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Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms

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A B S T R A C T

This paper explores relationships between lean manufacturing practices, environmental management (e.g., environmental management practices and environmental performance) and business performance outcomes (e.g., market and financial performance). The hypothesized relationships of this model are tested with data collected from 309 international manufacturing firms (IMSS IV) by using AMOS. The findings suggest that prior lean manufacturing experiences are positively related to environmental management practices. Environmental management practices alone are negatively related to market and financial performance. However, improved environmental performance substantially reduces the negative impact of environmental management practices on market and financial performance. The paper provides empirical evidences with large sample size that environmental management practices become an important mediating variable to resolve the conflicts between lean manufacturing and environmental performance. Additional contextual analyses suggest that differences exist in terms of the strengths and statistical significance of some of the proposed relationships. Thus, for effective implementation of environmental management, firms need to measure environmental performance through which the impact of environmental management on other business performance outcomes is examined.

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1. Introduction

With an increasing social demand of environmental sustainability, firms embrace the strategic importance of environmental management practices for competitive advantage (Porter and van der Linde, 1995; Sroufe, 2003; Kleindorfer et al., 2005; Pagell and Gobeli, 2009; Yang et al., 2010). In spite of the ongoing debate on the relationships between environmental management and financial performance, the previous research is often inconsistent and ambiguous (Russo and Fouts, 1997; Jiménez and Lorente, 2001; Rao and Holt, 2005). The business press also reflects this debate among practitioners regarding the compatibility of environmental objectives with economic viability (Hayward, 2009; Stavins, 2009; Totty, 2009). In light of these divergent views, while organizations recognize that environmental sustainability has implications for their competitive positions, firms are unclear about the implementation details of environmental management practices (Montabon et al., 2007).

Good research requires rigor, relevance and clarity (Palmer et al., 2009; Suddaby, 2010). Building sound theory may start with the obvious and then move into more unclear, controversial and fuzzy areas (Handfield and Melnyk, 1998). In this paper, we start with the relationship between lean manufacturing and environment management practices. We then present an integrated framework that includes lean manufacturing, environmental management practices, and environmental and business performance. In the next section we provide a research model conceptual framework that presents key variables based on relevant literature review. In the hypotheses development section the inter-relationships between variables are defined and explained. In the subsequent section we discuss the research design, analysis and results. The final section presents the theoretical and managerial implications, and concludes with a summary of limitations and future research directions.

2. Literature review

An important task of empirical validation is to test the internal and external validity. For this reason, construct clarity is to measure what needs to measure (Suddaby, 2010). In this paper, we have carefully defined each construct in terms of essential characteristics with the support of relevant literature base. The detail measures ensure adequate construct validity. We then examine

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Table 1
Variables definition and supporting literature.

Variables	Definition	Supporting literature
Lean manufacturing	A set of practices focused on reduction of wastes and non-value added activities from a firm's manufacturing operations.	Womack et al. (1990), McLachlin (1997), Shah and Ward (2003, 2007), Li et al. (2005), Browning and Heath (2009)
Just-in-time flow	A set of interrelated practices for managing production flow.	McLachlin (1997), Shah and Ward (2003), Swink et al. (2005)
Quality management	A set of interrelated initiatives to assure the quality of the products and the equipment used to manufacture them.	McKone et al., (1999), Fullerton et al. (2003), Shah and Ward (2003, 2007), Linderman et al. (2006)
Employee involvement	The human element of lean manufacturing such as formal training programs, problem solving groups, self-directed work teams and autonomous problem solving.	MacDuffie (1995), McLachlin (1997), Shah and Ward (2003, 2007), Tu et al. (2006)
Environmental management practices	A set of programs to improve environmental performance of processes and products in the forms of environmental management system, Life-Cycle Analysis, Design for Environment, Environmental certification.	Miettinen and Hamalainen (1997), Melnyk et al. (2003), Sroufe (2003), Matos and Hall (2007), Montabon et al. (2007)
Environmental performance	The degree to which an organization improves its performance in respect to its environmental responsibilities.	Sroufe (2003), Kleindorfer et al. (2005), Matos and Hall (2007), Montabon et al. (2007)
Market performance	The degree to which an organization achieves market-valued outcomes (e.g., sales and market growth).	Narasimhan and Kim (2002), Lin et al. (2005), Menor et al. (2007)
Financial performance	The degree to which an organization achieves profit-oriented outcomes (e.g., ROS and ROI).	Narasimhan and Kim (2002), Lin et al. (2005), Menor et al. (2007)

how these constructs are related. Table 1 is a summary of each construct (definitions and supporting literature). Appendix A shows the items of each construct, mean, standard deviation, factor loadings and *t*-value

2.1. Lean manufacturing (LM)

Since the conception of the assembly line and the following development of the Toyota Production System (TPS), efficiency has been a central objective of manufacturing (Holweg, 2007). Lean manufacturing focuses on the systematic elimination of wastes from an organization's operations through a set of synergistic work practices to produce products and services at the rate of demand (Womack et al., 1990; Fullerton et al., 2003; Simpson and Power, 2005; Shah and Ward, 2007). Lean manufacturing represents a multifaceted concept that may be grouped together as distinct bundles of organizational practices (McLachlin, 1997; MacDuffie, 1995). A list of bundles of lean practices includes JIT, total quality management, total preventative maintenance, and human resource management, pull, flow, low setup, controlled processes, productive maintenance and involved employees (McKone et al., 1999; Swink et al., 2005; Linderman et al., 2006; Shah and Ward, 2007). For the purpose of this study we define *lean manufacturing* as a set of practices focused on reduction of wastes and non-value added activities from a firm's manufacturing operations (Womack et al., 1990; McLachlin, 1997; Shah and Ward, 2003, 2007; Li et al., 2005; Browning and Heath, 2009).

