Implementing Corporate Lean Programs:
The Effect of Management Control Practices

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ABSTRACT

We examine how management control practices relate to the implementation of a corporate lean program at the factory level. Our empirical analysis uses data from a large manufacturing firm that is implementing a corporate lean program in its global plant network. We find that using dedicated teams to lead the lean program, developing and frequently reviewing lean-focused performance reports, and using nonfinancial rewards linked to lean implementation are favorably associated with more extensive implementation of lean practices in the factories. We do not find evidence that the use of management-initiated internal audits and financial rewards tied to lean implementation are strongly associated with more extensive lean implementation. We also present evidence of a positive relation between lean implementation and improvements in operational performance in the factories. Overall, these findings suggest that when implementing a corporate lean program, the firm must pay careful attention to the type of management control practices it uses for controlling the input, process, and output aspects of the lean program.

Keywords: *management control; lean manufacturing; lean implementation; factory performance*

1. INTRODUCTION

Corporate lean programs aim to implement lean manufacturing practices in the firms' global plant networks. Despite the documented benefits of these practices (Shah and Ward, 2003; Womack and Jones, 1996; Womack et al., 1990), many global manufacturers often struggle to implement such programs in their production networks (Netland and Aspelund, 2014; Pay, 2008; Schonberger, 2008). As with the implementation of any company-wide improvement program, the management control practices used can foster or impede the lean implementation process (Ahlström and Karlsson, 1996; Anand et al., 2009; Bititci et al., 2011; Fullerton et al., 2013; Kennedy and Widener, 2008; Liker, 2004). This paper investigates the relation between the use of several common management control practices and the implementation of a corporate lean program.

We organize our analysis using the conceptual framework of management control articulated most recently by Merchant and Stede (2012). The framework views management control as elements that seek to control and coordinate the inputs to a process, the process itself, and the outputs of a process. This input-process-output control framework guides our empirical analysis, which uses factory-level data collected from a world-leading commercial vehicles manufacturer regarding its on-going effort to implement lean on a global scale. Specifically, we use internal company data from formal audits of lean implementation in 36 plants of the manufacturer as well as data from a questionnaire survey collected from multiple respondents in the same plants. The audit data were compiled by an internal team of experts from the manufacturer who had conducted on-site assessments of the extent of lean implementation at each factory. We combine the audit data with our survey data, which include information regarding the use of management control practices in each factory, as well as changes in the operational performance of the factory. We supplement the quantitative data with factory visits and semi-structured interviews with factory employees to improve our understanding of the manufacturer's lean program and management control practices.

We use two-stage least-squares methods to analyze the data. The first-stage regression tests the extent to which management control practices relate to the extent of lean implementation. The second-stage regression examines the relation between the extent of lean implementation in a factory and changes in its operational performance. To operationalize our conceptual framework of management control, we identify the extent to which factory managers create dedicated lean implementation teams that support the lean program (i.e., *input control*), develop lean-focused performance reporting and initiate top-down lean implementation audits (i.e., *process control*), and use financial rewards and non-financial rewards to incentivize lean implementation in the factory (i.e., *output control*).

This paper contributes to the literature on the role of management control practices in implementing large-scale strategic initiatives such as corporate lean programs (e.g., Bititci et al., 2011; Fullerton et al., 2013; Kennedy and Widener, 2008). We show that use of dedicated lean implementation teams, lean-focused (bottom-up) performance reports, and nonfinancial rewards relate positively to extensive implementation of corporate lean programs in factories. We do not find a similar relation between lean implementation and deployment of financial rewards (tied to predetermined implementation targets) or use of internal audits initiated by factory management (top-down) to evaluate adherence to the lean program. Overall, these findings suggest that when implementing a corporate lean program, the firm must pay careful attention to the type of management control practices it uses for controlling the input, process, and output of the lean program. Our research also confirms the positive relation between implementation of lean manufacturing and performance in a plant (e.g., Browning and Heath, 2009; Cua et al., 2001; Fullerton and Wempe, 2009; Furlan et al., 2011; Jayaram et al., 2010; Mackelprang and Nair, 2010; Nair, 2006; Shah and Ward, 2003).

Section 2 reviews the literature and develops our hypotheses. Section 3 provides details on our research setting and methodology. Section 4 reports our empirical evidence, which is discussed in more detail in Section 5. Section 6 presents concluding remarks.

2. HYPOTHESIS DEVELOPMENT

Studies document positive associations between the implementation of production improvement programs, such as lean manufacturing, and firms' operational performance (e.g. Fullerton et al., 2014; Jayaram et al., 2010; Mackelprang and Nair, 2010; Shah and Ward, 2003). Hence, the research question of primary interest in the literature is no longer whether lean can benefit performance, but rather *how* to implement it with success (Liker and Convis, 2011; Netland and Ferdows, 2014; Rother, 2010).

The literature on management control, which has been defined as "the process by which managers ensure that resources are obtained and used effectively and efficiently in the accomplishment of the organization's objectives" (Anthony, 1965, p. 17), represents a useful conceptual framework with the potential to provide insights into the implementation of lean. The management control literature has long focused on the development of an input-process-output model of control to coordinate and motivate employees to implement the firm's strategic objectives (Anthony, 1965; Campbell, 2012; Eisenhardt, 1985; Merchant, 1982; Merchant and Stede, 2012; Ouchi, 1979). *Inputs* can be managed by social control, which seeks to align preferences in the organization by socialization of values and beliefs (Merchant and Stede, 2012; Ouchi, 1979). Employing "the right people at the right places" is arguably the most important mechanism of input control (Campbell, 2012). *Processes* can be managed by action control, which guides specific actions in the organization. Standard operating procedures supported by performance reporting systems and frequent internal audits represent important sources of process control (Fullerton et al., 2014; Merchant and Stede, 2012; Power and Terziovski, 2007). *Outputs* can be managed by result controls, which motivate employees to support organizational change through the provision of financial and nonfinancial incentives based on realized results (Merchant and Stede, 2012; Shaffer and Thomson, 1992; Snell and Dean, 1994).

