the *competing values framework* (CVF) on the use of LM practices.

Therefore, this second group covers studies that address how lean tools mediate between culture and performance. Their message is that lean tools need to be cultivated in an already fertile cultural soil (Alves and Alves, 2015). Apart from these theoretical approaches, quantitative studies (e.g., Prajogo and McDermott, 2011), assessed this relation in greater depth by also using the CVF from Naor (2008) to determine how the different dimensions of organizational culture affect performance (cost, quality, innovation, etc.). Likewise, Pakdil and Leonard (2017) address how different cultural issues (e.g., uncertainty avoidance and long-term orientation) are positively associated with a high level of lean adoption, in terms of employee involvement and standardization, and —in turn—improved results.

Model 3. Finally, a third group of authors assessed how organizational culture moderates the relation between lean tools and performance. Kull et al. (2014), for example, used the GLOBE National Culture Scheme to determine how the different dimensions of organizational and national culture affect the results of different LM practices. Although institutional collectivism and risk aversion positively moderate the relation, other dimensions (e.g., assertiveness and performance orientation) might moderate it in a negative manner. Hardcopf and Shah (2014) carried out a similar analysis using the CVF. Their results present both positive and negative moderation depending on the cultural dimension and the key performance indicator considered.

In the same vein, the studies by Wiengarten et al. (2011, 2015) assessed how national and organizational culture affect certain lean practices (Kanban, pull systems, 5S, etc.). These authors used the models drawn up by Naor (2008) to measure national and organizational culture, respectively. Their conclusions are clear: In cultural environments with low levels of individualism lean practices are more efficient. Finally, Camuffo and Gerli (2016) engaged in a lean effort that investigated the moderation of "high-involvement" management culture. Here the organizational culture appears to be essential because it creates an environment in which lean techniques and tools are enhanced.

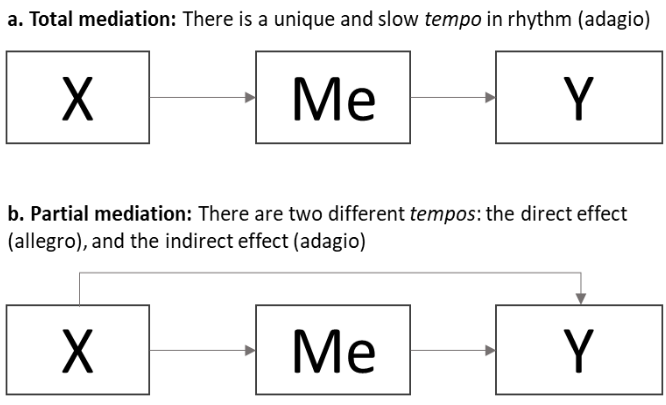
According to these three alternative models, we posit three sub hypotheses to be tested. The first two alternatives consider a mediation relation (Models 1 and 2), whereas the third evaluates moderation by culture (Model 3).

- **H1a**: Lean culture development mediates the relation between the implementation of lean tools and improved plant performance.
- **H1b**: The application of lean tools mediates the relation between the adoption of lean culture and improved plant performance.
- **H1c**: The adoption of lean culture positively moderates the relation between the implementation of lean tools and improved plant performance.

2.3. Evaluating rhythm in lean transformations from an evolutionary point of view

Rhythm refers to the timing of events in a lean transformation, since the pace at which organizational tools or cultural change happen may be different in any two firms even if they follow the same sequence of events. Tempo refers to how fast or slow the rhythm is. To be sure, different tempos in a same sequence can yield different results. Rhythm can be proxied tentatively by finding a partial or a total mediation in H1a and H1b (Figure 2).

Figure 2. Possible rhythms according to the type of mediation (Hypothesis 2)



Note: Whereas total mediation implies the existence of a unique path (the mediation) between X and Y, partial mediation entails Y could be influenced through two different paths: the direct and the indirect effect (mediation). The existence of a direct effect suggests a faster tempo (allegro) in model b.

Whereas total mediation evokes the existence of a unique and slow tempo in rhythm (adagio in Figure 2 case a), partial mediation entails plant performance could be influenced in two different tempos: the direct and faster effect (allegro), and the indirect effect (adagio) (Figure

2, case b). We do not analyze rhythm in H1c because, by definition, a moderation is a simultaneous process (Maas et al., 2016).

Following *Evolutionary Theory* (Nelson and Winter, 1982; Hoss and ten Caten, 2013), the notion of routines and selection environments are key here. On the one hand, although firms are subject to stochastic processes giving rise to irregular and unpredictable patterns of behavior, the concept of routine reflects what is permanent in a firm's behavior. Routines operate as protocols whose capacity for reproduction —like genes in biology— preserves and reproduces the information they contain over time (Nelson and Winter, 1982), just as lean tools try to generate a series of procedures and standards that instill workers into a particular way of doing. On the other hand, selection environments matter because they determine which routines are adaptive (adaptation being the equivalent to a positive plant performance). For instance, a one-piece flow may deliver good results in an assembly process implemented with a series of workstations, whereas in some continuous processes involving chemical transformation, such as a paint baking oven with conveyor, it may become an inappropriate approach. In the first case, one-piece flow allows to remove intermediate stocks between workstations; however, in the second case, the number of units in the oven process is the result of the time required to cure the paint and the pace or production potential of the process.

