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Abstract

Purpose – The purpose of this paper is to study management control mechanisms (social, behavioral, and output control mechanisms) and their complementary effects on firm performance in lean manufacturing firms.
Design/methodology/approach – The study uses second-order structural equation modeling to analyze survey data from 368 different lean manufacturing facilities.
Findings – The paper finds that the complementary effects of management control mechanisms in lean manufacturing firms outweigh their additive effects on firm performance.
Research limitations/implications – Applying isolated lean management control mechanisms leads to inferior performance, as these management control mechanisms are complementary. Thus, to realize the full potential of lean manufacturing, this paper suggests that lean management control mechanisms should be implemented as an integrated control system.
Practical implications – Firms seeking to benefit from the implementation of lean manufacturing should understand the complementarity among the management control mechanisms, as the performance effects of lean management control mechanisms when applied together are greater than their isolated additive effects.
Originality/value – This paper is the first to provide empirical evidence of the superior firm performance effects of complementary lean management control mechanisms compared with their additive effects. This paper also expands the understanding of how to conceptualize lean management control mechanisms. Specifically, this is the first paper to distinguish between social cultural control and social visual control mechanisms as well as between non-financial and financial control mechanisms. This paper is also the first to use a second-order structural equation model to properly test and account for the complementary effects on firm performance that stem from multiple control mechanisms.

Keywords Lean manufacturing, Firm performance, Complementarity, Second-order model, Management control mechanisms

Paper type Research paper

1. Introduction

Interest in complementarity and in its role in the design of organizations has garnered increasing attention in the academic literature (Ennen and Richter, 2010). Practices that work together are considered to be complementary when doing more of one practice increases the marginal return of another practice and vice versa (Milgrom and Roberts, 1995). Lean manufacturing is an ideal setting in which to study complementarity (Furlan *et al.*, 2011) as it is recognized as an enterprise-wide management system consisting of interdependent practices (Roberts, 2004; Shah and Ward, 2007). Lean manufacturing was conceptualized by Krafcik *et al.* (1988), when studying Toyota as part of the MIT International Motor Vehicle Program, and it is generally accepted that lean manufacturing improves firm performance (e.g. Fullerton and Wempe, 2009; Hofer *et al.*, 2012; Jayaram *et al.*, 2010; Maiga and Jacobs, 2008).

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However, both Shah and Ward (2003) and Furlan *et al.* (2010) suggested that it is the simultaneous, systematic implementation of several practices that contributes to firm performance through the complementary effects of these practices. This implies that the partial implementation of practices or of practices that do not work in concert will contribute to a lesser extent to firm performance.

The implementation of lean manufacturing has been found to be associated with companies' management control mechanisms[1] (e.g. Åhlström and Karlsson, 1996; Fullerton *et al.*, 2013; Kristensen and Israelsen, 2014; Netland *et al.*, 2015), and it is recognized that management control mechanisms can either hinder or help lean manufacturing implementations (Åhlström and Karlsson, 1996; Fullerton *et al.*, 2014). However, there is still much to understand about how management control mechanisms work in the lean manufacturing context. In this study, we investigate the complementary effects of management control mechanisms[2] on firm performance in lean manufacturing companies. As it is imperative that we examine these management control mechanisms from a holistic perspective (Ennen and Richter, 2010), we utilize the conceptual framework developed by Kennedy and Widener (2008), who extended the work of Ouchi (1978, 1979) and Snell (1992) to management control mechanisms in lean manufacturing companies. Kennedy and Widener's (2008) framework views management control as interdependent mechanisms consisting of training, visualization, empowerment, peer pressure (social control mechanisms), standardization of practices and rules (behavioral control mechanisms), and performance measurements (output control mechanisms). We extend social management control mechanisms to also include lean thinking (Emiliani *et al.*, 2003), as it is an important catalyst for successful lean manufacturing implementation, and we increase the granularity of Kennedy and Widener's (2008) framework by distinguishing between social cultural control and social visual control mechanisms as well as between non-financial and financial control mechanisms.

Different strategies are used when testing for complementarity between organizational variables. Ennen and Richter (2010) described two strategies: the interaction strategy, focusing on the complementarity of two organizational variables, and the systems strategy, focusing on the complementarity of a broader set of variables. Using a sample of 368 American lean manufacturing facilities, we adapt the systems strategy and follow the procedure developed by Tanriverdi and Venkatraman (2005). We develop and compare two competing structural equation models: the first model utilizes a second-order factor to capture multilateral interactions and covariance among the management control mechanisms as well as the effects of the second-order factor on firm performance. The second model conceptualizes the management control mechanisms as first-order factors and explores their additive effects on performance.

This study makes two major contributions to the small body of knowledge on this topic. First, we find that the performance effects of a complementary set of management control mechanisms are superior to their isolated additive effects. In fact, three of five management control mechanisms – visual social control mechanisms, financial output control mechanisms, and non-financial output control mechanisms – do not additively contribute to firm performance. Second, our study is the first to provide empirical support from a large sample of firms suggesting that the full set of lean management control mechanisms is complementary. Moreover, we provide detailed descriptions of how lean management control mechanisms work together in order to facilitate a deeper understanding of the complementarity effects on firm performance. We are especially motivated by Fullerton *et al.* (2013), who call for an extension of their study to encompass all the management control mechanisms from the Kennedy and Widener's (2008) framework, and by Malmi and Brown (2008), who welcome research on more specified management control mechanisms.

The remainder of this paper is organized as follows: in Section 2, we describe the literature and develop our two competing hypotheses. In Section 3, we present our sample and methods and, in Section 4, we present our results. We discuss and conclude the paper in Section 5. Limitations and recommendations for future research are presented in Section 6.

2. Literature and hypotheses development

It is well established that lean manufacturing is positively associated with firm performance (e.g. Hofer *et al.*, 2012; Fullerton *et al.*, 2014; Khanchanapong *et al.*, 2014; Maiga and Jacobs, 2008). Hence, the focus here is not on whether lean manufacturing can benefit performance but rather on how management control mechanisms assist lean manufacturing companies in achieving improved firm performance. Management control mechanisms have garnered attention in the lean manufacturing literature (e.g. Fullerton *et al.*, 2013; Netland *et al.*, 2015) and have been conceptualized as consisting of social, behavioral, and output controls (Kennedy and Widener, 2008). Research has found that lean manufacturing is related to these management control mechanisms. For example, lean manufacturing has been found to be related to visualization (Banker *et al.*, 1993), peer pressure (Ezzamel and Willmott, 1998), employee empowerment (Lind, 2001), and training (Woolson and Husar, 1998). Lean manufacturing has also been found to be related to standard operating procedures (Rondeau *et al.*, 2000) and rules (Shah and Ward, 2003). Evidence also suggests that lean manufacturing relies on non-financial performance measurements (Banker *et al.*, 1993) and financial performance measurements (Emiliani *et al.*, 2003). Table I depicts the management control mechanisms used in this study. These are drawn from Kennedy and Widener's (2008) framework, but we increase the granularity of the framework as we distinguish non-financial control mechanisms from financial control mechanisms as well as social cultural control mechanisms from social visual control mechanisms.

Empirical research suggests that lean management control mechanisms are interrelated, but there is limited evidence of their complementarity. For example, in their case study of a lean manufacturing company, Kennedy and Widener (2008) found that social, behavioral, and output controls were interrelated, meaning that, for example, performance measurements (output control mechanism) went hand in hand with employee empowerment (a social control mechanism), and standard operating procedures (behavioral control mechanism), similarly, went hand in hand with visualization (social control mechanism). Kristensen and Israelsen (2014) studied balance among social control mechanisms, behavioral control mechanisms, and output control mechanisms in a single firm. Their results indicated that greater balance led to greater firm performance, and they argued that the results were evidence of complementarity. However, their methodology made it difficult to capture patterns of interactions and covariance among the lean control mechanisms because the control mechanisms were collapsed into two aggregate measures. Without using the management control mechanism terminology, Emiliani *et al.* (2003) found that social, behavioral, and output controls were interrelated in a lean manufacturing company. Emiliani *et al.* (2003),

Social controls		Behavioral controls	Output controls	
Social cultural controls	Social visual controls	Standard operating procedures	Non-financial output controls	Financial output controls
Employee empowerment Peer pressure Training Lean thinking	Visualization	Rules	Non-financial performance measurements	Financial performance measurements

Table I. Lean management control mechanisms

Kennedy and Widener (2008), and Kristensen and Israelsen (2014) were single firm studies, which makes their findings difficult to generalize. Furthermore, Emiliani *et al.* (2003) and Kennedy and Widener (2008) did not study the complementary effects of the management control mechanisms on firm performance. In a cross-sectional study, Fullerton *et al.* (2013) investigated fragmented parts of the lean management control mechanisms. They found that employee empowerment (social control mechanism) and visual performance information (output control mechanism) were interrelated. Fullerton *et al.* (2013) did not study the complementary effects on performance, and their reductionist method is problematic when studying complementarity (Ennen and Richter, 2010).