Despite the view that management control systems are an important tool that could foster and support lean implementation (e.g., Fullerton et al., 2013; IMA, 2006; Lawler, 1994; Liker, 2004), there is little empirical evidence regarding the control practices that might support the integration of lean into the firm's day-to-day operations (Bititci et al., 2011; Worley and Doolen, 2006). We contribute to the literature on management control and lean production by investigating the extent to which the use of several management control practices that are often used during the implementation of large-scale programs support the implementation of lean. We use the input, process, output model of management control to organize the development of hypotheses and to guide our empirical analysis. As such, we treat management control as consisting of three key features: the inputs via the allocation of responsibilities across employees, the process via routine performance reporting and internal audits, and the outputs via employee financial and nonfinancial reward systems. The remainder of this section applies this conceptual framework to develop our hypotheses.

2.1 Input control: Allocation of responsibilities for lean implementation

Studies provide mixed evidence regarding the potential benefits of allocating responsibilities for lean implementation to a dedicated implementation team. On one hand, Anand et al. (2009, p. 446), discussing continuous improvement programs, argue that the tendency of traditional management systems to centralize authority among top management exclusively is likely to impede implementation, as lean requires broad-based employee participation. Their case study evidence suggests interesting questions, notably (Anand et al., 2009, p. 458): "Would it be better to use a more organic approach to

[lean] under which, instead of specialist [lean] method experts, all middle managers continually serve as [lean] leaders?" Boppel et al. (2013) also note that the use of dedicated implementation teams might cause shop-floor employees to view the lean program as a short-term, management-driven project instead of a long-term strategic change in production strategy.

One the other hand, the management control literature argues that strategic initiatives which change employees' daily tasks requires a heavy reliance on people: "Finding the right people to do a particular job, training them, and giving them both a good work environment and resources is likely to increase the probability that the job will be done properly" (Merchant and Stede, 2012, p. 88). To this end, Kotter (1995, 2012) advises firms to "assemble a group with the power and energy to lead and support a collaborative change effort." As such, one input control used to support lean implementation is to form a dedicated team of lean experts from among middle-management and shop-floor employees who have a mandate to provide on-going support for the lean program. Consistent with this view, anecdotal evidence from Swank (2003) suggests that a "lean team" of experts is essential for the successful implementation of lean in a financial services firm. Anand et al. (2009, p. 454) document that all firms in their sample use teams of cross-functional employees to "serve as independent facilitators" and encourage coordination of continuous improvement initiatives.

There are at least three advantages to forming an implementation team to lead the lean effort. First, a dedicated team comprised of lean experts, middle-management and shop-floor employees departs from the approach of centralizing authority among top management while retaining a degree of coordination across the entire factory to ensure that all aspects of the lean program receive attention and progress in level of maturity. Second, dedicated teams often receive extensive and specialized training in both lean techniques and in best practices in their implementation. This training likely makes a dedicated team a valuable source of knowledge that can educate and assist shop-floor employees to implement the significant changes in daily production tasks that accompany the implementation of lean. Third, the team's performance evaluation and career opportunities are frequently linked to implementation success. Hence, lean implementation might be enhanced by a team that has the responsibility, knowledge, and incentives to ensure implementation.

Overall, we expect the advantages of responsibility, knowledge, and performance incentives associated with the use of dedicated implementation teams will relate positively to the extent of lean implementation in the factory. The above discussion leads to the following hypothesis:

> **H1a:** The use of dedicated implementation teams is positively associated with more extensive implementation of a corporate lean program.

2.2 Process control: Performance reporting and internal audits

Anecdotal evidence suggests that timely, operation-focused performance reporting is essential in helping employees continuously improve processes, evaluate process performance, and enable factory managers to establish strategies. For instance, Ahlström and Karlsson (1996) document how executives of a Swedish manufacturer suspended its lean program after the firm's backward-looking, financially-oriented performance-reporting process reported that costs were increasing at a faster rate than production improvements despite shop-floor evidence that the lean program was providing benefits. Only after the controller modified the performance reporting process to emphasize timely, operationally-oriented performance measures did the executives believe their lean program was sustainable.

Ittner and Larker (1995) argue that performance-reporting systems can be organized into bottom-up and top-down reporting processes. A typical *bottom-up* reporting process begins at the shop floor with the use of daily team meetings. In these meetings, all employees report and review detailed, locally-collected performance measures. These meetings can help shop-floor employees and factory managers quickly identify and address production issues. Consistent with this notion, studies have generally found that firms change their performance-reporting processes to integrate nonfinancial measures into performance reports when implementing a production improvement program (Fullerton and McWatters, 2002; Ittner and Larcker, 1995). Banker et al. (1993) show that posting defect charts helped support the implementation of advanced TQM initiatives, suggesting that performance feedback is necessary for employees to relate their decisions to outcomes. Similarly, Perera et al. (1997) document that firms rely more on nonfinancial measures than on financial measures when shifting to a customer-focused manufacturing strategy. Jazayeri and Hopper (1999) provide case-based evidence of how a U.K. chemical firm modified its reporting process to include operationally-focused measures to support the implementation of a new manufacturing strategy. Hence, we expect a positive relation between the greater use of bottom-up performance-reporting processes and more extensive lean implementation. The above discussion leads to the following hypothesis:

> **H1b:** Greater use of bottom-up performance reporting is positively associated with more extensive implementation of a corporate lean program.

In a typical *top-down* reporting process within the lean context, senior factory managers conduct routine audits of the extent of lean implementation in the factory (e.g., monthly shop-floor audits of implementation status and progress). The factory managers then integrate audit results into performance reports that are circulated among managers for decision-making purposes. Merchant and Stede (2012, p. 624-5) suggest performance audits can provide an independent check of implementation progress, providing information that guides next steps and motivates further implementation. The latter point is achieved because employees are aware that their implementation efforts will be routinely audited. Studies have argued that the use of management-initiated internal audits can motivate employees to maintain their focus on strategic change, evaluate employee performance, and communicate to employees the importance of the lean initiative (Angell and Corbett, 2009; Caffyn, 1999; Ritchie and Dale, 2000; Witcher et al., 2008). For instance, Angell and Corbett (2009) document a favorable relation between formal audits and the success of continuous improvement programs in a sample of New Zealand firms. In contrast, Power and Terziovski (2007) show that quality audits do not deliver the results they promise, and may shift attention from continuous improvements toward compliance with the static audit standards. On balance, we expect that routine implementation audits will encourage more extensive lean implementation.