With this background in mind, some authors use a biological reasoning to suggest that, in order to achieve the expected lean results, it is previously necessary to develop the right selection environment (the right culture) so that typical lean routines can be deployed efficiently in the long term (Pakdil and Leonard, 2014, 2017). Other authors, however, posit the reverse causation: routines themselves could alter and conform the selection environment in a planned or emergent way to end impacting on plant performance (Fujimoto, 1999; Aldrich et al., 2008).

Both perspectives present something in common: lean culture and lean tools are not only necessary, but both see an interactive role between tools and culture that affects plant performance, regardless of which one of the two precedes the other. However, Evolutionary Theory can also justify why some selection mechanisms can be mild enough so as to stimulate adaptation for organizations with very different routines (just as mild climates have a greater biodiversity), and simultaneously supports that organizations with the best routines can be adaptive in very different environments with diverse selection mechanisms (just as some species can adapt to very different environments). This means that we could observe a direct effect from lean culture or lean tools to plant performance, beyond the mutual influence that one may exert over the other.

Under a total mediation in H1a, the implementation of tools (routines) is what causes the transformation of shop floor culture and, in turn, improves plant performance. Individuals learn to solve problems through standard, well-known tools, which, to the extent they prove to be useful, end up becoming tacit and embedded in the organization to improve results eventually (Wincel and Kull, 2013; Pakdil and Leonard, 2014, 2017). Firms should not therefore be in a hurry to see the change generated by the adoption of tools since it will largely depend on the firm's absorption capacity (Martínez-Senra et al., 2013). In fact, a faster adoption rate than the firm's capacity for assimilation may not only slow down the improvement in plant performance but even eliminate it. By contrast, a partial mediation in which there exists a direct effect from lean tools to plan performance would be the consequence of their intrinsic technical nature. To put it bluntly, regardless of managerial philosophies, business goals, corporate cultures, etc., the implementation of lean tools such as Heijunka or Kanban can enhance performance in the short term due to their focus on particular technical issues to which trained middle-management professionals must give an answer (e.g., Matzka, Di Mascolo and Furmans, 2012). Indeed, once the span of technical answers is developed, workers may be involved in their implementation but —very often— only to the extent they may affect labor conditions in the production line (e.g., work pace). In extreme cases, the object of negotiation for workers is precisely how to hold back the values associated to “management by stress”, which is at the root of LM (Mehri, 2006). This would be coherent with literature surveys pointing out that there is much more emphasis on instrumental techniques for improving system performance than on the human behavior side (Pettersen, 2009). Against this background, two hypotheses can be stated:

- **H2a**: Lean culture totally mediates the relation between the implementation of lean tools and plant performance.
- **H2b**: Lean culture partially mediates the relation between the implementation of lean tools and plant performance.

Analogously, under a total mediation in H1b, it would be necessary to adapt organizational culture initially to subsequently implement lean tools in an efficient and sustainable way (Gambi et al., 2015, Alves and Alves, 2015). This second proposition argues that there can be no effective implementation of lean tools (and therefore a positive impact on results) unless there has been a previous cultural change throughout the organization or, at least, in the specific pilot areas where the initial tools are to be implemented. This obviously requires time. In fact, very often, positive results last shortly, precisely because the cultural context in which tools are implemented reflect selection mechanisms that are not coherent with a lean transformation (Netland and Ferdows, 2014). However, there is an alternative view: the philosophy and values presented by the Toyota Way 4P model (Figure 3) do not actually belong exclusively to the LM paradigm. Being long-termed oriented, nurture respect for people, develop partners… have taken part in the core of many other managerial philosophies such as "Flexible and Innovative Workplace Systems", "High Performance Work Organization", "High Commitment Human Resource Management", "Total Quality Management", and many others (Arocena et al., 2011). So, just as many lean tools can appear to be intrinsically efficient regardless of whether they can spread the right culture, some values could also be considered intrinsically efficient and therefore influence performance directly regardless of whether organizations are in an initial or more advanced stage of lean tools implementation (Jaakson, 2010). Based on these alternative explanations, our perspective on rhythm can also take the form of two additional hypotheses:

- **H2c**: Lean tools totally mediates the relation between lean culture and plant performance.
- **H2d**: Lean tools partially mediates the relation between lean culture and plant performance.

3. DATA AND VARIABLES

We use a 4-year database (2008–11) stemming from a survey carried out annually for manufacturing plants (NAICS 331-339) by IndustryWeek (IW) and the Manufacturing Performance Institute (MPI). The survey was electronically mailed each year to plant managers and controllers from IW/MPI's database of manufacturing plants, so it is a convenience sample. By using anonymous questionnaires sent out at random by post or by e-mail, top-level informants —mainly subscribers of IW— were contacted in each company (e.g., CEO, industrial manager). A total of 1,692 valid questionnaires were obtained, which represented an annual average response rate of 12.9%. This is a high response rate compared to other studies in this field (e.g., 7.5%, Nahm et al., 2004; 6.7%, Shah and Ward, 2003). Sample representativeness can be furthermore reflected by comparing the average productivity per employee in our sample ($258,348) to the average productivity of U.S. manufacturing plants ($253,868) as reported in the U.S. Census (Shah and Ward, 2007). This difference is not statistically significant (t=0.37; p=0.35).