To establish clear evidence of complementarity among lean management control mechanisms, firm performance effects stemming from individual management control mechanisms must be compared with performance effects stemming from complementarity of the complete set of management control mechanisms (Tanriverdi and Venkatraman, 2005). Furthermore, a detailed exploration of how the interrelatedness and complementarity of management control mechanisms can support lean manufacturing companies (Maskell *et al.*, 2012) is needed in a cross-sectional setting (Kennedy and Widener, 2008). As we will explain in the sections below, we expect that lean management control mechanisms are complementary and that the complementary effects on firm performance are greater than the additive effects from management control mechanisms. We follow the same argumentation logic and structure as Tanriverdi and Venkatraman (2005). First, in Sections 2.1-2.3, we describe lean management control mechanisms and explain how management control mechanisms are interrelated; second, in Section 2.4, we develop our hypotheses and describe how we expect complementarity to exist between management control mechanisms.

2.1 Social control mechanisms

According to Kennedy and Widener (2008), social control mechanisms in lean manufacturing companies encompass visualization, peer pressure, training, and employee empowerment. Visualization is essential in lean manufacturing companies (Belekoukias *et al.*, 2014; Cunningham and Fiume, 2003), and it goes hand in hand with both behavioral and output control mechanisms. Boards are used in the manufacturing area to visualize the current and future state of operations (a non-financial output control mechanism) and to show standard operating procedures (a behavioral control mechanism). Boards also show whether current activities are deviating from standards (Emiliani *et al.*, 2003) and provide real-time, easy-to-understand performance metrics that direct employees' attention to potential improvement areas and manufacturing-related problems, ensuring that production objectives are aligned with the lean strategy (Liker, 2004). Training matrices and employee capabilities indicators are used to highlight the skills required for working in a manufacturing cell and to show the current skills for each individual employee working in that cell (Kennedy and Widener, 2008; Maskell *et al.*, 2012). This assists employees during the planning of their work activities. However, visualization goes beyond informing employees about standards, improvement potential, performance, and skills: visualization also includes a structuring of the entire manufacturing area with high visibility, which should allow employees to assist one another between work processes and to help them understand how their own work activities are related to other areas of the facility (Liker, 2004). This can be referred to as global transparency (Adler and Borys, 1996). Global transparency reduces the risk of sub-optimization and enables employees to identify problems and improvement potentials in other manufacturing cells than their own.

For visualization to be effective, employees in lean manufacturing companies must be trained in lean principles (Fullerton *et al.*, 2013) such as kaizen, standard operating procedures, and creativity. Employees not trained in lean principles will not be able to fully grasp, act, and react to the information on the boards or to use this information to solve problems and identify potential improvement areas. The lean training can be done onsite, e.g. by employees continuously going to the gemba and figuring out solutions or improvements (Farris *et al.*, 2009). Employees are motivated to undergo training, as cell capability indicators highlight whether they are experts in a certain skill (Kennedy and Widener, 2008). The training also facilitates the empowerment of employees responsible for quality, cost, and flow, enabling them to make timely and effective decisions and adjustments to their work (Cua *et al.*, 2001; Fullerton *et al.*, 2013). This is especially important in lean manufacturing companies with reduced buffer inventories, as potential breakdowns have severe effects downstream (Callen *et al.*, 2005; Kristensen and Israelsen, 2014). Additionally, the empowerment of employees enables them to carry out experiments and perform continuous improvement, potentially improving their own and others' work processes. This, of course, is not something that happens without employees being motivated or being encouraged to do so. A possible motivational element is that lean thinking permeates the minds of employees and managers. Lean thinking enables them to think, act, and behave with a passion for lean manufacturing (Wood *et al.*, 2015), and it therefore functions as an internal motivational factor (Bhamu and Sangwan, 2014). Here, we extend Kennedy and Widener's (2008) framework, inspired by clan controls[3] (Ouchi, 1979). Peer pressure is another catalyst for employees to solve problems, identify improvement potentials, and undergo additional training (Kennedy and Widener, 2008). Peer pressure in lean manufacturing companies can occur when employees at the same hierarchical level mutually reinforce their desire to obtain additional knowledge, work skills, and higher performance, both in comparison to other employees in the manufacturing cell as well as in comparison to other manufacturing cells and value streams. The monitoring and highlighting of skills and performance within and between manufacturing cells (a non-financial output control mechanism) can lead to a sense of pride among employees and can improve motivation (Kennedy and Widener, 2008). We have decided to distinguish between social cultural control mechanisms and social visual control mechanisms, because the former is input oriented, intended to affect behavior *ex ante*, whereas the latter is process oriented, intended to guide immediate behavior.

2.2 Behavioral control mechanisms

Behavioral control mechanisms in lean manufacturing companies consist of standard operating procedures and rules (Kennedy and Widener, 2008). These are seen as an aid to help employees reach the desired output, both in terms of levels output and quality and in terms of the best practice in reaching that output (Secchi and Camuffo, 2016). They are not seen as strict instructions from which deviations are not acceptable but as systematic descriptions of value-added and non-value-added activities that enable employees to perform continuous improvement (Adler and Borys, 1996; Kristensen and Israelsen, 2014). In fact, without standard operating procedures, continuous improvement becomes impossible, as any improvement will be just another variation of the work processes (Liker, 2004). Standard operating procedures are updated to incorporate proven improvements, or they are changed in response to changes in demand or other contingencies (Ahrens and Chapman, 2004). For example, a cell may optimize standard operating procedures affecting other production cells, or changes in market conditions may require manufacturing cells to perform activities differently to meet customer demand.

Standard operating procedures go hand in hand with social control mechanisms, described in Section 2.1. For example, standard operating procedures are visualized (a social visual control mechanism) to employees: pictures of the assembly of parts are made visible on boards in a manufacturing cell, floor markings indicate the flow of materials and finished goods (Kennedy and Widener, 2008), and visual controls indicate whether or not work-in-progress levels are under control (Kristensen and Israelsen, 2014).

Furthermore, employees in lean manufacturing companies undergo training (a social cultural control mechanism) that enables them to understand, perform, and challenge the standard operating procedures (Liker, 2004).

Standard operating procedures work together with non-financial output control mechanisms as well. For example, whiteboards are used in the manufacturing cells to post numbers showing the ability to deliver on time, indicating how well employees are performing. This operating information is used in concert with standard operating procedures to help employees determine whether corrective actions are needed (Kristensen and Israelsen, 2014). The corrective action may adjust current activities, but it may also involve changing and improving the standard operating procedure.

Behavioral controls go beyond standard operating procedures. For example, the Kanban system ensures the replenishment of materials (Shah and Ward, 2007). It includes paper cards that are utilized to pull the right materials to the right places, in the quantities needed, when needed (Emiliani *et al.*, 2003). This demands standards for quantities, materials, procedures for internal customers, and the exact point for when to pull additional materials. One-piece flow and the use of line balancing and level schedules (heijunka) are behavioral controls as well. Optimally, one-piece flow ensures that a part moves to the next operation only when the prior operation is successfully completed (Emiliani *et al.*, 2003). In essence, one-piece flow is then a rule that demands that products are produced only as needed; for this to happen, companies need standard operating procedures that document the sequence of operator work, machine work, and operator movement that is required to produce one unit of a product or part (Miltenberg, 2001). Likewise, line balancing and level schedules demand close relationships with suppliers (Chavez *et al.*, 2015) and standards for production planning and the delivery of products in order to reduce fluctuations in demand and output (Liker, 2004).