2.2. Environmental management practices (EMPs)

Firms that have successfully reduced their internal waste through lean production methods also implement practices for better environment management (Melnyk et al., 2003; Sroufe, 2003; Montabon et al., 2007). Such practices expand the scope of waste reduction efforts beyond efficiency within the organization (Zhu and Sarkis, 2004; Kleindorfer et al., 2005). A diverse set of stakeholders (e.g., customers, shareholders, local communities and government regulators) influence firms' decision making processes and their corporate strategic practices (Henriques and Sadorsky, 1999; Buysse and Verbeke, 2003). Environmental management covers from product development to final delivery and ultimate disposal of the product (Klassen and Whybark, 1999; Sroufe, 2003). ISO 14000 standards, an essential element of Environmental Management System (EMS) help firms in assessing, managing, coordinating and monitoring corporate environmental activities (Melnyk et al., 2003; Sroufe, 2003). In this paper, *environmental management practices* refer to programs to improve environmental performance of processes and products in the forms of eco-design (e.g., design for environment), recycling, waste management and life-cycle analysis (Miettinen and Hamalainen, 1997; Sroufe, 2003; Matos and Hall, 2007; Montabon et al., 2007).

2.3. Performance outcomes

Organizational performance is multifaceted and of interest for our research are the two aspects of environmental performance and business performance. *Environmental performance* refers to the organization's performance with respect to their environmental responsibilities (Kleindorfer et al., 2005). *Business performance* takes into account the organizations responsibilities towards their shareholders and has a profit maximization objective (Rappaport, 1987). In line with earlier research business performance may be conceptualized with the two dimensions of *market performance* and *financial performance* (Narasimhan and Kim, 2002; Lin et al., 2005; Menor et al., 2007).

3. Hypotheses development

Fig. 1 is a research framework that represents how lean manufacturing, environmental management practices, environmental performance, market performance and financial performance are related. Specific hypotheses are discussed next.

3.1. Lean manufacturing, environmental management practices and environmental performance

Lean manufacturing focuses on elimination of waste from within the firm's production systems through continuous improvement and process changes for reducing non-value added activities

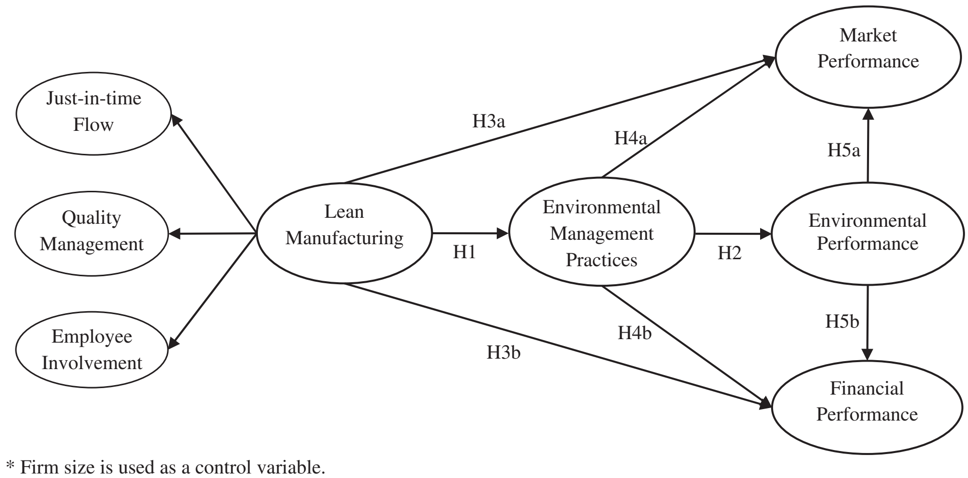


Fig. 1. Research Model*.

or elimination of wastes (Womack et al., 1990; Florida, 1996). Prior knowledge capacity related to JIT flow activities (e.g., value stream mapping, differentiation of value-added and non-value added tasks, use of metrics to track and reduce in-process waste and team problem solving) and ISO quality certification experiences might be relevant to the organizational efforts of environmental wastes (Cohen and Levinthal, 1990; King and Lenox, 2001). The importance of employee involvement in adopting environmental practices has been highlighted in existing research (Kornbluh et al., 1989; Florida, 1996). Lean manufacturing creates, within an organization, the orientation to increase employee responsibility and involve employees in waste reduction efforts (Shah and Ward, 2003; Tu et al., 2006). Such lean orientation may also help firms to adopt environmental management practices which aim at reducing wastes and pollutants reduction (Yang et al., 2010). Thus, experiences with lean manufacturing may enable organizations to adopt environmental management practices. Therefore, we hypothesize,

H1. Lean manufacturing will be positively associated with environmental management practices.

