Lean Supply Chain: empirical research on practices and performance

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Abstract

Due to an increasing competitive pressure for shorter lead times, lower costs and better quality, the principles of Lean Manufacturing have been incorporated into the supply chain integrative approaches. The adoption of Lean Supply Chain Management (LSCM) entails a different business model, in which improved profits arise from the cooperation rather than bargaining or imposing power over supply chain partners. This paper aims to examine the relationship between LSCM practices and the performance of the supply chain. The literature about LSCM is scarce and only suggests a positive association between LSCM and supply chain performance, but without testing empirically. The comprehension of the relationship between the implementation of LSCM practices and their effect on supply chain performance helps to anticipate occasional difficulties and sets the proper expectations along the lean implementation. In this sense, we postulate four bundles of inter-related and internally consistent LSCM practices, which have been conceptually proposed in previous researches. Base on a survey carried out with 89 Brazilian companies, we empirically validate these bundles and further investigate their simultaneous effects on supply chain performance. Results indicate that the effect of each bundle may not always happen as expected.

Keywords
Lean supply chain management; Contextual variables; Supply chain performance; Empirical research.

1. Introduction

Lean Manufacturing (LM) is widely deemed as one of the most disseminated production systems. Several literature evidences indicate a positive association between implementing LM and improving operational performance (Marodin and Saurin, 2013; Rezende et al., 2016). In a general approach, LM practices and principles aim at reducing waste and variability in the processes, adding more value to customers and providing operational performance improvement (Shah and Ward, 2003). Nevertheless, most successful companies are the ones that are expanding and linking their internal improvement processes with external customers and suppliers (Frohlich and Westbrook, 2001). Thus, supplier and customer integration emerges as an important element to improve competitiveness beyond the organizational boundaries (Flynn et al., 2010; Frazzon et al., 2015). This concept is perfectly aligned with classical Supply Chain Management (SCM) definitions, since it comprises the flow of goods from supplier through manufacturing and distribution chains until the end user (Power, 2005). In this sense, the focus of SCM practices must shift from functional and independent to general and integrative initiatives (Theagarajan and Manohar, 2015).
Hines et al. (2004) affirm that the understanding about LM evolved from the application of simple practices at the workstation level to a supply chain or value systems across multiple organizations, as a natural organizational

learning process expanding the knowledge boundaries. Further, several recent researches on LM (Moyano-Fuentes and Sacristán-Díaz, 2012; Bhamu and Singh Sangwan, 2014; Jasti and Kodali, 2015) indicate that the value system, which consist in involving and understanding the customer and suppliers, is considered to be one of the new frontiers of research on lean. Therefore, due to an increasing competitive pressure for shorter lead times, lower costs and better quality, the principles of LM have been incorporated into the supply chain integrative approaches (Cudney and Elrod, 2010). Previous studies (e.g., Lewis, 2006; Cagliano et al., 2006; Blanchard, 2010) have implemented LM principles and practices in SCM activities and reported improved organizational outputs. However, although widely discussed, the integration of LM principles and practices into SCM still has much to evolve in order to better comprehend the adaptation of lean approach (Shamah, 2013; Marodin et al., 2016).

The adaptation of LM principles to SCM activities is not a simple process (Hines et al., 2004) due to several reasons, such as: (i) waste is easier to be identified and quantified in shop floor environment rather than supply chain; and (ii) manufacturing processes can be controlled through top management, while SCM requires attention for the entire chain, from suppliers to customers (Anand and Kodali, 2008; Soni and Kodali, 2012). Thus, lean supply chain management (LSCM) can be defined as a set of organizations directly linked by upstream and downstream flows of products, services, information and funds that collaboratively work to reduce cost and waste by efficiently pulling what is needed to meet the needs of individual customers (Vitasek et al., 2005). The adoption of LSCM entails a different business model, in which improved profits arise from the cooperation rather than bargaining or imposing power over supply chain partners (Alves Filho et al., 2004; Naim and Gosling, 2011; Chiromo et al., 2015).

In this context, this paper aims to examine the relationship between LSCM practices and the performance of the supply chain. Since Womack and Jones (2003; 2005) argued that true lean enterprises must implement lean principles throughout the information and production flows considering both customers and suppliers, there are no empirical evidences about the relationship and consequences of a systemic implementation of LSCM and its effect in the supply chain performance. The literature about LSCM is scarce and only suggests a positive association between LSCM and supply chain performance, but without testing empirically (e.g. McIvor, 2001; Wee and Wu, 2009; Perez et al., 2010; Kisperska-Moron and Haan, 2011).