2.3 Output control mechanisms

Output control mechanisms consist of performance measurement systems (Kennedy and Widener, 2008). Lean manufacturing companies use detailed non-financial performance measurements to facilitate real-time analyses of cell performance (Fullerton *et al.*, 2014). These measurements track different kinds of cell performance, such as day-by-the-hour, first time through, work-in-progress to standard work-in-progress, and operational equipment effectiveness (Maskell *et al.*, 2012), and they provided fast feedback when problems arise (Banker *et al.*, 1993). These measurements also include past, current, and desired performances, which are supposed to function as motivators for employees and to direct attention to issues that need to be solved. Although different non-financial performance measures are used, this applies for value streams and the facility as well (Emiliani *et al.*, 2003; Maskell *et al.*, 2012). Besides tracking performance and providing feedback, the main purposes of these non-financial performance measures are to align behavior with lean manufacturing objectives (Liker, 2004). This is done in close relationship with social visual control mechanisms, as non-financial performance measures are visually displayed throughout the facility. For example, recurring problems are highlighted on visual boards to initiate kaizens (Emiliani *et al.*, 2003) and to enhance peer pressure in teams (a social cultural control mechanism). These non-financial performance measurements work together with the financial performance measurements presented in quarterly and annual reports (Liker, 2004). Financial performance measurements are also necessary to assist managers and employees in stimulating communication, sending signals related to strategic issues, and fostering learning throughout the organization (Henri, 2006). It is important to distinguish between lean non-financial and financial output control mechanisms, as they are inherently different.

Financial output controls typically lag non-financial output controls, because many of the non-financial output controls are measurement drivers of future financial results (Johnson, 1992).

2.4 Hypothesis development

The previous sections described lean management control mechanisms and clarified their interrelatedness. We expect that this interrelatedness will cause complementary effects on firm performance in that the benefits from any lean management control mechanism are greater when the mechanism is accompanied and integrated with the other lean management control mechanisms (Roberts, 2004). For example, performance measurement systems (output control mechanisms) drive behavior to a greater extent and are more likely to direct employees' attention to problems if they are visualized through social controls. The effect of peer pressure (a social control mechanism) will be higher if boards containing skill matrices are visualized (an output control mechanism) to other employees. Standard operating procedures (a behavioral control mechanism) may be tacit knowledge for employees, but they are more effective if they are visualized, ensuring that all employees work according to the best standard currently known. The visualization of standards also enables employees to challenge and improve these standards. Additionally, the effectiveness of standard operating procedures will likely be higher if all employees are trained according to these standards (social control mechanism).

When complementarities exist among management control mechanisms, a firm needs to coordinate the use of these management control mechanisms by implementing them simultaneously. Thus, we follow the same procedure as Tanriverdi and Venkatraman (2005) and develop a latent second-order construct. The first level of this construct captures the sub-additive effects arising from social, behavioral, and output control mechanisms, and the second level captures the super-additive effects from the complementarity of management control mechanisms. When assessing the performance effects of a complementary system of management control mechanisms, we have to compare the performance effects of individual management control mechanisms with the performance effects of the complementarity among management control mechanisms, and we have to ensure that the complementarity performance effects outweigh the individual effects (Tanriverdi and Venkatraman, 2005; see also Ichniouwski *et al.*, 1997; Whittington *et al.*, 1999). Following Tanriverdi and Venkatraman's (2005) procedure, we develop two competing hypotheses to test whether the performance effects of management control mechanisms in lean manufacturing companies are contingent on the complementarity of these management control mechanisms or whether the individual management control mechanism has an independent direct effect on performance: a "strong form," stating that the complementarity of management control mechanisms will have a direct positive effect on firm performance; and a "weak form," stating that each management control mechanism will have an independent direct positive effect on firm performance:

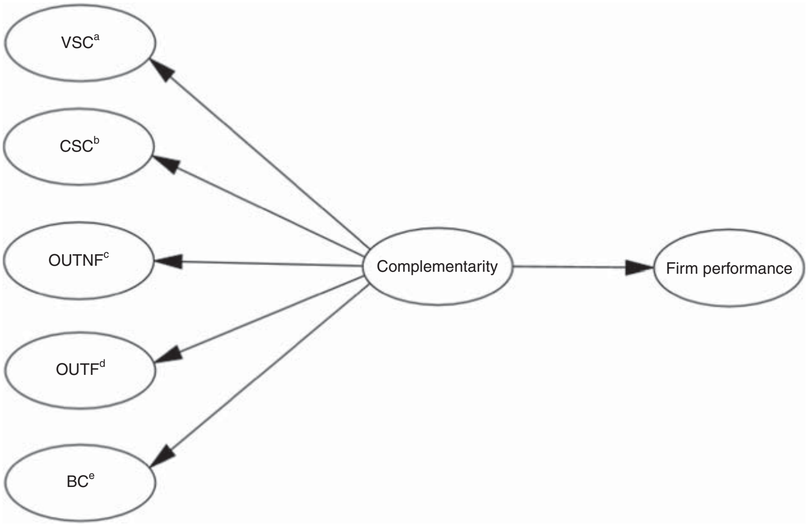
H1 (strong form). The complementarity of social control mechanisms, behavioral control mechanisms, and output control mechanisms has a positive effect on firm performance.

H2 (weak form). Social control mechanisms, behavioral control mechanisms, and output control mechanisms have independent positive effects on firm performance.

Figure 1 includes a conceptual model of the complementarity *H1*.

3. Methods

The survey was distributed online to 4,357 subjects, representing 697 manufacturing facilities, in September 2012, and responses were received until December 2012.



Notes: [a]Visual social controls; [b]cultural social controls; [c]non-financial output controls; [d]financial output controls; [e]behavioral controls

Figure 1.
Complementary hypothesis (*H1*)

The subjects were identified from the Shingo Prize[4], Organization database of individuals who had expressed an interest in receiving information about lean principles, Shingo seminars and workshops, and the Shingo Prize. We received responses from 510 individuals, representing 368 different facilities, yielding a response rate of 11.70 percent which is similar to other research papers on lean manufacturing (e.g. Hofer *et al.*, 2012; Shah and Ward, 2003). We averaged responses from plants from which we received multiple responses, leaving us with a usable sample size of 368 and a facility response rate of 52.8 percent. Collectively, the 368 facilities represented 195 different organizations. In total, 30 percent of the organizations produced vehicles or provided components to the automotive industry, 29 percent produced healthcare-related products, 23 percent made products for the aerospace industry, and 19 percent produced components for the department of defense.

Of the facilities, 52 percent had more than 500 employees and 53 percent of the facilities had sales of over $100 M. The average management experience of the respondents within their current firms was 11.3 years. This is important to our study, as experienced managers are likely to understand our holistic set of questions regarding management control, lean manufacturing, and performance in their facilities[5]. Of the respondents, 53.5 percent were responsible for lean, quality, or continuous improvement. Survey questions were intended to assess the level of lean manufacturing and management control implementation at the respondents' facilities as well as to obtain a self-assessment of firm performance.

In the following sections, we describe how we developed our variables. We also go through our statistical tests and explain why we decided to utilize Tanriverdi and Venkatraman's (2005) test for complementarity. Figure 2 illustrates the sequence of the statistical tests.

3.1 Measures

Although the questionnaire included 148 questions, we only included a portion for analysis in the present paper. We drew upon Kennedy and Widener (2008) in developing most management control mechanism items, and we adapted several items from Fullerton *et al.* (2013, 2014).

We developed four items covering cultural social control mechanisms, intended to cover the degree to which the entire facility is trained in lean principles (CLTR 4), employee empowerment (CLTR 3 and CLTR 1), and peer pressure (CLTR 8). Furthermore, we developed three additional items, CLTR 5, CLTR 6, and CLTR 7, intended to capture the degree to which the facilities work with continuous improvement, the degree to which management is focused on eliminating waste, and the degree to which lean thinking has permeated all operations, respectively. CLTR 2 was adapted from Fullerton *et al.* (2013) and was intended to cover the degree to which management is committed to quality-related training. Of the seven items covering visual social control mechanisms, MAS 2, MAS 4, MAS 5, and MAS 7 were adapted from Fullerton *et al.* (2013), while the remaining three items were developed in accordance with Kennedy and Widener (2008). All items were intended to capture the degrees of different types of visualization.