As our dependent variable, we used plant productivity (operating revenue over total plant personnel) as a proxy of plant performance. This is a measure widely used in the operations management literature to assess manufacturing performance (e.g., Vázquez et al., 2016; Sartal et al., 2019). To avoid any distortion caused by variance in values across the sample, we use the logarithmic transformation (Damanpour, 1992).

Concerning independent variables, our proxy for lean tools (Lean_tools) is the result of synthesizing ten tools that, according IW-MPI survey, are widely used from the lean toolbox point of view. We have also prepared Table 1 to endorse this by reviewing some of the most cited works in the field of LM. The survey's questions are described in Table A2 in the Appendix.

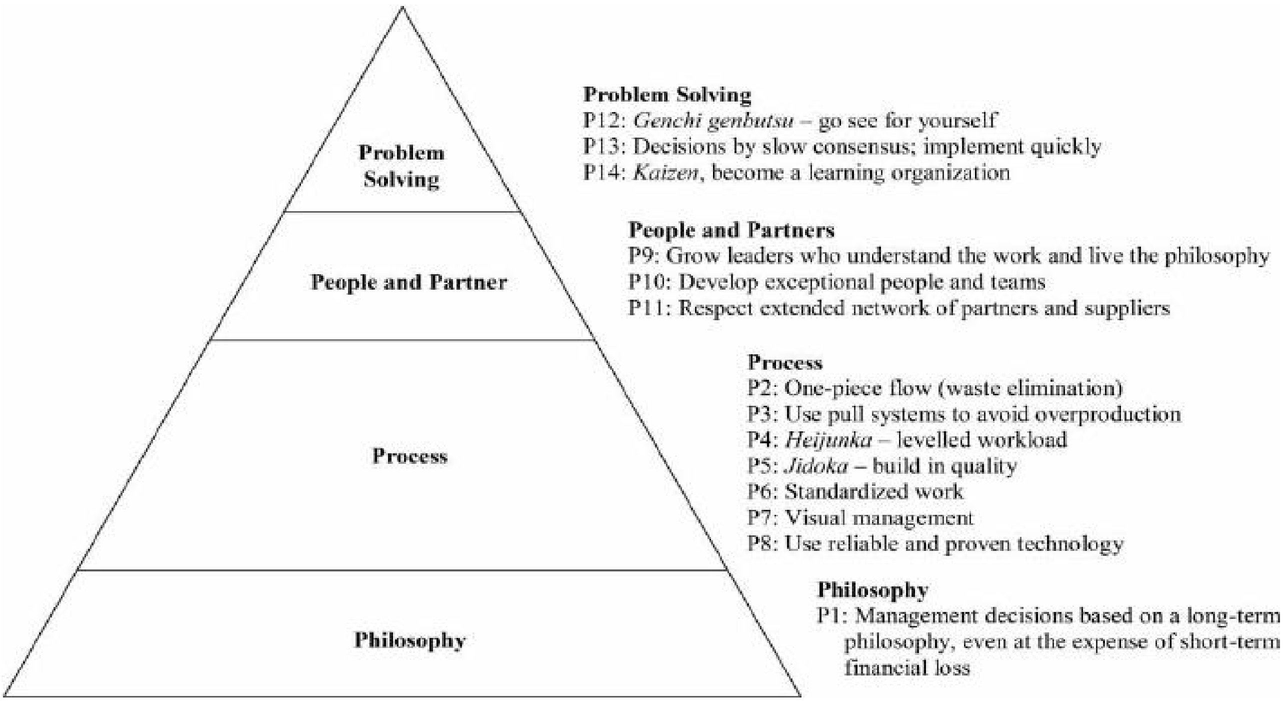
Table 1. Lean Tools used to operationalize the Lean_Tools construct (cross-marks indicate references addressing the tools)

	Sugimori et al. (1977)	Voss and Robinson (1987)	Bicheno (1989)	Shingo Prize Guidelines (1996)	Monden (1998)	White et al. (1999)	Cua et al. (2001)	Fullerton and McWatters (2002)	Shah and Ward (2003)	Doolen and Hacker (2005)	Shah and Ward (2007)	Dalpont et al., (2008)	Yang et al. (2011)
Production leveling techniques are applied	x	x			x	x	x	x	x	x	x	x	
Kaizen/blitz events are performed	x	x	x	x	x	x	x	x	x		x		x
VSM techniques are applied		x		x			x			x			
Unit flow techniques are applied	x	x	x	x	x	x	x	x	x	x	x	x	x
Pull systems with Kanban signals are used	x	x	x	x	x	x	x	x	x	x	x	x	x
Parts and materials supermarkets are used	x				x					x			
SMED techniques are applied	x	x	x	x	x	x	x	x	x	x	x	x	x
Periodic quality audits are performed	x	x	x	x	x	x	x	x	x	x	x	x	x
TPM-related techniques and tools are used		x	x	x	x	x	x	x	x	x	x		x
PDCA problem-solving techniques are used				x							x	x	