Environmental management practices help an organization implement process and procedures which take into account environmental consideration across all functions (Sroufe, 2003). Such process and procedures are expected to reduce an organization's negative impact on its environmental performance, especially in conjunction with ISO 14001 Certification (Melnyk et al., 2003). Similarly, design for environment allows an organization to design eco-friendly products reducing their impact on the environment and improving environmental performance (Sroufe, 2003). Life-cycle analysis provides an organization with a process to analyze and understand the influence of its products and processes on the environment through their life cycle and helps improve environmental performance (Matos and Hall, 2007). In brief, environmental management practices (e.g., Environmental Management Systems, Design for Environment, Life-Cycle Analysis and ISO 14001 Certification) allow organizations to improve environmental performance. Thus, we hypothesize,

H2. Environmental management practices will be positively associated with environmental performance.

3.2. Lean manufacturing and business performance

Lean manufacturing practices enhance manufacturing productivity by reducing setup times and work in process inventory improving throughput times, and thus improve market performance (Tu et al., 2006). Lean manufacturing, with the use of Six Sigma, achieves innovative problem solving in business processes (e.g., new product development, order fulfillment, customer services) and achieves customer satisfaction by increasing customer responsiveness and reducing customer lead time (Shah and Ward, 2003; Ward and Zhou, 2006). Lean manufacturing is also expected to enhance the firm's ability to improve customer value in terms of lower prices and quality products which will enhance market performance of firms. Thus, we hypothesize,

H3a. Lean manufacturing will be positively associated with market performance.

Lean manufacturing influences financial performance through improving organizational processes, cost efficiencies (Fullerton et al., 2003; Christopher and Towill, 2000; Fullerton and Wempe, 2009) and labor and asset productivity increase (Blackburn, 1991; Golhar and Stamm, 1991; Kinney and Wempe, 2002). Thus, we hypothesize,

H3b. Lean manufacturing will be positively associated with financial performance.

3.3. Environmental management practices, environmental performance and business performance

Implementation of environmental management practices may require resource reconfigurations which starve other important projects for resources, especially once the easy opportunities have been harvested (Walley and Whitehead, 1994). This may adversely influence other aspects of organizational performance. Specifically, for market performance, increasing resource requirements for implementation of environmental management practices may lead to reduced resources for marketing efforts which can negatively affect market performance (Keller, 1993; Krasnikov et al., 2010). Further, with increasing consumer awareness of environmental issues, firms with relatively short history of implementing environmental management practices may not yet be noted for their 'green' reputation. This is especially true in case where demand may be highly elastic and environmental improvements lead to increase in product cost. Thus, we hypothesize,

H4a. Environmental management practices will be negatively associated with market performance.

Environmental management practices require organizations to make investments in human, structural and social capital for their implementation. For example, implementation of recycling and product reuse practices requires additional structural and infrastructural investments in the reverse supply chain for product recovery (Kocabasoglu et al., 2007). Such investments increase the cost burdens of firms. Environmental considerations in the product design may also demand additional time commitments for design work and training for employees who should track data and environment regulatory requirements. These investment requirements would change the cost structures of firms potentially leading to reduce profitability, especially in the short term. Thus, we hypothesize,

H4b. Environment management practices will be negatively associated with financial performance.

The improved environmental performance is expected to attenuate the negative direct influence of environmental management practices on business performance. Improved environmental performance indicates the organizations commitment to minimize its ecological impact (Starik and Rands, 1995). Commitment to minimize ecological harm may improve the firm's brand image, positively influencing market performance (King and Lenox, 2002). In fact, improved environmental performance is seen as a component of an organization's corporate social performance (Pagell and Gobeli, 2009; Orlitzky et al., 2003). Improved environmental performance may benefit firms with respect to their consumers such as customer–firm identification, customer satisfaction and loyalty leading to improved firm image which is expected to positively influence market performance (Brown and Dacin, 1997; Luo and Bhattacharya, 2009). Thus, we hypothesize,

H5a. Environmental performance will be positively associated with market performance.

Environment performance in terms of reduced emissions, waste prevention and less waste treatment on-site are associated with higher financial performance (Hart and Ahuja, 1996; King and Lenox, 2002). The positive corporate social performance due to improvements in environmental performance may also lead to higher market valuation of firms (Klassen and McLaughlin, 1996; Russo and Fouts, 1997; Luo and Bhattacharya, 2009). Thus, we hypothesize,

H5b. Environmental performance will be positively associated with financial performance.

4. Research methodology

4.1. Research database

In order to test the proposed hypotheses, we use the International Manufacturing Strategy Survey (IMSS-IV) data collected in 2005. IMSS is a worldwide research project and has been carried out since 1992 by an international network of operations strategy researchers for the purpose of identifying the strategies, practices and performance of manufacturing firms' worldwide. IMSS data collection is conducted by the international coordinator along with national coordinators. The survey is prepared in English. National coordinators handle the translation of the survey as needed. The rigorous process ensures that the two-stages of translation are conducted. Other details about IMSS survey are available in IMSS-related publications (Voss and Blackmon, 1998; Frohlich and Dixon, 2001; da Silveira, 2005, 2006; Cagliano et al., 2006; Hong and Roh, 2009; Hong et al., 2009).

Given the large scale scope of the survey for IMSS, the data are useful for exploring contemporary strategic operations management issues. One of the co-authors of this paper participated in the design process of the IMSS IV. Based on the prior experiences of IMSS I, II and III, the general research themes and objectives of survey were conceived at the time of design of IMSS IV for testing what well-grounded theories suggest about the plausible relationships (i.e., confirmatory). With the new set of IMSS IV data is also useful to explore the relationships that have not been tested before (i.e., exploratory). Thus, a specific model that is presented in this paper is both exploratory and confirmatory.