Three of four items covering behavioral control mechanisms were adapted from Fullerton *et al.* (2013) and were intended to cover the degree of facilities' use of standardization of manufacturing procedures (MFG 1), a Kanban system (MFG 2), and one-piece flow (MFG 3), and we developed MFG 4 to capture the use of line balancing and level schedules.

The three items covering non-financial output controls were intended to capture the importance of non-financial performance measures related to cell performance (PRF 1), value stream performance (PRF 2), and facility performance (PRF 3). As these measures are rather generic, we follow the same procedure as Fullerton *et al.* (2013) and include a test for criterion validity where we correlate our non-financial output controls with criterion variables in order to demonstrate plausibility. This test can be found in Table AI. We developed four additional items covering financial output control mechanisms, intended to capture the importance of performance measures related to market share (PRF 4), cash flow (PRF 5), overall financial results (PRF 6), and customer satisfaction (PRF 7). One of the six items covering performance (LIMP 3) was adapted from Fullerton *et al.* (2014), while we developed the remaining items in order to cover the extent to which lean initiatives have freed inventory resources (LIMP 1), improved capacity management effectiveness (LIMP 2), improved quality (LIMP 4), improved communication (LIMP5), reduced costs (LIMP 6), and improved profitability (LIMP 7). Thus, our performance items cover both a goal-centered and an accounting approach (Kihn, 2005). Survey items can be found in Table AII.

All items were measured on a five-point labeled Likert scale. Eustler and Lang (2015) have shown that labeled scales are superior to unlabeled scales as they reduce measurement error and response bias.

3.2 Exploratory factor analysis

We conducted an exploratory factor analysis including our exogenous variables with oblique rotation. We removed one item that loaded greater than 0.4 on more than one variable[6]. After the removal of one item, we conducted another exploratory factor analysis, which yielded five factors with eigenvalues greater than 1, collectively explaining 66.8 percent of the variance: cultural social controls, visual social controls, behavioral controls, non-financial output controls, and financial output controls. Additionally, we performed an exploratory factor analysis for the performance items yielding one factor with an eigenvalue greater than 1, explaining 65.5 percent of the variance. Along with the

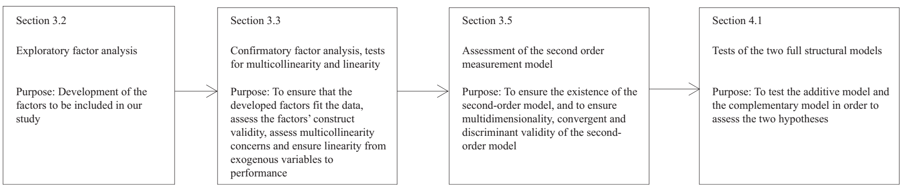


Figure 2.
Sequence of statistical tests

exogenous factors, the performance factor represents the variables used in this study (see Table II). All factors' Cronbach's α's are between 0.786 and 0.913 (see Table III), demonstrating good to excellent reliability (Kline, 2011).

3.3 Confirmatory factor analysis

We perform a confirmatory factor analysis in AMOS 23 including our factors, using maximum likelihood estimation. This is a two-step procedure where the measurement model without structural paths is evaluated to ensure that it fits, and this is followed by an evaluation of the entire structural model (Hair *et al.*, 2014). We evaluate the measurement model using several fit indices, as recommended by Kline (2011). We assess χ^2 to degrees of freedom (Bollen, 1989), as it seems to be the consensus in the SEM literature, although Kline (2011) stated that there is little statistical and logical foundation for using this measure of model fit. We assess the root mean square error of approximation (RMSEA) and the

Factor	Cultural social controls	Visual social controls	Non-fin. output controls	Financial output controls	Behavioral controls	Firm performance	Mean	SD
Indicator								
CLTR1	0.585						3.49	0.99
CLTR2	0.517						3.84	0.83
CLTR3	0.707						3.33	0.95
CLTR4	0.568						3.33	0.79
CLTR5	0.727						3.42	1.07
CLTR6	0.851						3.44	1.05
CLTR7	0.755						3.50	1.01
CLTR8	0.766						3.18	1.08
MAS1		−0.629					3.68	0.94
MAS2		−0.651					4.08	0.87
MAS3		−0.724					3.35	1.15
MAS4		−0.849					3.72	1.06
MAS5		−0.745					3.39	1.04
MAS6		−0.854					3.67	1.08
MAS7		−0.745					3.37	1.14
PRF1			−0.851				3.18	1.10
PRF2			−0.790				3.02	1.13
PRF3			−0.852				3.18	1.05
PRF4				0.825			3.43	1.17
PRF5				0.869			3.72	1.13
PRF6				0.749			4.17	0.87
PRF7				0.509			4.19	0.89
MFG1					−0.413		3.86	0.82
MFG2					−0.727		3.52	1.06
MFG3					−0.719		3.27	1.11
MFG4					−0.779		3.50	1.06
LIMP1						0.754	3.24	0.95
LIMP2						0.850	3.59	0.86
LIMP3						0.848	3.72	0.87
LIMP4						0.785	3.64	0.86
LIMP5						0.768	3.62	0.84
LIMP6						0.828	3.60	0.89
LIMP7						0.829	3.53	0.90

Notes: KMO of sampling adequacy for the management control mechanism factors: 0.944, Bartlett's test of sphericity is significant $p < 0.000$. KMO of sampling adequacy for the firm performance factor 0.887, Bartlett's test of sphericity is significant $p < 0.000$. The KMO values above 0.5 and the significance of the Bartlett's test of sphericity indicates that the data are suitable for exploratory factor analysis, and that there are patterns among items (Field, 2005). Only loadings exceeding 0.400 are shown

Table II. Exploratory factor analysis and descriptive statistics

Table III. Confirmatory factor analysis, composite reliability, and Cronbach's α

Factor indicators	Standardized loadings	t-value (all significant $p < 0.01$)	CR	α
Cultural social controls			0.908	0.904
CLTR1	0.71	a		
CLTR2	0.62	11.58		
CLTR3	0.71	13.22		
CLTR4	0.50	10.23		
CLTR5	0.76	14.01		
CLTR6	0.82	15.24		
CLTR7	0.83	15.41		
CLTR8	0.88	16.32		
Visual social controls			0.912	0.909
MAS1	0.70	13.71		
MAS2	0.78	15.44		
MAS3	0.73	14.31		
MAS4	0.83	16.52		
MAS5	0.80	15.82		
MAS6	0.81	16.15		
MAS7	0.76	a		
Behavior controls			0.826	0.821
MFG1	0.65	a		
MFG2	0.75	11.84		
MFG3	0.78	12.19		
MFG4	0.77	12.17		
Non-financial output controls			0.913	0.913
PRF1	0.89	a		
PRF2	0.90	24.24		
PRF3	0.86	22.39		
Financial output controls			0.805	0.797
PRF4	0.75	a		
PRF5	0.77	12.90		
PRF6	0.70	12.03		
PRF7	0.62	10.86		
Firm performance			0.913	0.912
LIMP1	0.72	a		
LIMP2	0.82	15.56		
LIMP3	0.83	15.82		
LIMP4	0.75	14.07		
LIMP5	0.79	14.96		
LIMP6	0.78	14.79		
LIMP7	0.72	13.50		

Notes: χ^2 to degrees of freedom: 2.299, RMSEA: 0.060, SRMR: 0.054, IFI: 0.923, TLI: 0.915, CFI: 0.922, CAIC: 0.429 (1,663.439/3,875.435 saturated model). "a" Indicates a loading fixed to 1

standardized root mean square residual (SRMR). Additionally, we evaluate the comparative fit index (CFI) (Bentler, 1990), incremental fit index (IFI) (Bollen, 1989), and Tucker-Lewis index (TLI) (Tucker and Lewis, 1973). In general, there are no accepted minimal thresholds for what constitutes acceptable model fit (Schermelleh-Engel *et al.*, 2003). However, there are suggested parameters in published academic work for what would represent acceptable fit: χ^2 to degrees of freedom should be less than 3, indicating acceptable fit (Kline, 2005); a RMSEA value below 0.08 would indicate acceptable fit (Browne and Cudeck, 1993; Kline, 2011); a SRMR value below 0.1 indicates acceptable fit (Schermelleh-Engel *et al.*, 2003); and CFI, IFI, and TLI are evaluated for their closeness to 1.0 (Byrne, 2010) with values over 0.9 (Bentler, 1992; Kline, 2005), indicating acceptable fit. Finally, we evaluate the Consistent Akaike's Information Criterion, addressing the issue of parsimony in the assessment of model fit, taking sample size into account (Bozdogan, 1987), where the ratio of the hypothesized model and the saturated model should be less than 1 (Byrne, 2010). Although the χ^2 is significant ($p < 0.001$), the χ^2 to degrees of freedom is less than 3, and fit indices are more than acceptable (see Table III).