Sugimori et al. (1977); Voss and Robinson (1987); Bicheno (1989) ; Shingo Prize Guidelines (1996); Monden (1998); White et al. (1999) ; Cua et al. (2001); Fullerton and McWatters (2002); Shah and Ward (2003); Doolen and Hacker (2005); Shah and Ward (2007); Dalpont et al., (2008); Yang et al. (2011)

To operationalize the lean culture variable (Lean_Cult), we draw a construct that summarizes the Toyota Way 4P model (Figure 3) into 14 basic principles (Liker, 2004). Table A3 in the Appendix develops each category (philosophy, process, people and partners, and problem solving) to present the questions used in the IW/MPI survey. Although culture can be measured in different ways, this is one of the most used in the management field (e.g., Snyder et al., 2016).

Figure 3. The Toyota Way model used to operationalize the Lean_Cult construct (Liker, 2004)



Both constructs were built upon several dichotomous questions associated, in each case, to the presence (1) or absence (0) of lean tools and values. Although continuous or at least ordinal variables have better statistical properties, these 1/0 values could have the benefit here of reducing subjective assessments. When surveys ask participants about aspects that are considered inherently positive, such as, “How do you perform relative to three years ago and to main competitor(s)?” or “How often are you in close contact with suppliers?” (Shah and Ward, 2007; Yang et al., 2011), respondents tend to overestimate their skills and even lie consciously about it (Bertrand and Mullainathan, 2001; Vazquez, 2018).

Under these circumstances, Lean_Tools and Lean_Cult stem from the application of Categorical Principal Components Analysis (CATPCA) to the dichotomous questions just mentioned above. Lean_Tools is thus a construct of 10 items, and Lean_Cult is a construct of 14 items. It is worth noting that CATPCA is a method for optimal scaling that is especially appropriate for summarizing data when variables are categorical. Both constructs were furthermore validated using reliability analysis (Cronbach’s α) and Principal Component Analysis with varimax rotation (Tables A4 and A5). The Cronbach’s α of the two constructs (Lean_Tools [0.847]) and Lean_Cult [0.866]) are above 0.7, which is the usually recommended value (Nunnally, 1978).

Finally, we include three control variables (Table 2) and annual dummies. The size of the production plant (measured as the natural log of total employees) is relevant because productivity might benefit from economies of scale and scope (Vázquez et al., 2016). Second, we include plant age (Sartal et al., 2018) and differentiate between “new” plants (<10 years), “adolescent” plants (10 to 20), and “old” plants (>20 years). Although some authors have claimed that there exists a positive effect from potential learning curves, others (e.g., Shah and Ward, 2003) have suggested that a negative effect may exist based on a “process of obsolescence.” Thirdly, we also include sectoral technological dynamism (i.e., the rate of change in and the unpredictability of new technologies, as defined by Wu et al., (2005) because it has been shown that the scientific and technological know-how that is relevant for each sector advances at different speeds and entails different productivity effects (Martínez-Senra et al., 2013). We use OECD's classification of industries according to their investment in R&D as a proxy variable (OECD, 2001), so we included a dummy that takes the value 1 for high and medium-high technology industries, and 0 for low and medium-low technology industries. Lastly, taking 2008 as the reference year, three annual dummies were introduced (2009, 2010 and 2011). These dummies isolate the influence that a particular shock in a specific year (e.g., 2008 Financial Crisis) could have on plant performance.

Table 2 gives a description of main descriptive statistics, whereas Table 3 describes the correlations matrix. Thus, our sample shows a productivity average of $258,350,000, although with a high standard deviation. They are medium-sized business, since the mean for the number of employees is 323. Plants also show an average of 2.41 in the age variable, which means that a typical establishment is between 10 and 20 years old. Concerning correlations, we can observe the highest positive association between the lean tools and the lean culture variables. Other relevant associations exist between plant performance and lean culture, and between lean tools and size. In any case, the table does not suggest potential multicollinearity in the model, and in fact the variance inflation factors (VIF) are all below 10, which is the most widely used limit for anticipating this type of problems (Kleinbaum et al., 1988).

Table 2. Description of Variables and Main Descriptive Statistics

Variable	Proxy/Operationalization	Obs	M	SD	Min	Max
Plant Performance (Perf)	Productivity = Log (net sales / no. of employees)	1,692	258.35	603.93	5	5,400
Lean Tools (Lean_Tools)**	Set of tools normally associated with lean Production (Shah and Ward, 2003; 2007)	2,081	-0.01	1.01	-1.13	2.84
Lean Culture (Lean_Cult)**	Set of principles normally associated with lean thinking (Liker, 2004)	2,081	-0.03	1.04	-2.00	2.17
Plant Age (Age)	Categorical variable: (1) new plants, (2) "adolescent" plants and (3) old plants (Shah and Ward, 2003)	2,074	2.41	0.80	1	3
Plant Size (Size)	Log (no. of employees)	2,016	323.15	1140.18	1	20,000
Technological Dynamism (Tech_dyn)	Dummy: high and medium-high technology sector (1), or low and medium-low technology sector (0)	2,081	0.47	0.49	0	1

* Descriptive statistics are not in logs, but in natural numbers.