4.2. Measures

We use a combination of single- and multi-item scales to test our hypotheses. The research team selected measurement items from the IMSS database based on existing literature to ensure face and content validity. Appendix A provides survey items used in our study. Perceptual measures with a five point Likert scale are used to measure responses. Lean manufacturing (LM) is conceptualized as a second-order construct with three sub-dimensions: just-in-time flow (JITF), quality management (QM) and employee involvement (EI). Two items each are used to measure the sub-dimensions. Environmental management practices (EMP) are measured through a single item[3] aimed to capture multiple aspects of environmental programs such as Environmental Management System, Life-Cycle Analysis, Design for Environment, and Environmental Certification (i.e., ISO 14001).

Market performance is operationalized using measures for sales and market share, financial performance is operationalized using perceptions regarding return on assets (ROA) and return on sales (ROS) and environmental performance is operationalized by capturing respondent perceptions regarding their environmental performance improvements over the last 3 years and compared to their competitors. Finally, larger firms are more likely to implement lean manufacturing practices (Shah and Ward, 2003) and implement environmental training programs (Aragon-Correa, 1996). Therefore, we also include firm size (number of employees) as a control variable in our analysis.

4.3. Sample, respondent profile and biases

This study uses 309 samples of the diverse manufacturing firms. The sample covered firms under the two-digit ISIC codes between 28 and 35. The distribution according to the ISIC code is as follows: ISIC 28 (fabricated metal products, except machinery and equipment) 31.7%, ISIC 29 (machinery and equipment not elsewhere classified) 20.7%, ISIC 30 (office, accounting and computing machinery) 1.6%, ISIC 31 (electrical machinery and apparatus not elsewhere classified) 12.9%, ISIC 32 (radio, television and communication equipment and apparatus) 4.2%, ISIC 33 (medical, precision and optical instruments, watches and clocks) 2.3%, ISIC 34 (motor vehicles, trailers and semi-trailers) 10.0%, ISIC 35 (other transport equipment) 8.1%, and ISIC 36 (other miscellaneous products not listed) 8.4%. The demographic information (region/country) is provided in Table 2. The data do not have an indicator for early versus late responses limiting our ability to conduct the

[3] It is important to note that single items have been demonstrated to be valid for capturing complex constructs (Wanous et al., 1997; Bergkvist and Rossiter, 2007) and have been used in operations and supply chain management research (Rosenzweig and Roth, 2004; Ellis et al., 2010). Further, single items assume that the item completely measures the construct and has zero measurement error. We conducted sensitivity analysis by relaxing this assumption. Our results are robust and hence mitigate concerns for using single items.

Table 2
Sample by region and country ($n=309$) (n, %).
Source: IMF, 2009.

Europe		Non-Europe (North/South America, Asia/Pacific, Turkey)	
Developed countries [a]	Developing countries [b]	Developed countries [a]	Developing countries [b]
Belgium (15/12.4)	Estonia (10/25.6)	Australia (4/8.9)	Argentina (32/30.8)
Denmark (8/6.6)	Hungary (29/74.4)	Canada (13/28.9)	Brazil (5/4.8)
Greece (5/4.1)		New Zealand (7/15.6)	China (23/22.1)
Ireland (4/3.3)		USA (21/46.7)	Turkey (29/27.9)
Israel (8/6.6)			Venezuela (15/14.4)
Italy (12/9.9)			
Netherlands (26/21.5)			
Norway (3/2.5)			
Portugal (7/5.8)			
Sweden (25/20.7)			
United Kingdom (8/6.6)			
121 (100.0)	39 (100.0)	45 (100.0)	104 (100.0)

[a] > 20,000 (Int'l $).
[b] < 20,000 (Int'l $) (GDP purchasing per parity).

commonly used test for non-response bias (Armstrong and Overton, 1977).

Given that single respondents were used for collecting data the potential for common method bias to influence results needs to be evaluated. We conduct Harman's single factor test using confirmatory factor analysis. The model fit indicates that a single factor model does not represent the data well ($\chi^2=986.818$, df=104, GFI=0.673, CFI=0.403, IFI= 0.409, NFI=0.383, RMSEA=0.166, SRMR=0.141). Further, the average variance extracted by a single factor is 19.6% indicating that a very small proportion of the variance in the data is accounted for by a single factor. While this test does not help preclude the possibility of method bias it helps mitigate concerns that common method bias may be driving our results.

5. Data analysis and results

Structural equation modeling (SEM) is used to analyze the data and its relationships (Hair et al., 1998). We follow Anderson and Gerbing's (1988) recommended two-step approach to test our hypotheses. In step 1 we test the measurement model to establish validity and reliability of the scales used in our analysis and followed by the test of structural relationships in step 2. These are discussed next.

5.1. Measurement model, validity and reliability

We assess the overall fit of the first-order measurement model. In line with Shah and Goldstein's (2006) and Hu and Bentler's (1999) recommendation, multiple fit indices – the goodness of fit index (GFI), comparative fit index (CFI), incremental fit index (IFI), normed fit index (NFI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR) – are above the range for acceptable fit and with multiple values indicating a good fit ($\chi^2=180.144$, df=93, GFI=0.932, CFI=0.941, IFI=0.943, NFI=0.889, RMSEA=0.055, SRMR=0.045).