To assess construct validity, we investigate the factors' convergent validity, composite reliability (CR), and discriminant validity. All our factors show good convergent validity, as their average variance extracted (AVE) is above 0.5 (see Table IV) and their CR is well above 0.7 (Hair *et al.*, 2014). Furthermore, as indicated in Table III, all factor loadings (standardized coefficients) are above 0.5 (Bagozzi and Yi, 1988). Discriminant validity is assessed by comparing the square root of the AVE of the factors with their correlation (Fornell and Larcker, 1981), where the square root AVE of individual factors should be greater than the interfactor correlation. Square root AVE of factors is indicated at the diagonal of Table IV and is greater than the interfactor correlations[7]. Additionally, none of the interfactor correlations exceed their αs, which is another indicator of discriminant validity (Crocker and Algina, 1986). Table IV also indicates that all factors correlated significantly. Our measurement model did not indicate multicollinearity issues, as none of the variance inflation factors exceeded 2.8, and all tolerance statistics exceeded 0.36.

Before running the two full structural models, we also test all relationships from exogenous variables to performance for linearity. All relationships are significantly linear $p < 0.01$ and have R^2 values ranging from 0.146 to 0.656 and F-values between 62.658 and 697.191. In addition, the number of free parameters to be estimated compared with the sample size is well above the minimum ratio of 1:5 recommended by Worthington and Whittaker (2006) in both the first-order structural model and the second-order structural model.

3.4 Testing for complementarity

There are several strategies when testing for complementarities in research. Ennen and Richter (2010) divided these strategies into two main categories: the interaction approach and the systems approach. The interaction approach is of a reductionist character (Drazin and Van de Ven, 1985), as it only includes pairs of interactions and their main effects in a regression model. This is often a function of statistical necessity, as individual variables in complementary systems are heavily correlated and, furthermore, heavily correlated with the interaction term. When the main variables and their pair-wise interaction terms are heavily correlated, coefficient estimates obtained from the regression model do not reflect the inherent effects of any particular independent variable on the dependent variable but only the marginal effects or the partial effects, given the other, independent variables in the model (Tanriverdi and Venkatraman, 2005). Our independent variables are significantly correlated, as shown in Table IV. Likewise, our multiplicative interaction terms are heavily correlated with each other and with their main variables (correlations ranging from 0.311 $p < 0.001$ to 0.935 $p < 0.001$)[8]. Furthermore, by focusing only on pairs of interactions,

Table IV. Factor correlations, squared average variance extracted, and average variance extracted

Factor	No. of measures	1	2	3	4	5	6	AVE
Non-financial output controls	3	0.883						0.779
Visual social controls	7	0.620**	0.773					0.598
Cultural social controls	8	0.667**	0.678**	0.739				0.547
Behavioral controls	4	0.528**	0.607**	0.609**	0.738			0.544
Financial output controls	4	0.411**	0.447**	0.428**	0.475**	0.713		0.508
Firm performance	7	0.627**	0.674**	0.762**	0.718**	0.491**	0.774	0.600

Notes: All measures are a labeled Likert scale from 1 to 5. Square roots of AVE are shown at the diagonal. **Significant at the $p < 0.01$ level researchers that are not able to detect the expected complementarity between two variables might overlook that the expected complementarity is a function of a third variable (Ennen and Richter, 2010). Our theory concerns complementarities among multiple variables. Given the theoretical development and explanations leading to our complementarity hypothesis, the interpretational problems inherent in the interaction approach render it an ineffective means of testing the hypothesis.

The systems strategy testing complementarity involves focusing on a holistic set of variables (Ennen and Richter, 2010). However, Ennen and Richter (2010) do not elaborate on the statistical testing techniques of this strategy. Profile deviation analysis is suggested by Gerdin and Greve (2004). Studies that use profile deviation analysis segment data based on a criterion variable and find the ideal state of systems within each of these segments (see e.g. Hult *et al.*, 2007). As a second step, researchers use the city block distance or the Euclidian distance, expecting that the deviations from the ideal state are negatively associated with performance. However, the city-block distance only accounts for additive effects, and it is unclear exactly what is captured by the Euclidian distance. Another possibility when pursuing systems strategy is to apply higher-order interactions in a regression model. However, this approach will increase the correlations between individual variables and their multiplicative interactions, leading to interpretational problems of the regression model (Tanriverdi and Venkatraman, 2005). Other studies that apply the systems strategy attempt to capture the nature of organizational systems by using a categorical variable that studies whether or not a particular factor is in place (e.g. Furlan *et al.*, 2011). However, this approach provides little information on the nature of the relationships that drive the complementarity effects observed (Ennen and Richter, 2010).

As the tests described here were not appropriate for testing our hypotheses on complementarity, we sought an alternative statistical method and decided to utilize the approach applied by Tanriverdi and Venkatraman (2005). Tanriverdi and Venkatraman (2005) constructed two models in order to test for complementarity: a first-order model to capture the sub-additive effects of their variables on performance and a second-order factor model to account for the multilateral interactions and covariance among their variables, in order to test for the complementary effects on performance. A second-order factor is an entity that is reflected by first-order factors serving as its indicators (Williams *et al.*, 2004) and is the main source of covariance among first-order factors; it explains why the first-order factors coexist and co-vary with each other (Rindskopf and Rose, 1988). Utilizing Tanriverdi and Venkatraman's (2005) procedure, we avoid the interpretational challenges of the other tests for complementarity of multiple variables (in our case, control mechanisms), and we can compare the additive effects on firm performance with the complementary effects on firm performance. We are thus able to test both our hypotheses and to determine whether the complementary effects outweigh the additive effects as well as whether some of the management control mechanisms affect firm performance in isolation.

3.5 Assessment of the second-order measurement model

Following Tanriverdi and Venkatraman's (2005) procedure[9], we need to compare the first-order measurement model where we correlate our management control mechanisms with the second-order measurement model in order to assess the existence of a second-order model and to ensure the multidimensionality, construct, and convergent validity of the second-order model. Marsh and Hocevar (1985) developed the target coefficient statistic, which is the ratio of the χ^2 of the first-order model to the χ^2 of the second-order model. The target coefficient has an upper limit of 1.0 (Tanriverdi and Venkatraman, 2005), and support for the existence of a second-order factor becomes stronger when the target coefficient approaches unity (Marsh and Hocevar, 1985). The value of the target coefficient of our second-order complementarity factor is 0.98, indicating that a second-order factor explains 98 percent of the relations among the first-order factors. Furthermore, all second-order factor loadings are highly significant ($p < 0.001$), providing further acceptance of a second-order model. Collectively, these results support the existence, multidimensionality, convergent and discriminant validity, and reliability of a second-order complementarity construct (Tanriverdi and Venkatraman, 2005) (see Table V).