> **H1c:** Greater use of routine internal audits to assess the extent of lean implementation is positively associated with more extensive implementation of a corporate lean program.

2.3 Output control: Employee financial and nonfinancial rewards

The use of employee financial and nonfinancial rewards to motivate change is widely-regarded as a fundamental management control practice (Jensen, 1983; Merchant and Stede, 2012; Stonich, 1984). Arguably, reward systems are particularly important in high-involvement programs, such as lean, because rewards aim to motivate all factory-level employees to continuously improve their portion of the production process (Fullerton and McWatters, 2002; Ittner and Larcker, 1995). Snell and Dean (1994, p. 1110) posit that "adjusting compensation systems may be among the most instrumental methods for eliciting and reinforcing behavior required for the success of integrated manufacturing [i.e., lean]." Similarly, Kerr and Slocum (2005, p. 137) conclude that cultural change can be engineered by "a careful consideration of reward system design [which] can help decision makers successfully modify the organization's culture." By linking financial and nonfinancial rewards to strategic objectives, factory managers can communicate the importance of the lean program and encourage employees to develop the requisite skills and capabilities to support it (e.g., learn new methods and tools) (Jazayeri and Hopper, 1999). Lean production also alters the mix of job tasks by requiring all employees to focus on reducing waste, improving quality and productivity, and helping their co-workers to do the same. Therefore, there is likely a favorable relation between the use of employee reward systems that emphasize such behavior at all levels in the factory and more extensive lean implementation.

There are two central questions in executing these reward systems. First, who should be eligible for such awards? Second, do financial and nonfinancial rewards provide differential benefits in terms of strategy implementation? Our focus in this study is on the latter issue, particularly the extent to which financial rewards (e.g., bonus payments based on operational improvements tied to lean implementation) and nonfinancial rewards (e.g., celebrate employees who achieve significant operational and financial improvements by implementing lean practices) relate more strongly to lean implementation.

In a meta-review of 45 incentive studies, Condly et al. (2003) show that reward systems have a significant positive relation with productivity. The study also highlights how the use of financial and nonfinancial reward systems coexist, and provides evidence that the use of financial rewards provides greater benefits vis-à-vis nonfinancial rewards on average. Merchant and Stede (2012, p. 380) point out that "monetary rewards can have potent impacts on employee's behaviors because virtually everyone values money." Financial rewards also offer a visible way for gainsharing in implementations of improvement programs (Lawler, 1994) by answering the criticism related to the question "what's in it for me?" Indeed, Veldman et al. (2014) find that, under certain conditions, monetary bonuses tied to process improvements can be highly effective. The above discussion leads to the following hypotheses:

> **H1d:** Greater use of financial rewards to motivate lean-related results is positively associated with more extensive implementation of a corporate lean program.

Another stream of literature indicates that nonfinancial rewards such as employee recognition and praise may be more effective when implementing large-scale improvement programs. Merchant (1982), among others, suggests that when performance outcomes are difficult to measure and there is limited knowledge of how to implement change, control practices that emphasize "softer" people-centric control practices over "harder" pay-for-performance practices might be preferred. The lean context offers at least two interrelated characteristics that create challenges in measuring and contracting on output: first, objectives are stated in multidimensional and relatively intangible terms, and second, performance benefits that arise from lean implementation are expected to occur over a relatively long time horizon. This is broadly consistent with ideas advanced in Snell and Dean (1994) whereby implementing lean is ultimately about changing the corporate culture (Liker, 2004; Womack and Jones, 1996), creating a need for rewarding teams and individuals with on-going recognition and praise. The above discussion leads to the following hypothesis:

> **H1e:** Greater use of nonfinancial rewards to motivate lean-related results is positively associated with more extensive implementation of a corporate lean program.

2.4 Implications of lean implementation for factory-level operational performance

Our primary focus is to provide evidence on how management control can support the implementation of lean. However, it remains important for our analysis to "close the circle" such that we also link more extensive lean implementation to performance. The literature generally concludes that the implementation of production improvement programs, such as lean, relates positively to various measures of operational performance, including quality, customer delivery performance, inventory turnover, and productivity (e.g. Browning and Heath, 2009; Cua et al., 2001; Jayaram et al., 2010;

McKone et al., 2001; Shah and Ward, 2003). As such, we expect a positive relation between more extensive lean implementation and changes in factory-level operational performance.

> **H2:** More extensive factory-level lean implementation is positively associated with the operational performance of a factory.

3. RESEARCH SETTING AND DATA

The research site for this study is Global Equipment Manufacturer (GEM), which produces a variety of commercial vehicles and components. In 2013, GEM reported approximately $31 billion in revenue, with 100,000 employees and 67 factories operating on six continents. The data for this study come from GEM's lean implementation performance scorecard, combined with our survey data collected from GEM regarding the use of management control practices, and perceived changes in the operational performance of individual factories. Our initial sample is based on the intersection of the factories for which we obtain complete survey data from at least two respondents per factory (57 factories; we discuss the survey in more detail in the following subsections) *and* had been assessed by GEM corporate auditors during the time period covered by our survey (2010-2012). This intersection is comprised of 41 factories from which we removed two factories that had recently been closed (leaving 39 factories), as well as three factories that had received only a single lean assessment (leaving 36 factories). As such, our final sample consists of 36 factories for which we have complete assessment and survey data.

We further visited 29 of these factories and conducted 140 semi-structured interviews with factory managers, lean managers, and shop-floor personnel. We interviewed on average five people in each plant (minimum 2 and maximum 10). The interviewees ranged from line supervisors to senior factory managers. The interviews typically lasted between 30 minutes and one hour, covering questions related to the plant's implementation of the corporate lean program and the use of management control practices. Each visit also included a two- to three-hour plant tour, which enabled us to "see" the lean program in action and to speak with shop-floor employees about their experiences with lean implementation. Directly after each factory visit, we compiled extensive case study reports that were designed to assist in providing better contextualization of our empirical analysis. This qualitative data helped supplement our quantitative assessment and survey data.