The research provides managerial implications that may support leaders and practitioners to better comprehend the need and the advantages of a systemic lean implementation across organizations. Since LM is initially implemented on shop floor area and further deployed across the supply chain, LSCM practices tend to be less adopted and senior managers' awareness regarding its benefits is still limited. Furthermore, the understanding of the relationship between the implementation of LSCM practices and their effect on supply chain performance helps to anticipate occasional difficulties and sets the proper expectations along the lean implementation, providing improvement guidelines that might support certain supply chain objectives. We postulate four bundles of inter-related and internally consistent LSCM practices, which have been conceptually proposed by Jasti and Kodali (2015); these are: customer-supplier relationship management (CSRM), logistics management (LOM), elimination of waste and continuous improvement (EWCI), and top management commitment (TMC). We empirically validate these bundles and further investigate their simultaneous effects on supply chain performance.

2. LSCM practices and bundles

A lean supply chain should allow a flow of goods, services and technology from suppliers to customers without waste (Goldsby et al., 2006; Wee and Wu, 2009). The LSCM approach moves away from the current "trading mentality", in which profit targets are short term and highly dependent on market prices and the ability to negotiate strongly with suppliers or customers, to a strategy based on a long term commitment to supply chain partners, with a cooperative and systematic waste elimination along the chain (Yusuf et al., 2004; Agarwal et al., 2006). However, many organizations have struggled to implement LSCM practices due to lack of awareness and improper implementation approach. Further, several studies have focused only on individual aspects of LSCM and very few researches have approached both upstream and downstream activities of the organization (Anand and Kodali, 2008; Jasti and Kodali, 2015; Riet et al., 2015). Moreover, despite the fact that the stable and unidirectional theory and concepts of LSCM are not yet fully developed (Anand and Kodali, 2008), most of the studies have been restricted to a particular sector instead of a generalization of the LSCM framework (Perez et al., 2010; Petra and Marek, 2015).

A lean implementation across multi-levels of a supply chain is extremely difficult to achieve (Bruce et al., 2004; Taylor, 2006). Additionally, at the level of the whole supply chain it may be impracticable to achieve such ideal perfection. However, from the perspective of a specific supply chain echelon, it becomes easier to identify whether or not current practices are lean as well as their level of adoption (Levy, 1997; McCullen and Towill, 2001; Yusuf et al., 2004; Wong et al., 2014). Further, most literature evidences have concentrated on outlining practices and benefits, assuming that once companies are aware of a set of lean practices, a lean implementation would automatically be initiated (Stratton and Warburton, 2003; Cagliano et al., 2006; Naim and Gosling, 2011). A review of this literature reveals a number of practices that are commonly associated with LSCM, as summarized in Table 1. Table 1 lists the key LSCM practices most cited in the studied literature. It shows that there is a varying degree of frequency that each of the practices is considered in the studies reviewed. Practices LSCM1 (pull system), LSCM2 (close relationship between customer, supplier and relevant parties) and LSCM3 (leveled scheduling) appear to be most frequently included. On the other hand, the practices LSCM20 (establishment of distribution centers), LSCM21 (consignment stock) and LSCM22 (functional packaging design) seem to be more recently associated to the LSCM literature and, hence, studies that reference those practices are more scarce. Overall, the 22 practices emerge from an extensive literature review and provide a representative view of the main practices adopted in a LSCM.

There are many ways to combine individual practices to represent the multi-dimensional nature of a lean system (Shah and Ward, 2003). Previous studies in operations management literature have used exploratory or confirmatory factor analysis to combine individual practices into a multiplicative function to form orthogonal and unidimensional factors (e.g. Shah and Ward, 2007; Tortorella et al. 2016; Marodin et al., 2016). Specifically within the LSCM literature, few researches have tried to establish the main components that characterize a LSCM. For instance, Blos et al. (2015) suggest a framework based on eight SCM operational constructs, whose purpose is to keep the supply chain more resilient for both internal and external risks: (i) customer service, (ii) inventory management, (iii) flexibility, (iv) time to market, (v) finance, (vi) ordering cycle time, (vii) quality, and (viii) market. Perez et al. (2010) indicate a seven dimension model for lean SCM implementation. Each dimension has been categorized in terms of the five lean principles (Womack and Jones, 2003; Womack and Jones, 2005): value, value stream, flow, pull, and perfection. Soni and Kodali (2012) and, later, Jasti and Kodali (2015), based on an extensive literature review of the past thirty years with regards to LSCM, found at least 30 lean SCM frameworks proposed in the literature. Moreover, the authors identified about 129 unique LSCM elements/practices, from which eight practices were defined as pillars of lean SCM implementation: (i) information technology management, (ii) supplier management, (iii) elimination of waste, (iv) JIT production, (v) customer relationship management, (vi) logistics management, (vii) top management commitment, and (viii) continuous improvement. From these, we selected inter-related practices to combine into four main practices bundles associated with CSRM, LOM, EWCI and TMC.