Convergent validity may be assessed by checking the significance of the loading for an item on its posited underlying construct (Anderson and Gerbing, 1988). The loadings for the first-order measurement model indicate that all items load significantly on their posited constructs in Appendix A indicating convergent validity. Further, the item loadings are similar between the first- and second-order measurement models indicating that the measurement is robust when specifying the second-order construct of lean manufacturing.

Table 3 shows an adequate level of discriminant validity with the average variance extracted by the items of the construct is greater than the average shared variance (square of the correlations in the off-diagonals) between two constructs (Fornell and Larcker, 1981). Table 3 also shows an adequate reliability values over 0.6 for all constructs indicating acceptable reliability of the measurement items (Cronbach, 1951; Nunnally, 1978; Chen and Paulraj, 2004).

5.2. Structural model results

Fig. 2 shows the structural model with parameter estimates and t-values of the paths. Table 3 shows the structural paths and fit indices of the two structural models (model 1: proposed model—full mediation and model 2: direct model). The proposed model fit indices show that the model represents the data fairly well ($\chi^2=242.801$, df=105, GFI=0.915, CFI=0.907, IFI=0.909, NFI=0.850, RMSEA=0.065, SRMR=0.081). Using statistical significance of the paths assessed at $p<0.05$, hypothesis H1, H2, H3a, H3b, H4a, H5a and H5b are supported and hypothesis H4b is marginally supported with a $p<0.10$.

This study investigates the mediating (as opposed to a moderating) effect of environmental management practices on the relationship between lean manufacturing and environmental performance for two reasons. First, existing research indicates a mediating role of environmental management practices on the relationship between lean manufacturing and (environmental) performance (King and Lenox, 2001; Yang et al., 2010). Our hypotheses and results are in line with this view in literature. Second, the moderating effect of quality management and lean practices on the relationship between green practices and performance has been tested in previous study such as Zhu and Sarkis (2004) with inconclusive evidence. Collectively the literature indicates that environmental management practices will mediate the relationship between lean manufacturing and (environmental) performance providing theoretical support for our results.

Thus, we hypothesize full (or complete) mediation of the effect of lean manufacturing on environmental performance by environmental management practices (EMP). Mediation may be tested by two methodological rigors: (1) specifying the direct paths between the independent and dependent variable and the indirect paths from independent to mediating variable to dependent variable simultaneously (Judd and Kenny, 1981; James et al., 2006), and (2) Sobel test is used to examine the mediating effect (Baron and Kenny, 1986; Shah and Shin, 2007).

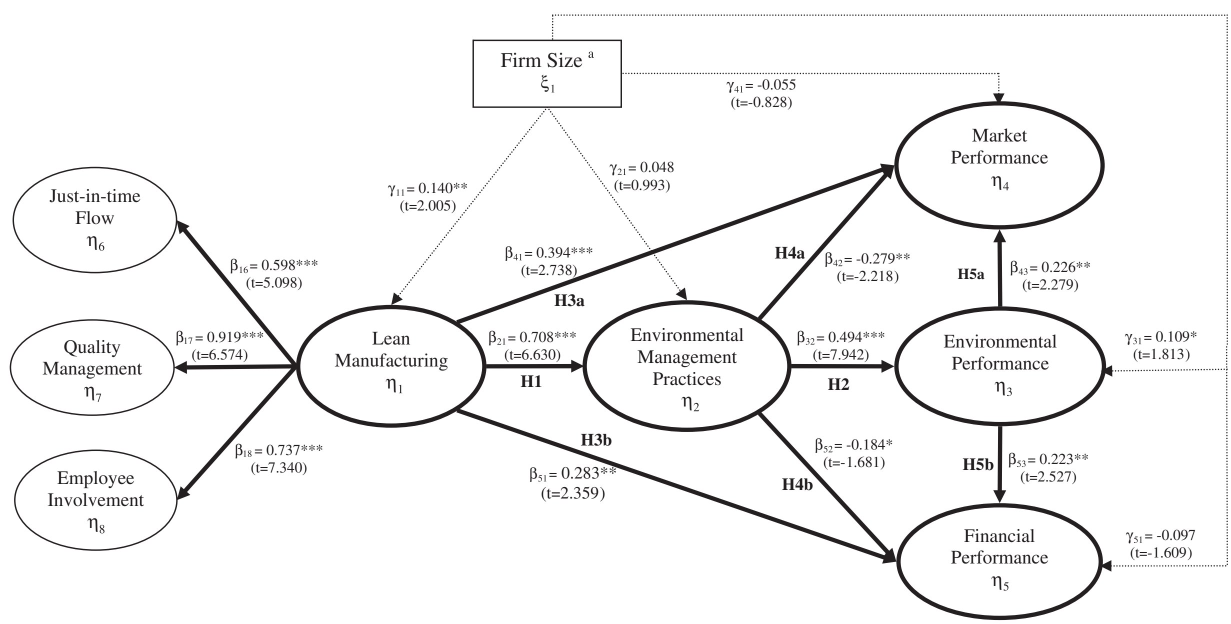
Table 4 presents the results of direct model (Model 2) with an additional direct path between lean manufacturing and environmental performance. The estimate of $\beta=0.033$ ($t=0.283$) is not significant ($p>0.1$) indicating support for full mediation of the effect of lean manufacturing on environmental performance by environmental management practices. Sobel test consists of the following components: (1) unstandardized beta coefficient; (2) standard error of beta coefficient; (3) p-value. Sobel test statistics (p-value): $t=5.113$ ($p<0.01$) indicates the full mediation effect of EMP.