Our research setting offers several advantages. GEM's corporate lean program is based on five lean principles that are common in most lean programs (Netland, 2013): just-in-time (JIT), total quality management (TQM), total productive maintenance (TPM), human resource management (HRM), and continuous improvement (CI). As discussed in the next section, these five principles are largely consistent with the literature on lean programs (Shah and Ward, 2003). This reduces concerns that our results are unique to GEM's design of the lean manufacturing concept. Further, GEM's lean program is a well-documented, highly standardized, prescriptive production system that consists of "principles," "modules," and "elements." Finally, as described in the next section, GEM maintains detailed, factory-level performance scorecards that measure the extent of lean implementation based on periodic reviews led by highly-trained auditors from GEM's headquarters. Combined, these advantages provide an opportunity to bring significant depth to our study.

3.1 Performance scorecard data used to measure factory-level lean implementation

We use performance scorecard data from GEM's most recent assessment of each factory's extent of lean implementation. Specifically, GEM defines *Lean Implementation* using five measures for the principles shown in in Table 1: JIT, TQM, TPM, HRM, and CI. The JIT principle consists of the modules "flexible manpower", "pull system", "takt time", "continuous flow processing", and "material supply" (Cronbach's alpha of 0.910). The TQM principle consists of the modules "zero defects", "quality assurance", and "product and process quality planning" (0.867). The CI principle consists of the modules "prioritizing", "problem solving methods", "improvement organization", and "improvement approach" (0.918). The TPM principle consists of the modules "standardized work", "production leveling", "maintenance system", and "5S" (0.862). The HRM principle consists of the modules "goal oriented teams", "cross functional work", and "organizational design" (0.827). GEM's five principles and the corresponding modules are largely consistent with those frequently used in the lean literature (Fullerton et al., 2014; Liker, 2004; Shah and Ward, 2003, 2007; Womack and Jones, 1996).

To support its corporate lean program, GEM has established a formal and standardized process to regularly assess the extent of lean implementation across its factories worldwide. Assessments are completed on-site by an internal GEM team that consists of two to three expert lean auditors from the corporate headquarters and two to four certified or in-training assessors from other GEM factories. These assessments are extensive, typically requiring four days of detailed review during which the team scores the factory on 103 "elements" according to a five-point scale. (Appendix A and Table A-1 provide additional description of the assessment process). The scores for the elements are first aggregated into module scores and then into scores for each of the five principles. Finally, the principle scores are aggregated using a simple average into a "Lean Assessment Score" for the factory. These data provide a reliable and consistent measure for measuring the extent of lean implementation at the factory.

We use the Lean Assessment Scores to measure the extent of lean implementation in a factory throughout our analysis. We also construct a factor using the five "principles" scores to ensure that our results are robust to alternative methods of measuring factory-level lean implementation. Table 1 describes the principles that comprise GEM's scorecard and reports descriptive statistics of the pooled sample of factory assessments.

INSERT TABLE 1 ABOUT HERE

3.2 Survey data used to measure management control practices

We used a survey to obtain the measures for management control practices and factory-level performance. The survey was part of a larger research project that asked managers over 50 questions about lean implementation; all the questions regarding the use of management control practices used a five-point Likert scale from “Never Used” to “Very Frequently Used.” The survey was pre-tested with managers from three GEM factories on two continents to ensure the clarity of questions. After revisions were made, we distributed the survey to 60 factories in 2012. Depending on factory size, we requested responses from up to ten respondents who worked on-site, had daily interactions with shop-floor employees, and were in positions that enabled them to understand and, if necessary, makes changes to management control practices. The survey asked respondents to self-report the use of management control practices. As discussed previously, we have complete survey data for all factories in our sample.

We received 226 responses from the 36 plants in our sample, providing an average of approximately six respondents per plant. One benefit of multiple respondents per factory is that it helps reduce the limitations of subjective survey measures (e.g., Flynn et al., 1995). Our survey respondents included a broad cross-section of factory senior management (29 percent of respondents in the sample), middle management (35 percent), lean program support employees (31 percent), and other positions (5 percent). One concern of multiple respondents is the potential for significant disagreement between respondents within the same factory. To mitigate this concern, we reviewed the responses by factory to assess the extent of agreement or disagreement across respondents; no factory had significant variance across the respondents within the same factory. As such, we used the average of the responses received from each factory to determine the factory's score for each question.

We used six questions from the survey, which asked managers to assess the degree to which five management control practices were used throughout the factory two years prior to receiving the survey. We use information from two years prior to reduce endogeneity concerns and to strengthen our evidence on whether practices that are in place while the factory is "going lean" relate to more extensive implementation. First, we measure how managers allocate responsibilities to implement the corporate lean program to employees in the factory using a survey question that asked the extent to which the factory used a dedicated team to implement the lean program (*Dedicated Teams*).

Our second and third measures of management control practices examine the bottom-up and top-down use of performance reporting and evaluation processes in the factory. To measure the use of bottom-up reporting, we define *Performance Reporting* using the responses to two questions, one regarding the extent to which regularly updated, lean-focused performance reports were available to all employees throughout the factory and the other regarding how regularly managers reviewed such performance reports. To measure the use of top-down reporting, we define *Internal Audits* using the responses to one survey question regarding the extent to which factory managers conducted routine internal audits of lean implementation.

Our final two measures of management control practices capture the type of employee rewards used to motivate lean implementation. We define *Financial Rewards* using responses to one question regarding the extent to which managers were rewarded with bonus payments based on operational improvements tied to lean implementation. We define *Nonfinancial Rewards* using responses to one question regarding the extent to which employees and teams received nonfinancial rewards, such as an award presented at a factory "town hall" meeting of all employees, based on operational improvements that relate to lean implementation. Table 2 reports descriptive statistics for *Dedicated Teams*, *Performance Reporting*, *Internal Audits*, *Financial Rewards,* and *Nonfinancial Rewards*. A higher value represents more extensive use of a management control practice in a factory.