We use the individual practices to examine the association between contextual variables and the pattern of implementation among the 22 practices listed in Table 1. The approach of measuring the maturity of lean implementation based on the assessment of the adoption level of pre-defined practices has been extensively used in previous studies (Shah and Ward, 2007; Netland and Ferdows, 2014; Marodin et al., 2015) and seems to be quite effective to comprehend companies' maturity. Further, the four bundles of LSCM practices are used to investigate the relationship between implementation and supply chain performance, since we are interested in synergistic effects of LSCM implementation.

Several studies relate the implementation of LSCM practices to improvements on supply chain performance (e.g. Wu, 2002; Blanchard, 2010). Overall, researches on LSCM indicate that the implementation of these practices is frequently associated with improvement on measures such as inventory levels (Bruce et al., 2004; Chiromo et al., 2015), quality (Wee and Wu, 2009; Perez et al., 2010), supply lead time (Agarwal et al., 2006; Naim and Gosling, 2011), delivery service level (Savino and Mazza, 2015; Petra and Marek, 2015) and cost (Stratton and Warbusrton, 2003; Theagarajan and Manohar, 2015). However, most studies are constrained to a few facets of LSCM, often including deliveries in small lot sizes, synchronization and leveling of scheduling and production, and close relationship between suppliers and customers in order to provide win-win situations. Cagliano et al. (2006) state that LSCM practices can be recognized according to two distinct objectives: (i) integration of the forward physical flows; and (ii) coordination and integration of backward information and data flows from customers to suppliers.

Despite the evidences regarding performance improvements related to these practices, relatively little research exists to gauge the existent of supply chain performance improvements. This gap is particularly increased if we add to the empirical investigation the simultaneous use of several LSCM practices. We aim to examine the implementation of LSCM practices and their implications on supply chain performance after controlling for the effects assigned to contextual variables. Previous researches argue that a truly lean system may obtain benefits from the mutual application of several complementary practices, whose adoption intensities may vary according to the existing problems within the organization (Womack and Jones, 2005; Kisperska-Moron and De Haan, 2011; Wong et al., 2014). Thus, we posit that the simultaneous implementation of various LSCM practices combined into bundles of practices will have a positive impact on supply chain performance. To represent that, we propose the following:

Proposition: Implementation of LSCM bundles, each representing groups of related LSCM practices, will have a positive impact on supply chain performance improvement.