4. Empirical tests and results

4.1 Test of hypotheses

The figures depict the models of our two competing hypotheses. Figure 3 shows a graphical representation of the model for testing *H1*. This depicts our management control mechanisms modeled initially as first-order factors. The second-order factor in the figure models the complementarity among our management control mechanisms by accounting for their covariance and multilateral interactions, and the directions of the structural links are from the second-order factor to the first-order factor, indicating that all the management control mechanisms are adapted simultaneously and systematically. In order to test our hypothesis, the second-order factor is related to firm performance. Figure 4 shows a graphical representation for testing *H2*. It shows the management control mechanisms as first-order factors, models their pair-wise covariance, and relates the management control factors additively to firm performance. In Figure 3, the structural parameter from the complementarity second-order factor to firm performance is positive and significant (standardized β coefficient: 0.927, $p < 0.001$, R^2: 0.859), providing support for *H1*, the strong form. This finding indicates that a second-order factor accounting for the complementarity among management control mechanisms has a positive effect on firm performance. In Figure 4, only two of the five structural parameters, cultural social control mechanisms (standardized β coefficient: 0.399 $p < 0.001$) and behavioral control mechanisms (standardized β coefficient: 0.400 $p < 0.001$, collective R^2 from all additive effects: 0.805), from management control mechanisms to firm performance are significant (also see Table VI, Panel A). Financial and non-financial output control mechanisms and

Table V. Assessment of the first-order and second-order measurement models

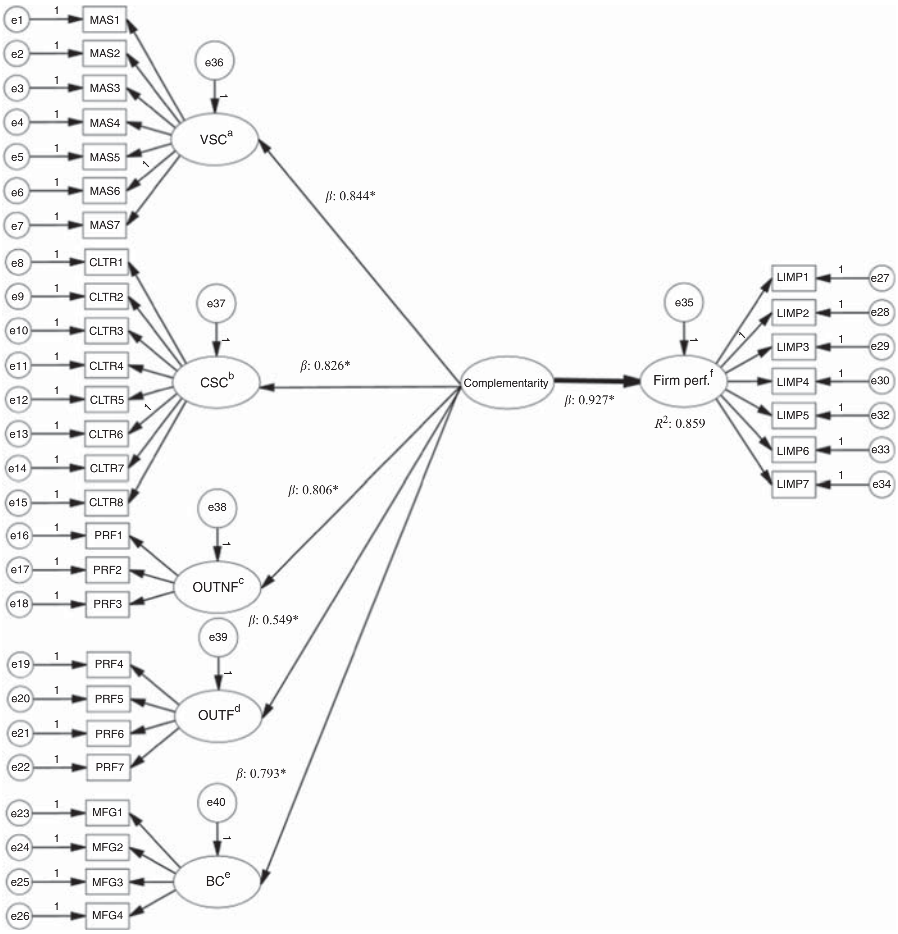
Panel A: fit indices for the first-order measurement model and the second-order measurement model

Fit indices	First-order measurement model	Second-order measurement model
χ^2	605.899	617.845
Degrees of freedom	289	294
χ^2 to degrees of freedom	2.097	2.012
IFI	0.946	0.945
TLI	0.939	0.938
CFI	0.946	0.944
RMSEA	0.055	0.055
SRMR	0.056	0.058
CAIC (default model to saturated model	0.422	0.422
Target statistic: 0.980 (605.899/617.845)		

Panel B: first-order factor loadings on complementary factor

Relationships	Standardized coefficient	*t*-values (all significant at $p < 0.001$)
Non-financial output controls ← complementarity factor	0.806	9.815
Visual social controls ← complementarity factor	0.844	9.060
Cultural social controls ← complementarity factor	0.866	10.101
Behavioral controls ← complementarity factor	0.793	a
Financial output controls ← complementarity factor	0.549	7.205

Note: "a" Indicates a loading fixed to 1

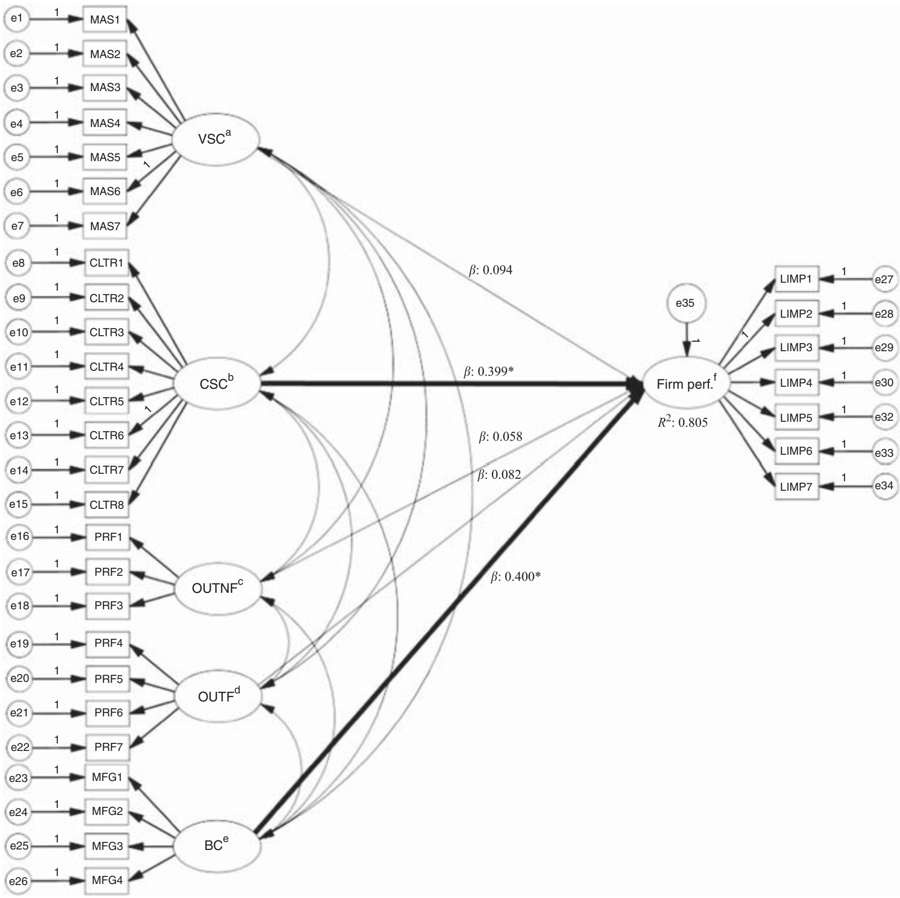


Notes: The bold arrow indicates a significant relationship from the exogenous variable to the endogenous variable. [a]Visual social controls; [b]cultural social controls; [c]non-financial output controls; [d]financial output controls; [e]behavioral controls. $\chi^2 = 1{,}136.651$; degrees of freedom = 489; χ^2 to degrees of freedom = 2.324; IFI = 0.92; TLI = 0.913; CFI = 0.919; RMSEA = 0.060; SRMR = 0.056; CAIC (default model to saturated model) = 0.042. *Significant at $p < 0.001$

Figure 3.
Hypothesis test 1 (strong form)

social visual control mechanisms do not contribute to performance in isolation. Thus, *H2*, the weak form, is not supported. Both the standardized β coefficient and R^2 from the complementary factor to firm performance are greater than the collective R^2 and the standardized β coefficients in the additive model. These results suggest that the complementary effects on firm performance among the complete set of lean management control mechanisms outweigh their individual performance effects, providing further acceptance for[10].

We have decided to report the fit indices in Figures 3 and 4, for which there are consensus in the structural equation modeling literature (Kline, 2011), although Tanriverdi and Venkatraman (2005) chose not to do so. All fit indices indicate acceptable fit.