INSERT TABLE 2 ABOUT HERE

3.3 Survey data used to measure factory-level operational performance

A series of questions in our survey asked the respondents to provide their perception of the extent to which the corporate lean program had changed the factory's operational performance along specific metrics over the last two years. We define *Operational Performance* using responses regarding on-time delivery, throughput time, inventory turns, productivity of machines and labor, product quality, and customer satisfaction. These measures are both consistent with the criteria used by GEM management to assess factory operational performance, and are representative of the measures used in related studies (Cua et al., 2001). We measure operational performance using the average of these six performance areas in our primary analysis, and construct an alternative measure using factor analysis to ensure that our results are robust. A higher value of *Operational Performance* represents a greater perceived positive change in operational performance. Table 2 reports that on a five-point Likert scale from 1 ("Substantially Declined") to 5 ("Substantially Improved"), *Operational Performance* ranged from 3.00 to 4.80, with a mean of 4.16.

3.4 Control variables

Lean Implementation and *Operational Performance* at the factory level likely depend on factory-specific characteristics. We control for the effect of factory size, unions, and product characteristics. We define *Size* as the natural logarithm of the number of full-time factory employees. Although larger factories could have greater flexibility in allocating resources and time to the lean program, such factories likely face greater challenges due to the scale of the implementation effort. To control for the effect of *Union* work rules that might relate to systematic differences in management control practices and operational performance across factories, we define an indicator variable equal to 1 if factory-level employees are unionized and zero otherwise. We obtain data on *Size* and *Union* from survey questions regarding the number of employees and union representation, respectively.

In order to account for unobserved heterogeneity from industry and product characteristics, we include an indicator variable for factories that produce powertrain equipment (*Product Type*). Powertrains are complex products that are produced for internal transfer to GEM's assembly factories, and thus differ from products sold to external markets (e.g., commercial vehicles). *Product Type* is an indicator variable equal to 1 if the factory produces powertrains, and zero otherwise. Table 2 reports descriptive statistics of our control variables. Table 3 presents correlations among the variables used in our multivariate analysis. We confirm that the magnitude of the correlations between our independent variables does not generate concerns about multicollinearity through post-estimation analysis of variance inflation factors (untabulated).

4. EMPIRICAL TESTS AND RESULTS

We model the extent of lean implementation and operational performance using two-stage least-squares.[1] The first-stage regression tests the extent to which management control practices relate to the

[1] Estimating this system using ordinary least squares will result in inconsistent parameters because the endogenous variables will be correlated with the equation errors. Our two-stage least-squares estimation, which replaces the endogenous variables with the predicted values from reduced form regressions, results in consistent estimates of the parameters in our model.

extent of lean implementation (Hypotheses 1a-1e). The second-stage regression tests the relation between the extent of lean implementation in a factory and factory-level operational performance (Hypothesis 2). The two regressions are estimated as follows:

$$\begin{aligned} \textit{Lean Implementation} = {} & \alpha_0 + \alpha_1 \textit{Dedicated Teams} + \alpha_2 \textit{Performance Reporting} \\ & + \alpha_3 \textit{Internal Audits} + \alpha_4 \textit{Financial Rewards} + \alpha_5 \textit{Nonfinancial Rewards} \\ & + \alpha_6 \textit{Size} + \alpha_7 \textit{Union} + \alpha_8 \textit{Product Type} + \varepsilon \end{aligned}$$

$$\begin{aligned} \textit{Operational Performance} = {} & \beta_0 + \beta_1 \textit{Lean Implementation} + \beta_2 \textit{Size} + \beta_3 \textit{Union} \\ & + \beta_4 \textit{Product Type} + \varepsilon \end{aligned}$$

4.1 Management control practices and lean implementation

Table 4 reports estimates from first- and second-stage regressions that assess the relation between management control practices, lean implementation, and changes in operational performance. The third column contains results for the model examining the relation between the use of management control practices and the extent of lean implementation in a factory. The results demonstrate that more extensive use of dedicated implementation teams, bottom-up performance reporting, and motivating employees with nonfinancial rewards relate positively to the extent of lean implementation. These results can be seen by the positive and statistically significant coefficient estimates on *Dedicated Teams* (Hypothesis 1a), *Performance Reporting* (Hypothesis 1b), and *Nonfinancial Rewards* (Hypothesis 1e), respectively ($b=0.245$, $p<0.05$; $b=0.272$, $p<0.01$; $b=0.333$, $p<0.01$, respectively). The results in the third column also show that more extensive use of management-initiated internal audits and motivating employees with financial rewards is not strongly related to the extent of lean implementation (*Internal*

Audits: b=0.188, p>0.10; *Financial Rewards*: b=0.137, p>0.10). This evidence does not support Hypotheses 1b and 1c.

INSERT TABLE 4 ABOUT HERE

The fourth column of Table 4 contains results for the second-stage regression model, which estimates the relation between the extent of lean implementation in a factory and changes in factory-level operational performance after estimating fitted values from the first-stage regression. The results in the fourth column demonstrate a positive relation between the extent of lean implementation in a factory and changes in operational performance (*Lean Implementation*: b=0.246, p<0.01). This evidence supports Hypothesis 2.

4.2 Robustness tests

Our regression analysis reported in the third and fourth columns of Table 4 use t-statistics based on standard errors corrected for small sample size and heteroskedasticity. We use the small sample correction to partially account for the fact that our sample consists of 36 factories. The fifth and sixth columns of Table 4 assess the robustness of our results regarding the relation between management control practices and lean implementation (i.e., the first-stage regression) using an alternative approach to the calculation of standard errors in small samples. We follow the recommended procedure in Mooney and Duval (1993) and re-estimate our first-stage analysis using bootstrapped standard errors based on 50 replications (fifth column) and 200 replications (sixth column). We use serial numbers from randomly drawn U.S. $1 bills (after removal of any letters) to set the seed for each bootstrap, which ensures that our procedures begin with random seeds. Consistent with our prior evidence, the results presented in the fifth and sixth columns show a positive and statistically significant estimate on *Dedicated Teams*, *Performance Reporting*, and *Nonfinancial Rewards*. We conclude that our results on the relation between these management control practices and lean implementation are robust to an alternative approach to the calculation of standard errors.