**Lean_Tools and Lean_Cult constructs were synthesized using CAPTA.

Table 3. Correlation Matrix

Correlation	1	2	3	4	5	6
1. Perf	1					
2. Lean_Tools	0.220**	1				
3. Lean_Cult	0.379**	0.555**	1			
4. Age	0.268**	0.156**	0.239**	1		
5. Size	0.183**	0.357**	0.285**	0.261**	1	
6. Tech_dyn	0.065**	0.057**	0.016	-0.009	0.015	1

** Significant correlation at 0.01 and * at 0.05

4. RESULTS

For the first hypothesis (H1), we evaluate in Table 4 the mediating role of culture (H1a) and lean tools (H1b), respectively, and in Table 5 the moderating role of Lean_Cult (H1c). Following authors such as Mackinnon (2012), the mediating effect can be interpreted here as a sequence in the deployment of lean tools and culture, while the moderation effect is considered as simultaneity (e.g., Maas et al., 2016; Náfrádi et al., 2018). Regarding the second hypothesis, we evaluate rhythm of implementation in Table 4 by delving into whether there is a partial or a total mediation for each of the possible mediators: lean culture (H2a and H2b), or lean tools (H2c and H2d). Whereas total mediation evokes the existence of a short term effect and a unique rhythm (indirect effect), partial mediation entails plant performance could be influenced through two different paths: the direct and the indirect effect (Figure 2). Rhythm is not analyzed with respect to hypothesis H1c because, by definition, a moderation is a simultaneous process (Maas et al., 2016).

Table 4 shows the estimations of equations (1), (2) and (3), and shows the four conditions to be met in order to verify mediation by Lean_Cult (H1a) or by Lean_Tools (H1b). For instance, to prove a mediation by lean culture, the econometric model must meet the following conditions:

a. A direct, significant, and positive effect of Lean_Tools on plant performance; that is, the parameter of Equation (1): β_{11} must be significant.

b. A positive and significant effect of applying Lean_Tools on the lean culture mediating variable (Lean_Cult); that is, the parameter of Equation (2): α_{21} must be significant.

c. A positive and significant effect of Lean_Cult (mediating variable) on plant performance; that is, the parameter of Equation (3): β_{32} must be significant.

In Table 4 we can therefore reject (H1b) and confirm the mediating role of culture (H1a) between the implementation of lean tools and improved plant performance. Additionally, we can check in Table 5 for the possible moderation of Lean_Cult (H1c), which means that it would influence the magnitude of the effect that Lean_Tools exerts over plant performance. Following Muller et al. (2005), we can confirm that the following parameters are significant (with the equation number given between parentheses): (1): α_{42}, and (2): α_{41}, and (3): α_{43}. Hence, we cannot confirm moderation because α_{43} (p = .466) is not significant. Accordingly, these results imply that lean transformations should begin with the implementation of lean tools in order to allow people to experience LM and thus act as vehicles for the cultural shift that can sustain a better plant performance.

Table 4. Model specifications to test mediation

Mediation by Lean Culture (Lean_Cult)	Mediation by Lean Tools (Lean_Tools)
Equations	
1) $Pfe = \beta_{10} + \beta_{11}Lean\_Tools + \beta_{12}Control\_Var + \varepsilon_1$	1) $Pfe = \beta_{10} + \beta_{11}Lean\_Tools + \beta_{12}Control\_Var + \varepsilon_1$
2) $Lean\_Cult = \alpha_{20} + \alpha_{21}Lean\_Tools + \alpha_{22}Control\_Var + \varepsilon_2$	2) $Lean\_Tools = \alpha_{20} + \alpha_{21}Lean\_Cult + \alpha_{22}Control\_Var + \varepsilon_2$
3) $Pfe = \beta_{30} + \beta_{31}Lean\_Tools + \beta_{32}Lean\_Cult + \beta_{33}Control\_Var + \varepsilon_3$	3) $Pfe = \beta_{30} + \beta_{31}Lean\_Cult + \beta_{32}Lean\_Tools + \beta_{33}Control\_Var + \varepsilon_3$
Requirements**	
a) β11 significant → met (p<0.001)	a) β11 significant → met (p<0.001)
b) α21 significant → met (p<0.001)	b) α21 significant → met (p<0.001)

c) $\beta 32$ significant → met ($p<0.001$) → **Mediation**	c) $\beta 32$ significant → Not met ($p=0.473$) → **No mediation**
d) $\beta 31$ significant → Not met ($p=0.473$) → **Total mediation**	
Results	
Total mediation by Lean_Cult between Lean_Tools and Pfe	No mediation