Notes: Bold arrows indicate significant relationships from exogenous variables to the endogenous variable. [a]Visual social controls; [b]cultural social controls; [c]non-financial output controls; [d]financial output controls; [e]behavioral controls. $\chi^2 = 1{,}103.884$; degrees of freedom = 480; χ^2 to degrees of freedom = 2.300; IFI = 0.923; TLI = 0.915; CFI = 0.922; RMSEA = 0.060; SRMR = 0.054; CAIC (default model to saturated model) = 0.043. *Significant at $p < 0.001$

Figure 4.
Hypothesis test 2 (weak form)

5. Discussion and conclusion

This study focused on complementarities among management control mechanisms in lean manufacturing companies. Little research has been carried out on this topic, which is rather paradoxical, as lean manufacturing is recognized as an enterprise-wide system consisting of interdependent practices (Liker, 2004; Maskell *et al.*, 2012). Our aim with this research was to study lean management control mechanisms and their complementary effects on firm performance. Earlier research provides limited evidence of complementarity among lean management control mechanisms. Emiliani *et al.* (2003) and Kennedy and Widener (2008) were single firm studies and found that lean management control mechanisms were interrelated, but did not provide evidence of complementary effects from lean management control mechanisms to firm performance. Kristensen and Israelsen (2014) was a single firm study showing that greater balance among management control mechanisms led to greater

Panel A: hypotheses tests (weak form)			
Independent variable		Dependent variable	Standardized coefficient
VSC	→	Firm performance	0.094
CSC	→	Firm performance	0.399***
OUTNF	→	Firm performance	0.058
OUTF	→	Firm performance	0.082
BC	→	Firm performance	0.400***
R^2 firm performance: 0.805			
Panel B: hypothesis test (strong form)			
Independent variable		Dependent variable	Standardized coefficient
Complementarity	→	Firm performance	0.927***
R^2 firm performance: 0.859			

Note: ***Significant at the $p < 0.001$ level

Table VI. Results

firm performance, but their method made it difficult to capture the covariance and interactions among lean management control mechanisms. Fullerton *et al.* (2013) was a cross-sectional study and found that management control mechanisms were interrelated. However, the study did not provide evidence of the complementary effects from lean management control mechanisms to firm performance, and did not encompass the complete set of management control mechanisms.

Informed by the lean manufacturing literature and complementary theory, we expected that lean management control mechanisms were complementary. We utilized the holistic framework developed by Kennedy and Widener (2008), which characterizes lean management control mechanisms as social, behavioral, and output control mechanisms. In order to confirm that management control mechanisms were complementary, we constructed two competing hypotheses. The first hypothesis predicted that the complementarity of management control mechanism was positively related to firm performance. The second hypothesis predicted that the management control mechanisms were independently, additively related to firm performance. By constructing two competing hypotheses, we were able to compare the performance effects of individual system components with the performance effects of the complementarity among system components, and we were able to point out the conditionality of individual effects on the effects of other system components (Tanriverdi and Venkatraman, 2005).

We contribute to the literature on lean management control mechanisms in two major ways. We are the first to show that the complementary effects among lean management control mechanisms outweigh their additive effects on firm performance. Thus, firm performance will suffer as a result of implementations that do not consider the complementarity among management control mechanisms (Roberts, 2004). Furthermore, only social cultural control mechanisms and behavioral control mechanisms were independently related to firm performance. Second, this research adds cross-sectional empirical evidence that the full set of lean management control mechanisms is complementary. We also add greater granularity to the understanding of lean management control mechanisms because we distinguish financial output controls from non-financial controls as well as social visual controls from cultural visual controls, and we add a detailed analysis of their systematic interrelatedness. In other words, we provide evidence of five different management control mechanisms compared with the three found in Kennedy and Widener's (2008), and Kristensen and Israelsen's (2014) studies. Inspired by Ouchi (1979), we also extend the Kennedy and Widener's (2008) framework by incorporating lean thinking into social control mechanisms. The greater granularity and greater level of detail are important steps forward in understanding lean management control mechanisms.

To illustrate our findings, consider that non-financial output control mechanisms are not recognized as complementary with peer pressure (a social cultural control mechanism) in the system. That will lead to a reduction of the motivational effects otherwise promoted by non-financial output control mechanisms. Likewise, the effects of structuring the manufacturing facility with high visibility (a social visual control mechanism) are reduced if managers do not recognize the complementarity with training in lean principles (a social cultural control mechanism), as employees will not be able to assist other manufacturing cells in preventing problems or improving work processes. Furthermore, if managers do not recognize that visualization of quality data (a social visual control mechanism) is complementary with standardization (a behavioral control mechanism), the effects of visualization of quality data are reduced, as it is difficult to leverage for continuous improvement, because employees have no baseline from which they can test potential improvements. The performance effects of financial and non-financial output control mechanisms and of social visual control mechanisms are thus not isolated additive effects; they affect performance through their complementarity with social cultural control mechanisms and behavioral control mechanisms.

In a lean manufacturing milieu, social cultural control mechanisms and behavioral control mechanisms are then not only enhancers of firm performance, but also enablers for the performance effects of financial and non-financial output control and social visual control mechanisms. In a similar vein, the effects of social cultural control mechanisms and behavioral control mechanisms on firm performance are greater when they are accompanied by non-financial output control and social visual control mechanisms in a complementary system. This underlines that the greatest benefits from lean management control mechanisms arise when they are implemented in a complete, systematic manner.

Methodologically, this study makes two contributions to the management control literature. First, we use a second-order factor technique to find evidence of complementarity among management control mechanisms. This technique is new to this body of literature and it overcomes the struggles of other techniques testing for complementarities. The second methodological advance of this study is that we show the specifics of management control mechanisms in a lean manufacturing context and show how individual management control mechanisms are related (Malmi and Brown, 2008).

Our findings have important managerial implications. First, companies will not achieve the full performance potential of implementing lean manufacturing if they decide to employ a system where some of the management control mechanisms are missing. In line with this reasoning, and if a company has already employed for example non-financial output control mechanisms, it should invest in implementing the remaining management control mechanisms rather than putting more effort into the existing one. Second, the implementation of all lean management control mechanisms affects the entire company, and employees might have to unlearn old principles and practices before new ones can be put fruitfully into use. Thus, the implementation of the full set of management control mechanisms should be performed with a great emphasis on company-wide coordination, and companies would benefit from preparing employees thoroughly before embarking on the lean manufacturing journey. Third, it is important for decision makers to understand that the performance effect of the implementation of one management control mechanism is dependent on the level of implementation of another management control mechanism, and vice versa, and that the company will not obtain the full performance effects until the system of management control mechanisms is completely implemented. Therefore, although initial performance effects might be lower than expected, the company should not hesitate with respect to increasing the level of the implementation of lean management control mechanisms. The implementation of the full set of complementary lean management control mechanisms requires complex organizational change and coordination, but this research enables decision makers a greater prior understanding of how the management control mechanisms work together. Thus, our research can assist and guide decision makers in overcoming some hesitations related to the implementation, and leaves less to understand after the implementation. Fourth, the set of questionnaire items that we developed in this research can be applied by practitioners during lean audits to ensure that they are on track and reaching lean manufacturing objectives, and the set of items can be used as a benchmarking tool between business units. Fifth, our evidence suggests that decision makers should understand that financial output control mechanisms remain important in lean manufacturing companies. In the literature, e.g. Johnson (1992), it is typically noted that such control mechanisms should be avoided and substituted with non-financial control mechanisms, but we have shown that non-financial and financial control mechanisms are complementary. Finally, lean management control mechanisms might be relatively easy to replicate between companies. Furthermore, knowledge of lean principles and practices is wide-spread. After all, these principles and practices have received abundant attention since the late 1980s (Bhamu and Sangwan, 2014). Therefore, despite that initial costs might be high, companies should go far in order to understanding the complementarity among the complete set of management control mechanisms as it may lead to a sustainable competitive advantage because it is difficult for competitors to replicate (Porter, 1996).