Table 1. LSCM practices and their appearance in key references

LSCM practices	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
$LSCM_1$ – *Kanban* or pull system	×	×	×	×	×	×	×			×				×	×	×	×	×	×		×	×	×		×	×
$LSCM_2$ – Close relationship between customer, supplier and relevant parties	×	×	×			×	×		×	×	×		×		×	×	×		×	×	×	×		×		×
$LSCM_3$ – Leveled scheduling or *heijunka*	×	×	×	×	×	×	×							×	×	×	×	×	×	×	×	×			×	×
$LSCM_4$ – Efficient and continuous replenishment	×			×		×	×			×							×		×	×	×	×	×		×	
$LSCM_5$ – Two-way feedback assessment	×	×				×	×		×	×					×		×		×		×	×	×			
$LSCM_6$ – Value chain management team		×					×					×			×	×			×	×	×	×	×	×		
$LSCM_7$ – Win-win problem solving methodology	×	×				×	×						×		×				×		×	×	×			
$LSCM_8$ – Value chain analysis or Value stream mapping			×		×									×	×			×	×	×	×	×		×		
$LSCM_9$ – *Keiretsu* (suppliers play a strategic role marshalling the efforts of their own suppliers)	×					×	×	×	×	×					×				×		×					
$LSCM_{10}$ – *Kyoryokukai* (suppliers' association that enhance lateral communication among suppliers, and act as an extra bulwark against customer opportunism)	×						×		×						×	×	×		×		×					×
$LSCM_{11}$ – Intervention strategy (customer is able to cooperatively intervene in the supplier's business operation and bring about change for better)	×					×	×			×	×						×		×		×		×			
$LSCM_{12}$ – Material handling systems				×	×							×			×			×	×		×				×	×
$LSCM_{13}$ – Standardized work procedures to assure quality achievement		×										×			×		×		×		×	×		×	×	
$LSCM_{14}$ – Open-minded and in depth market research conducted jointly (joint understanding of end-user requirements so that all players can work towards providing customer value)			×	×			×		×						×				×	×	×	×				
$LSCM_{15}$ – Open-book negotiation	×				×		×					×					×		×		×		×			
$LSCM_{16}$ – Inbound vehicle scheduling		×										×	×	×	×		×				×					×
$LSCM_{17}$ – *Hoshin Kanri* (policy deployment and development of a stretegy for the supply chain)					×		×				×				×	×	×		×		×					
$LSCM_{18}$ – Development of supply chain KPIs					×		×		×						×		×				×					×
$LSCM_{19}$ – Outbound transportation		×											×	×			×				×				×	×
$LSCM_{20}$ – Establishment of distribution centers					×							×		×							×					×
$LSCM_{21}$ – Consignment stock																×					×		×		×	
$LSCM_{22}$ – Functional packaging design																					×					×

Authors: (1) Lamming, 1996; (2) Levy, 1997; (3) Naylor et al., 1999; (4) Jones et al., 2000; (5) McCullen and Towill, 2001; (6) Stratton and Warburton, 2003; (7) Alves Filho et al., 2004; (8) Liker, 2004; (9) Yusuf et al., 2004; (10) Bruce et al., 2004; (11) Power, 2005; (12) Vitasek et al., 2005; (13) Agarwal et al., 2006; (14) Goldsby et al., 2006; (15) Taylor, 2006; (16) Cagliano et al., 2006; (17) Anand and Kodali, 2008; (18) Wee and Wu, 2009; (19) Perez et al., 2010; (20) Naim and Gosling, 2011; (21) Jasti and Kodali, 2015; (22) Theagarajan and Manohar, 2015; (23) Petra and Marek, 2015; (24) Boonsthonsatit and Jungthawan, 2015; (25) Chiromo et al., 2015; (26) Riet et al., 2015.

3. Method

3.1 Sample selection and characteristics

The criteria for selecting the sample of companies were the following: (a) to include companies located in a specific region of the country, in this case the Southern Brazil, as to reduce the effects of the external environment (e.g. regional culture, and socio-economic development), since this would be relatively homogeneous within the sample; (b) to include companies from different industrial sectors because lean has been expanding over many kinds of companies in recent years; and (c) respondents should have experience in lean and a role whose function was directly related to SCM in the company. The non-random choice of companies for surveys and the search for companies that are already known to the researchers is a commonly used strategy in other studies on LM (Boyle et al., 2011; Netland and Ferdows, 2014; Tortorella et al., 2016). For example, Shah and Ward (2007) used a sample with participants drawn from courses and training events when they conducted a survey on LM, since it was necessary that the respondents had experience in the subject. Kull et al. (2014) suggest that national culture could influence the implementation of lean practices. Therefore, a single geographic location also increases the homogeneity of the sample. Additionally, although implementing lean is usually associated primarily with high volume and discrete part manufacturers, pervasiveness of practices across the industrial spectrum is unknown (Tortorella et al., 2015).
Questionnaires were sent by e-mail to 497 former students of executive education courses on lean offered by a large Brazilian University since 2008. The institution is the only one in its region offering short courses on lean that are open to the general public. A first e-mail message containing the questionnaires was sent in January 2016, and two follow-ups were sent in the following weeks. The final sample was comprised of 89 valid responses (representing a response rate of 17.91%). The sample presents a relatively balanced amount of companies for each contextual variable. Most respondents were from large companies (64%); the majority of companies belonged to the automotive supply chain (27%). Most respondents (63%) belonged to companies that have been implementing LM for less than 5 years, and were positioned at the first and second tiers of their supply chains (57%). Finally, regarding the amount of onshore suppliers, there was a predominance of companies (69%) with more than 30% of their suppliers being onshore.