**Full estimations are given in the Appendix (Tables A4-A6).

Table 5. Requirements for testing moderation by Lean Culture

Equations
1) $Pfe = \beta_{10} + \beta_{11}Lean\_Tools + \beta_{12}Control\_Var + \varepsilon_1$
2) $Lean\_Cult = \alpha_{20} + \alpha_{21}Lean\_Tools + \alpha_{22}Control\_Var + \varepsilon_2$
3) $Pfe = \beta_{30} + \beta_{31}Lean\_Tools + \beta_{32}Lean\_Cult + \beta_{33}Control\_Var + \varepsilon_3$
Requirements**
$\alpha 41$ significant → met
$\alpha 42$ significant → met
$\alpha 43$ significant → Not met ($p=0.466$) → **No moderation**
Results
Lean_cult does not moderate the relation between Lean_tools and Pfe

**Full calculations are given in the Appendix A4 (Tables A4-A6)

After evaluating H1 and confirming that only lean culture (Lean_Cult) can act as a mediator, we must determine in Table 4 whether this mediation is total (H2a) or partial (H2b). H2c and H2d are therefore disregarded because H1b was rejected. Hence, if the mediation is partial (H2b), then coefficient β_{31} must be significant and its residual effect—the effect after discounting the indirect mediating effect—must be lower in absolute value than the total effect; that is, $|\beta_{31}| < |\beta_{11}|$. On the contrary, if there exists a total mediation (H2a), it means that the influence of lean tools on the global specification of the model is no longer significant; that is, the parameter of Equation (3): β_{31} is no longer significant. Table 4 shows that, when the Lean_Cult variable is introduced in the global model (Eq. 3 right), Lean_Tools no longer makes a significant contribution (requirement d).

It should also be pointed out that, in the case of mediation by lean tools (left), requirement c does not hold; that is, the parameter for Eq. 3 is not significant (left): β_{32}. The mediating role of Lean_Tools cannot, therefore, be confirmed. Accordingly, we not only find evidence that the most plausible alternative is the mediation by culture between lean tools and plant performance

(H1a), but also that this is a total mediation (H2a). Tools are thus the necessary starting point in any transformation, but they will only lead to the expected results if they manage to trigger the process of cultural change (indirect effect).

Finally, Table 6 shows the final specification of the model (total mediation by Lean_Cult), where we can observe that the control variables for plant age ($p < 0.01$) and technological dynamism ($p < 0.1$) are both significant. Size, however, is not significant ($p = 0.839$).

Regarding plant age, results confirm the contribution of the cumulative "learning effect" of mature organizations on productivity (Shah and Ward, 2003). While this issue positively affects plant performance, in many occasions this same fact is the reason for greater reluctance to change organizational routines in older firms. After all, these same routines have been improving their productivity over time. Similarly, the sector's technological dynamism also shows a significant influence on plant output, probably reflecting the influence of new technologies on productivity, but also the required dynamic capabilities (embedded in lean routines) that firms need to develop in order to generate and absorb higher rates of technological change (Sartal et al., 2017). Finally, the fact that size does not seem to influence productivity, an unexpected result in the industrial sector, is perhaps because its effect (the importance of economies of scale for productivity) is already included in plant age (i.e., larger firms tend to be older).

Table 6. Specification of the valid model (mediation by lean culture), including all variables

No. of observations	=	1,692
F (8, 1572)	=	40.83
Prob > F	=	0.000
R-squared	=	0.185
Root MSE	=	1.218

Variable	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Lean_Tools	0.027	0.037	0.72	0.473	-0.046	0.100
Lean_Cult	0.413	0.041	10.17	0.000	0.334	0.493
Tech_dyn	0.109	0.061	1.77	0.076	-0.012	0.230
Age	0.314	0.048	6.59	0.000	0.220	0.407
Size	0.064	0.032	0.20	0.839	-0.055	0.068
Const_	10.656	0.196	54.48	0.000	10.272	11.039

5. DISCUSSION AND CONCLUSIONS

5.1. Theoretical contributions

This paper captures the integrated nature of lean systems, but also delves into the sequence and rhythm in the deployment of lean tools and culture. Our results make two substantive contributions to existing research.

First, we synthesize the different interaction formulae that the literature identifies between culture and organizational tools in LM. After noting that different authors have diverse perspectives on lean transformations, we draw three alternative models reflecting the most widespread views. Our goal has been to test these perspectives to bring consensus to a still controversial debate. In fact, far from assigning culture a moderating or a triggering role in lean transformations, the only model finding empirical support is the one conveying lean tools a socialization role to change corporate culture and thus provoke a sustained plant performance improvement.

Second, beyond getting deeper into the sequence of events in lean transformations, the fact that the mediation of culture between lean tools and plant performance is complete (i.e., a "total mediation") should make managers and scholars think over the rhythm of events. While lean tools can activate specific shop floor improvements in a very short period of time, we find that they will only improve plant performance when they lead to a cultural change.