Lean manufacturing enhances environmental management practices (H1). The estimated coefficient of $\beta=0.708$ ($t=6.630$, $p<0.01$) between lean manufacturing and environmental management practices strongly supports H1. This finding is consistent with

Table 3
First-order inter-construct correlations, reliability and discriminant validity ($n=309$).

Construct	1	2	3	4	5	6	7	8	Reliability	
									Cronbach's α	Composite reliability [a]
1. JITF	[0.445][b]								0.635	0.632
2. QM	0.559***	[0.550]							0.615	0.664
3. EI	0.525***	0.679***	[0.480]						0.707	0.678
4. MP	0.308***	0.192**	0.060	[0.417]					0.725	0.740
5. FP	0.206**	0.117	0.173**	0.515***	[0.620]				0.801	0.823
6. EP	0.162*	0.379***	0.265***	0.190**	0.198***	[0.548]			0.674	0.702
7. EMP	0.334***	0.682***	0.532***	0.104	0.122*	0.502***	–		–	–
8. Firm Size	0.058	0.142**	0.090	−0.013	−0.045	0.178***	0.147**	–	–	–

[a] Calculated according to Fornell and Larcker (1981).
[b] Average variances extracted (AVE) are on the diagonal in brackets.
* $p<0.1$.
** $p<0.05$.
*** $p<0.01$.



*$p<0.1$, **$p<0.05$, ***$p<0.01$.
[a] Control variable. The effects of firm size are represented by the dotted lines.

Fig. 2. Structural model results.

earlier literature (King and Lenox, 2001; Yang et al., 2010). As an organization uses lean manufacturing practices, it is expected to reduce wastes from its production activities through environmental management practices (Womack et al., 1990). The knowledge utilized for internal waste reduction through lean manufacturing is useful in managing environmental wastes. Our empirical results suggest that knowledge and experiences acquired through lean manufacturing are substantially relevant and thus adoptable in environmental management practices.

Environmental management practices impact environmental performance (H2). The proposed relationship (H2) between environmental management practices and environmental performance is supported with an estimated coefficient of $\beta=0.494$ ($t=7.942$, $p<0.01$). Existing research indicates that while lean manufacturing enhances environmental performance by reducing environmental waste in process, firms that implement environmental management practices (e.g., life-cycle assessment, environmental certifications and environmental management systems) also improve their environmental performance. On the other hand, lean manufacturing alone does not significantly impact environmental performance ($\beta=0.033$, $t=0.283$). The indirect effect of lean manufacturing on environmental performance is 0.350. As such, our model and empirical results show that lean manufacturing affects environmental performance through environmental management practices (Rothenberg et al., 2001; King and Lenox, 2001).

Lean manufacturing on market performance (H3a). The estimated coefficient of $\beta=0.394$ ($t=2.738$, $p<0.01$) for the relationship between lean manufacturing and market performance is significant indicating support for hypothesis H3a.

Lean manufacturing on financial performance (H3b). Similarly the estimated coefficient for the relationship between lean manufacturing and financial performance is $\beta=0.283$ ($t=2.359$, $p<0.05$) which is significantly supporting H3b. This result is in line with earlier findings in literature (Fullerton et al., 2003; Fullerton and Wempe, 2009). Lean manufacturing improves productivity and reduces the asset base of a firm resulting in improved financial performance and thus the overall impact of lean manufacturing on financial performance is positive.

Environmental management practices on market performance (H4a). The estimated coefficient of $\beta = -0.279$ ($t = -2.218$, $p < 0.05$) supports H4a that environmental management practices have a negative influence on market performance (Walley and Whitehead, 1994). An improved environmental performance is significant in reducing the negative impact of environmental management practices on market performance.

Table 4
Results of the structural models ($n=309$).

		Proposed model (full mediation) Model 1	Direct model Model 2
Structural paths	Hypothesis		
LM→EMP	H1	0.708***	0.708***
EMP→EP	H2	0.494***	0.471***
LM→EP			0.033
LM→MP	H3a	0.394***	0.389***
LM→FP	H3b	0.283**	0.278**
EMP→MP	H4a	−0.279**	−0.279**
EMP→FP	H4b	−0.184*	−0.184*
EP→MP	H5a	0.226**	0.222**
EP→FP	H5b	0.223**	0.220**
Model fit statistics	Recommended values		
$\chi 2$		242.801	242.723
df		105	104
RMSEA	≤0.08 marginal fit [a]; ≤0.05 good fit[b,c]	0.065	0.066
GFI	>0.8 marginal fit; >0.9 good fit[b]	0.915	0.915
CFI		0.907	0.906
NFI		0.850	0.850
IFI		0.909	0.909
SRMR	<0.09[b]	0.081	0.081

[a] Handley and Benton (2009).
[b] Hu and Bentler (1998, 1999).
[c] Browne and Cudek (1993).
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Environmental management practices on financial performance (H4b). The estimated coefficient of $\beta = -0.184$ ($t = -1.681$, $p < 0.1$) marginally supports H4b (Montabon et al., 2007). A total effect of environmental management practices on financial performance is −0.079 out of which the direct effect of environmental management practices on financial performance is −0.184 and indirect effect of environmental management practices (via improved environmental performance) on financial performance is 0.110. Thus, the indirect positive effect (0.110) reduces the direct negative effect (−0.184) by 59.78% (=0.110/0.184). This also suggests that improved environmental performance is significant in reducing the negative impact of environmental management practices on financial performance.