3.2 Questionnaire development and data collection

Surveys that use data from single respondents may be affected by respondent's bias; to minimize that we followed some directions given by Podsakoff et al. (2003). The questionnaire had three parts. Supply chain performance was placed first and physically far from independent variables (LSCM practices) in the questionnaire. The first part aimed at assessing the level of change over the last five years of the supply chain performance indicators (dependent variables): (i) supply lead time, (ii) costs with supply and raw material, (iii) inventory level, (iv) delivery service level and (v) quality. A 5-point scale ranging from 1 (worsened significantly) to 5 (improved significantly) was used in the questionnaire. The second part aimed to collect information regarding the contextual variables of the companies. All contextual variables were re-coded into two categories each. The first category for tier level comprised companies from the first and second tiers, while the second category consisted of companies from tiers three and four. For plant size, large-sized companies were determined as the ones that presented more than 500 employees, and small-sized were characterized by companies with less than 500 employees, as suggested by SEBRAE (2013). LM experience was coded into (i) more than five years and (ii) less than five years of LM experience; according to Marodin et al. (2016), who suggest that companies with more than five years of LM implementation might in a stage where lean initiatives are being applied to suppliers and customers and the transition from top-down to bottom-up improvement would be completed. Finally, the variable onshore suppliers was categorized according to the amount of companies' suppliers that are located onshore. As suggested by Canuto et al. (2013), an index of 70% of onshore suppliers would be a reasonable threshold value specifically within the Brazilian industry scenario. Finally, the third part of the questionnaire assessed the implementation level of the 22 LSCM practices (independent variables). For that, we developed a questionnaire using a five-point Likert scale (1=low implementation to 5=high implementation). We used an adapted header of Shah and Ward (2003), which stated "*Please indicate the extent of implementation of each of the following practice in your supply chain?*". The instrument was pre-tested by three academics and three supply chain managers working in companies that were in the process of implementing lean in order to ensure face and content validity. The instrument was improved with the necessary modifications according to suggestions made.

3.3 Data analysis

The 22 LSCM practices were combined into four bundles. Each of the bundles was formed by adding the scores for each of the practices included in the bundle for each responding company. All 22 LSCM practices were entered for PCA (principal component analysis) and varimax rotation was used to extract orthogonal components, and four components were extracted. Thus, the bundles were empirically validated using PCA with varimax rotation and reliability analysis (Cronbach's alfa), as shown in Table 2. The results were replicated using oblique rotation as a check for orthogonality and the extracted components were similar. Additionally, unidimensionality of each component was verified and confirmed by applying PCA at the component level. A reliability assessment was performed determining the Cronbach's alpha values for each component, which depends upon the number of items in the scale and the average inter-item correlation (Meyers et al., 2006). All components displayed high reliability, with alpha values above 0.804. Finally, the response value for each bundle was obtained through the average of the corresponding practices included in the bundle weighted by their respective factor loadings from the PCA.
Regarding performance, a scale was constructed for supply chain performance measure based on PCA of the five indicators aforementioned, and the factor scores were used as the dependent variable. Table 3 shows that all five indicators load on one factor, with an eigenvalue of 2.857 explaining almost 60% of the variation. Further the obtained Cronbach's alpha value is 0.812.

Table 2. PCA to validate LSCM bundles–rotated component matrix

LSCM practices	Factor loadings			
	CSRM	LOM	EWCI	TMC
$LSCM_2$	**0.591**	0.072	0.131	0.308
$LSCM_{15}$	**0.728**	-0.052	0.166	0.230
$LSCM_{17}$	**0.795**	0.223	0.172	0.135
$LSCM_{18}$	**0.516**	0.314	0.220	0.276
$LSCM_4$	0.460	**0.588**	0.157	0.228
$LSCM_{12}$	0.353	**0.655**	0.183	0.090
$LSCM_{13}$	0.127	**0.757**	0.040	0.169
$LSCM_{14}$	0.122	**0.582**	0.140	0.373
$LSCM_{16}$	0.450	**0.709**	0.073	-0.029
$LSCM_{19}$	0.457	**0.572**	0.079	0.151
$LSCM_{20}$	0.241	**0.721**	0.205	0.090
$LSCM_{22}$	0.204	**0.684**	0.264	0.047
$LSCM_1$	0.525	0.017	**0.617**	0.208
$LSCM_3$	0.170	0.081	**0.693**	0.084
$LSCM_7$	0.415	0.058	**0.650**	0.034
$LSCM_8$	0.004	0.250	**0.762**	0.271
$LSCM_{21}$	0.103	0.213	**0.707**	-0.004
$LSCM_5$	0.301	0.112	0.031	**0.785**
$LSCM_6$	0.230	0.162	0.407	**0.581**
$LSCM_9$	0.212	0.160	0.529	**0.596**
$LSCM_{10}$	0.178	0.202	0.257	**0.712**
$LSCM_{11}$	0.021	0.310	0.073	**0.673**
Eigenvalues	8.556	1.897	1.700	1.293
Initial percent of variance explained	38.890	8.625	7.729	5.876
Rotation sum of squared loadings (total)	3.863	3.584	3.273	2.726
Percent of variance explained	17.560	16.290	14.877	12.393
Cronbach α (sample *n*=89)	0.804	0.865	0.805	0.817

Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalization.

Table 3 – Supply chain performance: factor loading, means, standard deviation and Spearman correlation

Five-year change in	Loading on first component	Mean	Std. dev.	Supply lead time	Correlation			
					Costs with supply and raw material	Inventory	Delivery service level	Quality
Supply lead time	0.81	3.12	1.06	-	0.47	0.49	0.52	0.52
Costs with supply and raw material	0.70	3.21	0.97	0.47	-	0.43	0.40	0.34
Inventory	0.78	3.03	1.11	0.49	0.43	-	0.55	0.52
Delivery service level	0.75	3.32	0.97	0.52	0.40	0.55	-	0.42
Quality	0.73	3.57	0.93	0.52	0.34	0.52	0.42	-
Eigenvalue	2.857							
(variance explained)	57.14%							
Cronbach α	0.812							

Pairwise deletion method used for missing data. All correlations are significant at 0.01 level (two-tailed)

4. Results

With regards to the effect of the LSCM practices on supply chain performance, a hierarchical regression model was undertaken. Regression analyses are a set of statistical techniques that allow one to assess the relationship between on dependent variable and several independent variables (Tabachnick and Fidell, 2013). Thus, an Ordinary Least Squares (OLS) regression analysis method was used to describe how the four LSCM bundles are associated with the factor score for supply chain performance. The regression was performed in two stages. In the first stage it was included only the contextual variables (tier level, plant size, LM experience and onshore suppliers) as control variables; while the second stage added the influence of the independent variables. Therefore, it allows us to evaluate the incremental effect of LSCM bundles regardless of contextual variables.
Table 4 shows the results from the hierarchical regression analysis. Model 1 indicates that contextual variables as a group account for a small but significant amount of variance; with tier level presenting a significant negative impact and plant size a positive influence on supply chain performance. The inclusion of the LSCM bundles (Model 2) results in a significant change in R^2. Overall, this model significantly explains 58.3% of the variance in supply chain performance.

Table 4. Results from hierarchical regression analysis - dependent variable is factor score for supply chain performance

	Standardized β coefficients	
	Model 1	Model 2
LM experience	0.013	0.084
Tier level	-0.332 ***	0.009
Onshore suppliers	0.088	0.092
Plant size	0.296 ***	-0.045
Elimination of waste and continuous improvement		0.075
Logistics management		0.411 ***
Top management commitment		0.184 *
Customer-Supplier relationship management		0.232 **
R^2	0.214	0.583
Adjusted R^2	0.177	0.542
Change in R^2	0.214	0.369
p-value of F statistic	0.000	0.000

The variance inflation factor is smaller than 5 for all variables in the models indicating no multicollinearity.
* p <0.1
** p <0.05
*** p <0.01

Tolerance values, which are used to indicate the degree of multicollinearity, can range from 0 to 1 with values near to 1 denoting a high degree of collinearity. The tolerance values of the contextual variables with LSCM bundles varied from 0.453 to 0.887, indicating that some degree of multicollinearity affects these variables. To assess if such multicollinearity could cause potential problems in predicting the performance effects to individual regressors, we calculated VIF (variance inflation factors) for all coefficients in the regression equation for Model 2. Previous researchers (e.g. Hair et al., 2006; Hayes and Matthes, 2009; Tabachnick and Fidell, 2013) suggest that values below