Both results regarding sequence and rhythm can also deliver a relevant byproduct. They suggest that the high failure of lean transformations in Western organizations is not necessarily based on the absence of a “Japanese culture”. For decades this has been a recurrent issue in the literature since the philosophy and many of the tools originally stemming from Toyota were deemed to be very idiosyncratic to Japan’s traditional values (Herron and Braiden, 2007). The reasons are probably varied, although some of them are addressed more frequently. At an individual level, for instance, western citizens could see ourselves differently in an organization. As many workers and managers put it in Volvo plants, “that type of Japanese thinking does not apply to our democratic work organizations” (Netland and Ferdows, 2014). More broadly, at the institutional level, Herron and Hicks (2008) highlight that the Keiretsu system encouraged persistent interlocking business in Japan, which made suppliers accept the support of their customers more easily. Be as it may, even if our results do not question that lean implementations can be sensible to cultural differences throughout the world (Kull et al., 2014), they do lead us to stress the relevance of lean tools to create the right culture, making rhythm and sequence of routine deployment a key element of lean journeys.

5.2. Managerial implications

Pay (2008) estimates that only 25% of firms are satisfied with lean results, whereas Netland and Ferdows (2014) suggest that lean improvements dissipate quickly over time. Managers should therefore rethink lean implementations, according to our results, to combine tools deployment and cultural change in a specific sequence and with a particular rhythm. The total mediation of culture between lean tools and plant performance suggests there are three basic aspects to think over: First, lean tools act as knowledge deposits that inculcate basic routines in the workforce for on-going improvement. Second, these tools are the transmitters of this know-how through learning by doing. Third, lean tools are the main instruments for socialization on the shop floor and, therefore, have the potential to become the triggers for cultural transformation (Nelson and Winter, 1982).

According to our results, there seems to be only one path to obtain successful results: Individuals learn to solve problems through standard, well-known tools, which, to the extent they prove to be useful, end up becoming tacit and embedded in organizations. This, in turn, instills workers into the culture of continuous improvement with principles and values represented in Figure 3.

In many occasions, however, this embedment process does not take place. Tools such as Heijunka, for example, can obtain positive results in the short term although it is not always easy to perceive how they can become the prompt of cultural change for the overall workforce. Monden (1998) called Heijunka the cornerstone of TPS, tracing its origins to maintenance job shops with the need to level people (not materials or demand). Today, however, it has become a highly complex challenge guided by logistics needs (Matzka, Di Mascolo and Furmans, 2012). Consultants or the logistic team in organizations implement ERP/MRP and thus put pressure on the workforce even if they are not acquainted with the algorithms, not even with the very same logic of ERP/MRP. As mentioned above, in extreme cases workers may even restrain Heijunka efforts (and therefore lean values) to the extent they may feel their work conditions in the assembly line (work pace, skills, stress related to decision making…) are being damaged (Mehri, 2006). In other occasions, the "westernized use" of lean tools prevents obtaining all the potential for cultural change they contain. For instance, lean tools such as 5S or Kaizen workshops can be the perfect start of a lean cultural transformation, but for this transformation to take place, they cannot be seen as simple and ad hoc cleaning (housekeeping) or problem-solving tools (Gapp et al., 2008). Furthermore, managers must also carefully consider the pace at which the different tools are introduced in order for the cultural transformation to be successful. A faster rate of implementation than the capacity of the organization to assimilate the values embedded in lean tools may cause workers' distrust and skepticism, which often leads the workforce to restrain cooperation in subsequent transformation initiatives (Huy, 2001).

5.3. Limitations and future avenues for research

There are several caveats in our work that could inspire future work. First, although the large-scale survey provides representative evidence to generalize results, the cross-sectional nature of the data limits the scope of the conclusions we can reach from a dynamic perspective. Future studies based on longitudinal data (e.g., Sartal and Vazquez, 2017) would therefore allow for an evolutionary and more accurate account of the relationships we are trying to grasp. Second, it is worth noting that this paper analyses the influence of lean routines in manufacturing firms (North American Industry Classification System 311-339) and at a plant level. A logical extension of this work would be consequently to replicate the tests in other sectors and, specially, within entire value chains where LM exceeds the limits of single organizations.

Last, the replication of the study in different countries could present an opportunity for future research. For example, it is interesting to verify whether the deployment of lean tools and the cultural transformation follow the same pattern or even suffer different moderators in countries with different traits in terms of technological dynamism, human capital or even labor market functioning. Formal and informal institutions play a role in designing the rules of the game at an organizational level and in determining the bargaining power of each agent involved (North, 2004). Identifying idiosyncratic practices affecting lean transformations could therefore be a productive field for future research.

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APPENDIX

Table A1. Distribution of Firms by Technological Intensity of Their Sector and by Size

Characteristics	%
Number of employees	
1-9	7.3%
10-49	25.5%
50-249	42.7%
250 -	24.5%
Technological intensity	
Low	16.9%
Medium-Low	35.8%
Medium-High	32.5%
High	14.8%
Annual sales	
< 2 M$	20.6%
2-10 M$	22.7%
10-50 M$	34.3%
50 M$ -	22.4%

Table A2. Lean Tools Construct (Lean_Tools)

Lean tools construct (Lean_Tools): questions used in the IW-MPI questionnaire	
Foundations of the TPS house	Are production leveling techniques applied? Are Kaizen events held? Are VSM techniques applied?
Practices associated with the JIT pillar (TPS house)	Are unit flow techniques applied? Are Pull systems with Kanban signals used? Are parts and materials supermarkets used? Are SMED techniques applied?
Practices associated with the Jidoka pillar (TPS house)	Are periodic quality audits carried out? Are TPM-related techniques and tools used? Are PDCA problem-solving techniques used?