Environmental performance on market performance (H5a). The estimated coefficient of $\beta = 0.226$ ($t = 2.279$, $p < 0.5$) supports H5a that environmental performance has a positive influence on market performance. Improved environmental performance may increase an organization's brand equity to the extent of improving its market performance.

Environmental performance on financial performance (H5b). Finally, in support of hypothesis H5b, the estimated coefficient of $\beta = 0.223$ ($t = 2.527$, $p < 0.5$) is significant indicating that improved environmental performance positively influences financial performance. This result is in line with prior studies (e.g., Klassen and McLaughlin, 1996; King and Lenox, 2002), which report that firms with better environmental performance experience improved financial performance.

5.3. Additional contextual analysis

While all hypotheses are supported throughout this empirical study, it also holds true that there exist regional and national differences (Voss and Blackmon, 1998; Frohlich and Dixon, 2001; Hong and Roh, 2009; Hong et al., 2009). Table 5 shows contextual analysis (small vs. medium/large firm, Europe vs. non-Europe and developed vs. developing countries).

These results indicate that contextual factors (firm size, regional differences and GDP per capita status) affect the implementation level of lean manufacturing (LM) and environmental management practices (EMP) and accordingly, performance outcomes (environmental and business performance). For the aggregated samples ($n=309$), all hypotheses are supported. However, differences are noticeable between small (employees <250) and medium/large firms (employees >250) in terms of the strengths of relationship between LM and market performance (MP) and EMP and MP. The relationships between environmental performance (EP) and MP

Table 5
Contextual analysis ($n=309$) (coefficient and p-value).

			Firm size		Regions			
Path	Hypotheses	Aggregated sample [a]($n=309$)	Small (<250) ($n=175$)	Medium/large (>250)($n=134$)	Europe ($n=160$)	Non-Europe [b] ($n=149$)	Developed countries ($n=166$)	Developing countries ($n=143$)
LM→EMP	H1	0.715***	0.711***	0.629***	0.644***	0.747***	0.780***	0.781***
EMP→EP	H2	0.508***	0.383***	0.513***	0.476***	0.516***	0.572***	0.451***
LM→MP	H3a	0.390***	0.516***	0.259	0.451**	0.185	1.151***	0.203
LM→FP	H3b	0.276**	0.274*	0.260*	0.384***	0.140	0.922***	0.159
EMP→MP	H4a	−0.185**	−0.328*	−0.136	−0.245	−0.158	−0.989***	−0.054
EMP→FP	H4b	−0.061*	−0.143	−0.161	−0.184	−0.133	−0.819***	−0.041
EP→MP	H5a	0.211**	0.193	0.265*	0.309**	0.117	0.340**	0.041
EP→FP	H5b	0.206**	0.156	0.268**	0.329***	0.126	0.459***	-0.041

[a] This aggregated model was tested without firm size as a control variable.
[b] Non-Europe includes North/South America, Asia/Pacific, and Turkey.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

and EP and financial performance (FP) are not statistically significant for small firms while significant for medium and large firms. Firms from Europe ($n=160$) show a bigger and statistically significant impact of LM on FP while non-European countries do not. Data from developed countries with higher GDP per capita (> $20,000) (IMF, 2009) show all statistically significant relationships in all the relationships while those from developing countries show somewhat inconclusive results to the proposed relationships. Future study may explore further about these contextual factors and the underlying causes of these differences.

6. Concluding remarks

This research model presents lean manufacturing as an important antecedent of environmental management practices. Organizations may respond to regulations, policy and public pressure by making efforts to improve environmental performance or may choose to proactively engage in such practices. However, the results of our research must be interpreted with caution. As with all research endeavors this paper has certain limitations which provide avenues for future research. First, this research uses a single item to measure environmental management practices. As research on environmental management evolves efforts to identify and develop scales for multiple dimensions of environmental management may be fruitful. Second, one may conjecture that the negative implications of environmental management practices are more short term in nature and the indirect positive implications are realized over a longer period. Longitudinal assessment with secondary data may help distinguish these effects and add to our body of knowledge regarding environmental sustainability. Finally, while our research uses large scale survey to provide empirical evidence for the proposed model, in-depth case studies may also help validate and extend this research, especially in regard to additional aspects such as regulations and carbon permit trading practices. Case studies which investigate the process of implementing environmental management practices may also be fruitful. In spite of these limitations, the empirical results of this study provide some valuable managerial insights.

First, lean manufacturing and environmental management practices are distinct and they both impact differently on business performance outcomes (Kleindorfer et al., 2005). From a managerial perspective, lean manufacturing and environmental management practices are synergistic in terms of their focus on reducing waste and inefficiency. However, lean manufacturing by itself will not improve environmental performance because there is a potential for conflicts between environmental performance objectives and lean manufacturing principles (Rothenberg et al., 2001). The focus of lean manufacturing on internal and process waste reduction to increase efficiency should be extended to a focus on environmental waste reduction increasing environmental efficiency by implementing environmental management practices. Environmental management practices do require additional resources investments. It is important for manufacturing firms to implement both lean manufacturing and environmental management practices in ways to enjoy eco-advantage through improvements in environmental performance. This will also enable firms to meet their business performance objectives better.