6. Future research and limitations

As with other studies, this study has its limitations. As our study is of a cross-sectional nature, it is difficult to claim causal inferences, and we cannot rule out that unobserved factors may be driving our evidence. Rather, our evidence must be considered as consistent with our theoretical arguments. Furthermore, our sample is not random, as it was drawn from a population of lean companies. This reduces the generalizability of our evidence to other manufacturing regimes, but it also increases the likelihood of the population understanding the survey questions and consequently helps alleviate some of the concerns about data collection in survey research (Fullerton *et al.*, 2013). Finally, surveying only one respondent in each firm represents a potential common method bias problem. However, we addressed this limitation and found that it was not a concern.

Our study suggests that examining the benefits or effects of financial and non-financial control mechanisms and social visual control mechanisms in isolation at lean companies may lead to inconsistent results due to a failure to control for social cultural and behavioral control mechanisms. Future research on management control in lean companies must then encompass a focus on the entire set of management control mechanisms. The simultaneous, systematic implementation of lean management control mechanisms might overwhelm employees' absorptive capacity (Cohen and Levinthal, 1990). A possible future research endeavor is then to clarify if the effects of lean management control mechanisms on firm performance are affected by the length of time companies have used lean manufacturing. A second future research idea is to clarify whether our findings are applicable to more loosely coupled manufacturing regimes. In these manufacturing regimes, the individual management control mechanism might work, as practices are less interdependent (Roberts, 2004). Testing for complementarities among management controls has recently been debated (see Grabner and Moers, 2013). We consider the second-order technique as an important addition to this debate, and we suggest that future management control research on complementarities should consider using the second-order technique.

Notes

1. We use the label "management control mechanisms" as Kennedy and Widener (2008) used this label. We believe that it is equivalent to the label "management control forms" used in other studies, e.g., Kristensen and Israelsen (2014).

2. Management control is defined by Anthony (1965, p. 17) as, “the process by which managers ensure that resources are obtained and used effectively and efficiently in the accomplishment of the organization’s objectives.”
3. Ouchi (1979, pp. 837) stated that some of the characteristics of clan controls are to ensure that employees try to achieve the “right” objectives.
4. The Shingo Prize is an award given to companies based on their world-class results and organizational culture. The database includes many companies, as most organizations do not wait to challenge for the Shingo Prize until they are likely to win it.
5. As the large majority of respondents had management experience and were responsible for lean at their facility, our constructs might be subject to common method bias. To reduce these concerns, we perform a Harman’s one factor test including all our latent variables. There is a potential bias if the majority of the variance is explained by one factor (Podsakoff and Organ, 1986). The test shows that the concern for common method bias is low, as a one factor solution only accounts for 45 percent of the total variance.
6. The 0.4 cut-off have been used in prior research on lean manufacturing (e.g., Fullerton and Wempe, 2009; Fullerton *et al.*, 2014). The removal of one item did not affect the composition of the five factors.
7. Squared AVE to inter-factor correlations is computed in SPSS 23. We compared the squared AVE to the inter-factor correlations in AMOS 23 as well. This test revealed discriminant validity issues only concerning the performance factor, the social controls one factor, and the behavioral controls factor. All of our factors correlated less than 0.85, not indicating poor discriminant validity (Kenny, 2012). Kenny (2012) also suggested restricting the correlation between two factors to 1, which is similar to collapsing the two factors (Hair *et al.*, 2014). This is done to investigate if a one-factor model is more appropriate than a two-factor model. A two-factor model is appropriate if $\chi^2/\mathrm{df}^{\mathrm{Diff.}}$ is significant (Hair *et al.*, 2014). We performed a test in AMOS 23 where we constrained correlations between both the performance factor and behavioral controls and the performance factor and social controls 1. In both instances, a two-factor model fitted the data significantly better: restricting the correlation to one between performance and behavioral controls yields a χ^2 of 1,199.22 and degrees of freedom: 482, resulting in a significant $\chi^2/\mathrm{df}^{\mathrm{Diff.}}$ ($p < 0.01$) and the following fit indices: RMSEA: 0.064, SRMR: 0.1307, IFI: 0.911, TLI: 0.902, and CFI: 0.911. Restricting the correlation to one between performance and social controls 1, on the other hand, yields a χ^2 of 1,143.806 and degrees of freedom: 482, resulting in a significant $\chi^2/\mathrm{df}^{\mathrm{Diff.}}$ ($p < 0.01$) and the following fit indices: RMSEA: 0.061, SRMR: 0.0748, IFI: 0.918, TLI: 0.910, and CFI: 0.918.
8. We computed the main variables and their pair-wise interactions and correlated them in SPSS 23.
9. Following Tanriverdi and Venkatraman’s (2005) procedure, we did not include the performance variable in this test.
10. As suggested by Camacho-Minano *et al.* (2013), we controlled for size and unionization. Size was proxied for by the number of facility employees and facility sales, and respondents were asked to indicate whether their facility was fully unionized or not. We ran tests with respect to both hypotheses where size variables were additively related to firm performance and χ^2 difference tests where size variables moderated all structural relationships. We ran the same tests regarding unionization. We find that all statistical inferences remain similar across all tests.

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Appendix

Table AI. Criterion validity for output non-financial control mechanisms

Measure	Test variable	Explanation for correlation	Properties test variable	Correlation
OUTNF	Cost of quality	If a firm uses non-financial control mechanisms, it is likely to measure the cost of quality	Single item	0.583**
OUTNF	Productivity	If you use non-financial management control mechanisms, you are likely to measure productivity	Single item	0.515**
OUTNF	On-time deliveries	If a firm uses non-financial management control mechanisms, we expect it to measure on-time deliveries	Single item	0.431**
OUTNF	First-pass yields	We expect that if a firm uses non-financial control mechanisms, it is likely to measure first-pass yields	Single item	0.538**
OUTNF	Cycle time improvements	If a firm uses non-financial management control mechanisms, it is likely to measure cycle time improvements	Single item	0.573**

Note: **Significant at $p < 0.01$ (two-tailed)

Social cultural controls	
Please indicate below what most closely represents your facility's organizational culture	
1: strongly disagree, 2: disagree, 3: neutral, 4: agree, 5: strongly agree	
CLTR 1	Management style is more participative than autocratic
CLTR 2	Management is committed to quality-related training
CLTR 3	All employees are involved in problem solving
CLTR 4	Our entire facility is trained in lean principles
CLTR 5	Every area of our facility works on continuous improvement
CLTR 6	Management is focused on eliminating waste everywhere
CLTR 7	Lean thinking has permeated all of our operations
CLTR 8	Team members feel peer pressure to perform
Social visual controls	
For the following items, please mark the most appropriate response related to your facility's management accounting system	
1: strongly disagree, 2: disagree, 3: neutral, 4: agree, 5: strongly agree	
MAS 1	Standard operating procedures are visible on the shop floor
MAS 2	Visual boards are used to share information
MAS 3	A training skills matrix is visible on the shop floor
MAS 4	Charts showing defect rates are posted on the shop floor
MAS 5	We have created a visual mode of organization
MAS 6	Information on productivity is updated frequently on the shop floor
MAS 7	Quality data are displayed at work stations
Behavioral controls	
Please indicate below the extent to which your facility has implemented the following	
1: not at all, 2: little, 3: some, 4: considerable, 5: great deal	
MFG 1	Use of standardization
MFG 2	A Kanban system
MFG 3	Use of one-piece flow
MFG 4	Use of line balancing and level schedules
Non-financial output controls	
Please indicate below how important these performance measures are to operations at your facility	
1: not at all, 2: somewhat, 3: important, 4: very important, 5: critical	
PRF1	Non-financial measures related to cell performance
PRF2	Non-financial measures related to value stream performance
PRF3	Non-financial measures related to facility performance
Financial output controls	
Please indicate below how important these performance measures are to operations at your facility	
1: not at all, 2: somewhat, 3: important, 4: very important, 5: critical	
PRF 4	Market share
PRF 5	Cash flow
PRF 6	Overall financial results
PRF 7	Customer satisfaction
Firm performance	
Please indicate to what extent lean initiatives have affected the following	
1: not at all, 2: little, 3: some, 4: considerable, 5: great deal	
LIMP 1	Inventory-related resources have been freed up
LIMP 2	Capacity is managed more effectively
LIMP 3	Cycle/production time is improved
LIMP 4	Quality is improved
LIMP 5	Overall communication is improved
LIMP 6	Costs are reduced
LIMP 7	Profitability is improved

Table AII.
Survey items

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