Table 5 report results from robustness tests that assess whether our inferences are sensitive to the definition of *Lean Implementation* and *Operational Performance*. In Panel A, we report results from estimating the two-stage least squares regression after replacing *Lean Implementation* with *Lean Factor*. Factor analysis of GEM's five principles (JIT, TQM, TPM, HRM, and CI) identifies one factor with an Eigenvalue greater than one; we use this procedure to define *Lean Factor*. The results in the third column of Panel A continue to demonstrate that more extensive use of *Dedicated Teams* (Hypothesis 1a), *Performance Reporting* (Hypothesis 1b), and *Nonfinancial Rewards* (Hypothesis 1e) relates positively to the extent of lean implementation ($b=0.313$, $p<0.05$; $b=0.341$, $p<0.05$; $b=0.457$, $p<0.001$, respectively). The results also continue to show that more extensive use of *Internal Audits* and *Financial Rewards* is not strongly related to the extent of lean implementation ($b=0.238$, $p>0.10$; $b=0.182$, $p>0.10$, respectively), which does not support Hypotheses 1b and 1c. The fourth column reports a positive relation between *Lean Factor* and *Operational Performance*, providing additional support for Hypothesis 2. The results in the fifth and sixth columns continue to show a positive and statistically significant estimate on *Dedicated Teams*, *Performance Reporting*, and *Nonfinancial Rewards* after boostrapping standard errors using the procedure discussed previously.

INSERT TABLE 5 ABOUT HERE

Table 5, Panel B augments the analysis presented in Panel A by replacing *Operational Performance* with *Operational Factor*. Factor analysis of survey responses regarding the six measures of operational performance, discussed previously, identifies one factor with an Eigenvalue greater than one; we use this procedure to define *Operational Factor*. The results in the third column of Panel B replicate those reported in the third column of Panel A, as the first-stage regressions are identical. The fourth column reports a positive relation between *Lean Factor* and *Operational Factor*, providing additional support for Hypothesis 2. As the model estimated in the third column of Panel B is identical to the model presented in the third column of Panel A, the bootstrapped evidence will also be identical. Hence, we do not repeat the analysis in Panel B.

We run several additional robustness tests in untabulated analysis. An alternative explanation for the pattern of evidence presented in Tables 4 and 5 is that differences in the level of resources allocated to individual factories for lean implementation is correlated with management control practices and lean implementation. For example, it is costly to form dedicated teams because they require managers to hire additional employees or to reassign existing employees to the implementation team. Similarly, modifying the performance reporting process to collect previously untracked operational data likely requires additional resources for the factory controller. To account for this, we augment our main analysis with a measure based on responses to a question in our survey regarding the perceived change in GEM's allocation of investment resources to the factory for projects that show clear links to the corporate lean program. All evidence is statistically similar when we include this additional control variable in our analysis (untabulated). We also assess the robustness of our results by controlling for factory age (natural logarithm of the number of years that factory has been in operation), and managers' experience (natural logarithm of the average number of years the survey respondents have worked for

GEM). We select these modifications to ensure that our results are not driven by our choice of control variables. Our inferences are robust across the various tests (untabulated).

5. DISCUSSION

Our results provide evidence that factory-level implementation of lean is significantly higher when there is more extensive use of dedicated lean implementation teams, lean-focused performance reporting, and nonfinancial employee rewards. However, similar evidence is not found for management-initiated internal audits or financial rewards. While our sample size of 36 factories might not provide sufficient statistical power to rule out the existence of a relation between the latter practices and lean implementation, our strong evidence regarding dedicated teams, performance reporting, and nonfinancial rewards suggests that internal audits and financial rewards have a comparatively less robust relation to lean implementation. The results also show that the change in factory-level operational performance is significantly higher when there is more extensive implementation of lean. We turn next to discussing these results in more detail by adding qualitative information from our factory visits.

5.1 The effect of input control mechanisms

We find that the creation of dedicated teams to implement the lean program is favorably related to the extent of implementation. This quantitative evidence relates to the case evidence presented in Anand et al. (2009, p. 454) regarding how teams can be "a mechanism to ensure cross-functional participation and systems thinking." Our evidence from factory visits suggests that dedicated teams can help all employees take initiatives to implement lean. Dedicated teams in GEM factories do not appear to disconnect the rest of the employees from engaging in the lean program or exempt plant senior and middle managers from responsibilities related to lean implementation. Rather, the teams serve a plantwide coordinating role. A lean program manager explained the typical set up we observed in plants with higher levels of lean implementation:

> "In our team we have a Lean Coordinator, a lean expert, and a trainee. The rest is up to the line organization; each manager is responsible for lean implementation in his/her area, and reports to the Lean Coordinator."

It was clear that the size and composition of these lean implementation teams were carefully considered at each factory. Some plants used a rule-of-thumb of "one dedicated team member per 150 factory employees" while the most advanced lean plants seemed to have carefully selected and trained the lean experts and shop-floor employees for these dedicated teams. The approach of the latter group is consistent with Campbell's (2012) findings regarding the importance of employee selection to implement strategic change. In the plants with the highest *pace* of implementation, we observed that the leaders of these teams were often recruited from sister plants that were more advanced in lean implementation. Further, senior lean experts in GEM regularly coached the teams in many factories.

On the whole, our interviews and observations confirm that careful attention to formation and support of lean implementation teams improve the team's role to serve as internal lean coordinator and trainer, including holding regular improvement workshops on the factory floor to teach and demonstrate the benefit of lean practices.

5.2 The effect of process control mechanisms

Our evidence from factory visits suggests a clear difference in the usage of the "team boards" between groups of plants with low and high levels of implementation. These boards provide a visual display of key operational and financial performance indicators, many of which are updated on a daily basis by the factory's shop-floor employees. As factories progress in their lean implementation, they seem to dedicate more space on the shop floor to team boards and *use* them on a more frequent basis. At factories with more extensive lean implementation, we often observed that managers and employees gathered by these boards on a regular basis for short meetings at the beginning of each production shift. A line manager in an assembly plant described these meetings—which are essentially bottom-up review of performance reports—to be one of the best mechanisms for implementing lean:

> "These daily, weekly, and monthly meetings provide the organizational structure needed for keeping up the motivation and pace of the improvement work."