five indicate that multicollinearity problems do not affect the coefficient. The VIF for all coefficients ranged from 1.00 to 2.11, allowing the regression model to attribute performance effects to all individual variables.
The regression analysis suggests that all LSCM bundles have a significant positive association with supply chain performance, except for EWCI. As a group, they explain about 37% of the variation in supply chain performance even after accounting for the effects of contextual variables. This provides support for synergistic effects of implementing LSCM practices, and partially supports proposition 1.
Surprisingly, the results for EWCI do not show a significant impact on supply chain performance, contradicts the expected effect. This outcome might indicate that Brazilian companies involved in this study sample are still much focused on their internal improvements, giving attention to stabilizing and reducing waste mainly on their manufacturing processes. EWCI bundle comprises practices such as pull system, leveled scheduling and value stream mapping, which are widely deemed as important for achieving a lean implementation and obtaining better operational performance (Shah and Ward, 2003 and 2007; Savino et al., 2015). However, their application outside companies' boundaries, i.e. along the supply chain, seems to be less pervasive than expected.
Further, although companies appear to be searching for lateral cooperation and establishing a collaborative environment along their supply chain, the initiatives regarding elimination of waste and continuous improvement are self-managed and their emphasis has been mostly on internal business needs. This result is somewhat consistent with the findings of Boyle et al. (2011) and Cagliano et al. (2006), which state that managers and practitioners who are highly involved in enhancing their manufacturing processes may struggle envisioning the benefits of incorporating or expanding improvement approaches to other agents of the supply chain. This inference is also supported by the results for proposition 3, which suggest a lower level of association between the implementation of LSCM practices and company's experience with LM than expected.

5. Conclusion

In this paper we have studied the relationship between LSCM practices and the performance of the supply chain. This research suggests two major findings. First, supply chain context, i.e. tier level, plant size, company's experience with LM and level of onshore suppliers, matters with regard to implementation of LSCM practices, although not all aspects matter to the same extent and effect. Second, applying synergistic bundles of LSCM practices concurrently appears to make a significant contribution to supply chain performance. We provide a deeper discussion on both findings in the following sections.
The results suggest that implementation of each of the bundles of LSCM practices under study contribute substantially to the supply chain performance, except for EWCI (elimination of waste and continuous improvement) whose result indicates an existing misalignment between internal improvement approaches and improvement initiatives among the supply chain agents. The three bundles LOM, CSRM and TMC explain about 37% of the variance of the supply chain performance after controlling for the effects of contextual variables. It is also worth noticing that none of the contextual variables present a significant association with supply chain performance when LSCM bundles are considered.
Although these findings may seem intuitive, such result has not been evidenced previously in the literature. As a matter of fact, correlated studies have proposed similar outcomes, but based on different methodologies or assumptions. For instance, Shah and Ward (2007) proposed an assessment instrument that combined lean practices related to supplier, customer and internal manufacturing processes. However, the supplier and customer practices comprised a set of 17 practices that differ from the ones presented here. Soni and Kodali (2013) and, later, Jasti and Kodali (2015) based on the integration of an extensive literature review and qualitative methods suggested a framework for LSCM implementation. Nevertheless, the proposed frameworks were not empirically validated. Therefore, a further contribution of this research consists in identifying and empirically validating four specific bundles of LSCM practices that were conceptually proposed by previous studies.
These findings provide unambiguous evidence that synergistic effects of LSCM practices are associated with better supply chain performance. The implication for managers and practitioners concerns the benefits outlined from the concurrent implementation of these LSCM practices, regardless of tier level, plant size, LM experience and onshore suppliers.
There are some limitations due to the nature of the sample used in the survey that must be highlighted. First, respondents were mostly from companies located in Brazil; their answers might thus be linked to national issues. Thus, as this limitation restricts the results to this geographic condition it also increases the certainty that they apply to those companies, and to others in countries with similar characteristics (developing economies).

Moreover, regarding the effect of the contextual variables on the implementation of LSCM practices, we examined their relationship separately. However, the contextual variables may present a synergistic effect so the end results may differ from the isolated ones. Therefore, a better comprehension of the concurrent influence of all contextual variables may enable to more precisely describe their impact on the implementation of LSCM practices.
Regarding the proposed objective, this investigation empirically validated the association between implementation of four LSCM bundles of practices and supply chain performance. However, further investigation would add more information regarding other potential bundles of LSCM practices, such as the ones proposed by Jasti and Kodali (2015), and help to establish a wider perspective about the problem. Such extension would require a more elaborate data collection and analysis.

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