Second, understanding the performance consequences of environmental management is critical in light of the ongoing debate on the conflict between environmental and economic objectives (Russo and Fouts, 1997; Derwall et al., 2005; Montabon et al., 2007). Our findings suggest both negative and positive impact of environmental management practices in two ways: (1) the direct impact of environmental management practices on market and financial performance is negative; (2) however, environment management practices positively affect environmental performance which in turn positively impacts market performance and financial performance. The short-term implementation focus of environment management practices is to enhance environmental performance by clarifying specific environment-related goals and objectives (e.g., reduction of pollutant materials, increasing usage of eco-friendly component parts, environmental safety records, and cost effectiveness of eco-friendly component parts). Firm level strategic commitment for environmental management might be well-communicated and understood through issuing comprehensive sustainability reports.

Third, environmental performance are related to business performance as an intermediate performance (Jiménez and Lorente, 2001; Delmas and Toffel, 2004). For effective implementation of environmental management practices it is essential to recognize the value of environment performance. In our paper we operationalized environmental performance with two measures of environmental improvement. Future research may need to develop multi-dimensional environment performance measures which predict the market and financial performance better.

Appendix

See Table A1 for more details.

Table A1
List of survey items ($n=309$).

Constructs/items	Mean	SD	Loading [a]	*t*-Value [b]
Indicate degree of the following action programs undertaken over the last 3 years (1: None to 5: High).				
Lean manufacturing (LM)				
just-in-time flow (JITF)				
JITF1 Restructuring manufacturing processes and layout to obtain *process focus* and streamlining (e.g., reorganize plant within-a-plant; cellular layout, etc.)	3.28	1.120	0.658	–
JITF2 Undertaking actions to implement *pull production* (e.g., reducing batches, setup time, using kanban systems, etc.)	2.92	1.156	0.675	6.331
Quality management (QM)				
QM1 Undertaking programs for *quality improvement* and control (e.g., TQM programs, 6σ projects, quality circles, etc.)	3.18	1.082	0.703	–
QM2 Undertaking programs for the improvement of your *equipment productivity* (e.g., total productive maintenance programs)	2.95	1.095	0.778	10.473
Employee involvement (EI)				
EI1 Implementing actions to increase the level of *delegation and knowledge of your workforce* (e.g., empowerment, training, autonomous teams, etc.)	2.87	0.919	0.754	–
	2.83	1.097	0.626	

Table A1 (*continued*)

Constructs/items	Mean	SD	Loading [a]	*t*-Value [b]
EI2 Implementing the *Lean Organization Model* by, e.g., reducing the number of levels and broadening the span of control.				7.702
Environmental management practices (EMPs)				
EMP1 Undertaking programs to improve *environmental performance* of processes and products (e.g., environmental management system, Life-Cycle Analysis, Design for Environment, Environmental Certification)	2.75	1.192	0.833 [c]	-
How has your operational performance changed over the last three years? How does your current performance compare with main competitor(s)?				
Environmental performance (EP)				
Compared to 3 years ago indicator has: 1 – deteriorated more than 10%, 2 – stayed about the same, 3 – improved 10–30%, 4 – improved 30–50% and 5 – improved more than 50%.				
EP1 Environmental performance	2.83	0.833	0.849	-
Relative to our main competitor(s), our performance is: 1 – much worse to 5 – much better.				
EP2 Environmental performance	3.31	0.690	0.610	6.542
How do you perform relative to three years ago and to main competitor(s)?				
Market performance (MP)				
Compared to 3 years ago indicator has: 1 – deteriorated more than 10%, 2 – stayed about the same, 3 – improved 10–30%, 4 – improved 30–50% and 5 – improved more than 50%.				
MP1 Sales	3.06	1.093	0.596	–
MP2 Market share	2.65	0.818	0.721	8.497
Relative to our main competitor(s), our performance is: 1 – much worse to 5 – much better.				
MP3 Sales	3.54	0.839	0.630	7.939
MP4 Market share	3.44	0.868	0.628	7.927
Financial performance (FP)				
Compared to 3 years ago indicator has: 1 – deteriorated more than 10%, 2 – stayed about the same, 3 – improved 10–30%, 4 – improved 30–50% and 5 – improved more than 50%.				
FP1 Return on Sales (ROS)	2.49	1.005	0.909	–
FP2 Return on Investment (ROI)	2.52	0.982	0.877	15.460
Relative to our main competitor(s), our performance is: 1 – much worse to 5 – much better.				
FP3 Return on Sales (ROS)	3.34	0.897	0.515	9.212
FP4 Return on Investment (ROI)[d]	–	–	–	–
Firm size[e]				
What is the size of the corporation of which your business unit is a part?				
Size (# of employee)	522.65	1057.139	–	–

[a] Standardized coefficients; all loadings are significant at $p<0.01$.
[b] Some items of *t*-value are not shown since their loading was fixed at 1.
[c] According to our sensitivity analysis—we assume that the indicator has 70% reliability. Then, error variance=(1−average reliability)(actual item variance)= $(1\text{–}0.7)(1.192)^2=0.426$, where 1.192 is the item standard deviation—factor loading for a single item is 0.833.
[d] This item was deleted during CFA due to very low factor loading.
[e] Control variable modeled as an observed variable.

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