Our factory visits provided additional insights into the benefits of the bottom-up performance reporting structure. These meetings often served as a forum for introducing new improvement suggestions and solving new problems quickly. Further, they created a shared awareness in the factory. The contrast between factories that did use these meetings effectively, which were generally more advanced in their lean implementation, and those factories that did not was noticeable. In the former group, employees from across the factory were engaged in regular (often daily) discussion of performance targets and analysis of performance trends directly on the shop floor. They used these meetings to identify the root causes of problems relentlessly and continuously. For example, a lean expert in one of the most advanced plants asserted: "We understood that the goal was not to apply principles, but to solve issues." In contrast, the factories with lower levels of lean implementation seemed to have a different approach to these meetings, often using them for "fire-fighting" or defending turfs. A vice president in one of the plants that had gone through the transition described the difference:

> "Earlier we did not have a management *team*, we had a management *group* that met once a week and individually defended their function. Our current bottom-up reporting system has created a common understanding and team feeling."

In contrast to bottom-up performance reporting, we do not find strong evidence that frequent internal audits initiated by factory managers (separate from GEM's corporate lean implementation audits) accelerate the implementation of a lean program. Our interviews and factory visits suggest that emphasizing audit results, rather than focusing on the lean program itself, might impede the cultural transformation needed for lean implementation. A repeated comment from our interviewees was that management-initiated internal audits diverted managers' attention away from the lean program itself by creating artificial deadlines and disagreements among employees about the design of the audit and the scoring system. This sentiment seemed to be shared by interviewees regardless of the extent of lean implementation in their factories. This finding supports Power and Terziovski (2007) that the effect of audits are limited by the strong focus on compliance rather than improvement.

However, our visits and interviews also suggest that in certain situations, these internal audits can be beneficial. For example, some factory managers expressed that such audits are effective in the very early stages of lean implementation because they convey management's commitment to the lean program.

Several managers in different plants that used both *bottom up* and *top down* reporting structures offered an additional interesting explanation for a fundamental benefit of audits. This was best captured by a lean manager in a plant that had experienced setbacks initially in implementing the lean program: "We need to go from a *push-based* implementation to a *pull-based* implementation." In other words, the implementation should be sought-after by employees, not just mandated from senior managers. The bottom up reporting structure seems to be an effective mechanism for creating such a pull. This supports the literature that emphasizes the importance of the soft factors of lean (e.g., Hines et al., 2011; Rother, 2010).

5.3 The effect of output control mechanisms

We do not find that more extensive use of financial rewards tied to lean implementation is favorably related to lean implementation. In our factory visits, we generally heard skepticism about the benefits associated with financial rewards. Some factories abandoned the used of financial rewards due to negative experiences. These experiences included reduced shop-floor cooperation, discontent regarding how the awards were computed and distributed among employees, and in some instances undesirable employee behavior. As a lean program manager in one of GEM's most lean plants explained:

> "We tried monetary rewards, but it was a disaster…some employees even started to sell their ideas!"

Other factories significantly reduced or eliminated financial reward systems in times of market downturns, which led to an immediate reduction in the continuous improvement activities. For instance, according to its lean program manager, it took one plant several years to achieve benefits from their continuous improvement program after terminating the financial reward system for implemented improvement suggestions:

> "In our factory, one guy even won a car after submitting winning improvement suggestions months after months... But, after we had to remove the reward system, it was very hard to restart the Kaizen program. It took extraordinary leadership skills. Today we do not use financial rewards."

Contrary to financial rewards, we find that an employee reward system that emphasizes nonfinancial rewards is favorably associated with more extensive lean implementation. We observed that plants using nonfinancial rewards seemed to create friendly competition among employees and teams to motivate the pace of lean implementation. Our observations from the factory visits suggests that the factories with more extensive lean implementation use reward systems that routinely encourage employees to nominate their peers for exceptional ideas that foster lean implementation. Certificates of the winning employees and teams were frequently on display around the shop floor, alongside estimates of the cost savings or performance improvements related to their ideas. We also observed that the delivery of nonfinancial rewards might enhance their motivational success. In all the plants that are advanced in their implementation of lean, senior managers do regular "gemba walks" and appreciate implementation face-to-face with shop floor workers. In some of these plants, the managers also hold factory "town hall" meetings to celebrate employees' achievements and foster the friendly competition.

5.4 Lean implementation and factory-level operational performance

Finally, our evidence suggests that more extensive lean implementation relates positively to changes in factory-level operational performance. This is hardly surprising considering the large amount of literature that document a positive relation between the implementation of lean and performance improvement (Mackelprang and Nair, 2010; Nair, 2006). Our factory visits provided additional qualitative support for this conclusion. Factory managers on all continents credited improvements in operational performance to the implementation of the lean program. During our factory visits we were presented numerous charts showing positive improvements in key performance indicators as a result of the factory's lean implementations. Some illustrative and repeated messages among the factories were: "Without the lean program, we would never be as good as we are today" (Lean Program Manager), and "I can assure you, the excellent results we now get is a result of our lean implementation" (Plant President).

6. CONCLUSIONS

This study finds a favorable relation between three management control practices and lean implementation: the use of dedicated implementation teams (e.g., organizing a small team of lean experts who assist the implementation), the development of lean-focused performance reporting processes (e.g., daily progress meetings on the shop-floor, encouraging visual displays of operational and financial performance), and the use of nonfinancial rewards (e.g., celebrating employees' achievements in factory "town hall" meetings). We do not find convincing evidence that two other management control practices—frequent management-initiated internal audits of the results of lean implementation and the use of financial rewards tied to implementation—relate to lean implementation. Finally, the study provides additional empirical support for the positive relation between lean implementation and operational performance using unique factory-level data collected from a large multinational implementing lean in its globally dispersed plant network.

6.1 Limitations and further research

A limitation of this study is that our data comes from a single firm, which gives rise to our small sample size. Our strong evidence regarding dedicated teams, performance reporting, and nonfinancial rewards suggests that the lack of evidence regarding internal audits and financial rewards likely relates to their comparatively weaker relation to lean implementation rather than simply low power tests. An advantage of working with a single firm is that it facilitates the collection of detailed data. We had access to detailed history in the firm, as well as the opportunity to visit many plants and hold direct discussions with key personnel. These conditions would be difficult to match in multi-firm studies using empirical data. Moreover, using data from a single firm holds many potentially confounding factors nearly constant (e.g., organizational culture, strategies, markets, etc.). Future empirical research could provide cross-company comparisons.