Table A3. Lean Culture Construct (Lean_Cult) based on the Toyota Production System 4P Model (Liker, 2004)

4P Pyramid	Main items	Question used in the IW-MPI questionnaire
1. PROBLEM SOLVING	Ongoing improvement and learning	Does the company have a culture of ongoing improvement and learning?
	Consensus-based decisions and fast implementation	Have group working methodologies been internalized (teaming/team-building practices)?
	Go to the workplace. See for yourself	Is the adoption of improvement methodologies being promoted in the plant?
2. PEOPLE & PARTNERS	Train leaders	Are there internal programs for developing leaders and supervisors?
	Respect your teams and make them evolve	Is there a formal program for employee training? Is there an annual internal program for review and promotion? Is there a formal program for health and safety?
	Respect and help suppliers	Is there a design for collaboration with suppliers? Is open-book management promoted with suppliers? Does the firm have programs for collaboration with suppliers in the long term?
3. PROCESS	Eliminate waste	Is there a culture for eliminating waste in the organization?
	Use reliable technology	Is the use of technology promoted in the organization?
	Use pull systems and create flow	Are JIT inventory policies promoted with suppliers?
4. PHILOSOPHY	Long-term goals	Is there a strategy for deploying policies in the organization?

Table A4. Component Loadings (Lean_Tools and Lean_Cult)

Model Summary				
			Variance Accounted For	
Variable	Dimension	Cronbach´s Alpha[a]	Total (Eigenvalue)	% of Variance
Lean_Tools	1	0.746	3.039	30.391
	2	0.165	1.175	11.748
	Total	0.847	4.214	42.139
Lean_Cult	1	0.778	3.602	36.019
	2	0.359	1.500	15.098
	Total	0.866	5.102	51.019

Note. [a]Total Cronbach's alpha is based on total self-values

Table A5. Component Loadings (Lean_Tools and Lean_Cult)

Lean_Tools (10 items)	Dimension 1	Dimension 2	Lean_Cult (14 items)	Dimension 1	Dimension 2
VSM	0.663	0.377	Waste reduction culture	0.398	0.843
Supermarket	0.619	- 0.03	Strategic vision in the organization	0.485	- 0.159
PDCA	0.105	- 0.649	Promotion of the use of technology	0.195	- 0.387
TPM	0.453	- 0.548	Continuous improvement philosophy	0.684	- 0.032
Heijunka_Techniques	0.535	- 0.111	Internal leadership	0.678	- 0.076
Pull_System	0.728	0.075	Problem resolution at the shop floor	0.302	- 0.203
Kaizen_Event	0.644	0.456	Health and safety programs	0.700	0.135
Onepiece_Flow_Techn	0.572	- 0.106	Open book policies	0.380	0.010
Quality audits	0.411	- 0.048	Group-work policies	0.637	- 0.194
SMED	0.522	- 0.266	Continuous training	0.535	- 0.269
			Collaborative design with suppliers	-0.263	- 0.565
			Internal promotion programs	0.651	0.178
			Long-term collaboration relationships	0.212	- 0.243
			JIT policies with suppliers	0.535	- 0.170

Table A6. Analysis of Lean Culture Mediation (Model 1), Lean Toolbox Mediation (Model 2), and Moderation by Culture (Model 3)

	Table A6a Analysis of Lean culture mediation			Table A6b Analysis of Lean toolbox mediation			Table A6c Moderation by Lean culture		
	Model 1.1	**Model 1.2**	**Model 1.3**	**Model 2.1**	**Model 2.2**	**Model 2.3**	**Model 3.1**	**Model 3.2**	**Model 3.3**
	Tools--> Pfe	Tools--> Cult	T+C-->Pfe	Cult--> Pfe	Cult--> Tools	T+C-->Pfe	Tools--> Pfe	Cult--> Pfe	T+C-->Pfe
Lean_Tools	**0.205*****	**0.472*****	**0.027**			**0.027**	**0.205*****		**0.040**
Lean_Cult			**0.414*****	**0.423*****	**0.525*****	**0.413*****		**0.427*****	**0.411*****
ToolsxCult									**-0.026**
Sector	0.105	-0.052	0.110	0.112	0.138***	0.110	0.105	0.112	0.109
Size	0.052	0.085***	0.006	0.011	0.129***	0.006	0.052	0.011	0.005
Age	0.353***	0.095***	0.314***	0.313***	-0.013	0.314***	0.353***	0.313***	0.313***
_cons	10.495***	-0.148**	10.656***	10.636***	-0.775**	10.656***	10.495***	10.635***	10.679***

Note. T and C represent lean tools and lean culture respectively