Our study does not consider all possible management control practices that could support lean implementation. One control practice of particular interest for future research would be to explore how employee selection affects the on-going success of lean. Theories from the management control and organizational behavior literatures predict that when it is difficult to align incentives by contracting on output, aligning preferences via inputs such as employee selection might facilitate strategy implementation. Future research could make progress by examining whether employees hired after a lean program begins respond differently to the lean effort compared with existing employees.

Lastly, future studies could investigate whether the effectiveness of management control practices vary at different stages of lean implementation. For instance, are dedicated teams more effective at the early stages of implementation than they are at later stages? Are financial rewards more effective at the later stages of implementation than they are at earlier stages? These are just a few examples of a rich set of research questions, for both scholars and practitioners, which need answers.

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APPENDIX A
Description of the Corporate Lean Program

We investigate the implementation of a global corporate lean program (hereafter, "lean" or "lean program") in the large firm of Global Equipment Manufacturer (GEM). This appendix provides a more detailed discussion of the assessment process than is presented in the main body of our study. In addition, Table A-1 documents three examples of the 103 elements, each of which is part of a different module and principle. The complete details of the assessment process are proprietary.

The lean program is a formal and standardized assessment process usually based on five principles: just-in-time (JIT), total quality management (TQM), total productive maintenance (TPM), human resource management (HRM), and continuous improvement (CI). Each principle contains three to five "modules," and each module has two to seven "elements," a total of 103 elements. A factory's Lean Assessment Score is an equally weighted sum of the extent to which an element has been implemented. For each of the 103 elements, GEM has defined five stages of implementation: 1 ("Basic"), 2 ("Structured"), 3 ("Improving), 4 ("Best-in-Industry"), and 5 ("World-Class"). Note that a factory will receive a score of zero if it has not reached the "Basic" level on an element. To achieve a high maturity stage, a factory must also qualify for all previous stages (i.e., a factory cannot jump a stage). Elements are scored according to scales similar to those shown in Table A-1. These scores are then aggregated by modules, which in turn are aggregated according to principle. Principle scores are aggregated into a Lean Assessment Score for the factory, which GEM considers the extent of lean implementation at the factory.

TABLE A-1
Three examples of the Lean Assessment Process

P*	M*	E*	1. Basic*	2. Structured	3. Improving	4. Best in industry	5. World Class
Just In Time	**Continuous Flow**	**Setup time/ cost**	Setup time/cost is known in the pilot area, and a formalized way of working with setup time/cost reduction is used, e.g., SMED.	Setup time/cost reduction is Continuously carried out at Bottleneck operations/costly Changeover equipment.	Setup reduction is continuously carried out at all operations AND setup time reductions are used to reduce batch sizes and not only raising overall utilization.	Single digit minute exchange of all dies.	Setup time/cost is insignificant, with one touch exchange of all dies where appropriate.
Continuous improvement	**Prioritization**	**Value Stream Maps (VSM)**	Value stream maps (VSMs) are used to highlight waste and prioritize improvement actions. The factory can demonstrate at least one complete cycle of use.	VSMs have been used for door-to-door factory (end-to-end) flow for at least one product family.	VSM is used on all product families (all areas) to understand the flow of material and information and associated wastes.	As Stage 1 for administrate /non-operational processes or extended VSMs for e.g. sale-to-cash process.	VSM is frequently used as in Stage 3 and Stage 4.
Total productive maintenance	**Workplace organization**	**5 steps (5S)**	5S implemented to *Sustain* level (5th S), in at least one pilot area.	5S implemented to *Sustain* level (5th S), in key areas defined by the factory.	5S is established in all applicable areas of the shop floor, warehouse and in the areas on the outside of the factory.	All areas of the facility have deployed 5S, including shop floor, and all support functions.	(...) 5S is totally engrained within the culture of the company, whilst still maintaining the highest execution in all areas.

* Note: if the factory has not reached the Basic level, it is scored 0 (zero).

The table provides three examples of the Lean Assessment Process. P*, M*, and E* refer to "principles," "modules," and "elements," respectively. Each principle contains three to five "modules," and each module has two to seven "elements," a total of 103 elements. For each element, GEM has defined and described five maturity stages: 1 ("Basic"), 2 ("Structured"), 3 ("Improving), 4 ("Best-in-Industry"), and 5 ("World-Class").

APPENDIX B
Variables

TABLE B-1
Variable Definitions

Variable Name	Data source	Description
Dedicated Teams	Survey	The factory has an organized team of dedicated employees who lead and support the implementation of lean.
Performance Reporting	Survey	Performance charts with performance indicators are regularly posted at the shop-floor areas. + Top-management routinely asks for performance reports of the lean implementation progress.
Internal Audits	Survey	Internal lean audits, aside from the GEM Lean Assessment Audit, are regularly undertaken to follow up lean implementation in this factory.
Financial Rewards	Survey	Personnel are regularly rewarded with financial remuneration based on operational improvements tied to lean implementation in this factory.
Nonfinancial Rewards	Survey	Personnel and teams are regularly rewarded with praise or nonfinancial benefits based on operational improvement tied to lean implementation in this factory.
Lean Implementation	GEM Lean Implementation Audit	The extent of implementation of the five GEM lean principles—JIT, TQM, CI, TPM, HRM (see Appendix A for details).
Operational Performance	Survey	Over the last two years, how has the performance of this factory changed along the following measures? • On-time delivery to customers • Throughput time (production lead-time) • Inventory turns in factory • Productivity of machines and labor • Percentage of first-time-through good quality products • Customer satisfaction

TABLE 1
Corporate Lean Program Principles and Descriptive Statistics

No.	Principle	Modules	Cronbach's Alpha	Mean	Std. Dev.	Min	Max
1	JIT	• Flexible manpower • Pull system • Takt time • Continuous flow • Material supply	0.910	1.89	0.82	0.68	3.97
2	TQM	• Zero defects • Quality assurance • Product and process quality planning	0.867	1.74	0.85	0.27	3.28
3	CI	• Prioritization • Problem solving methods • Improvement organization • Improvement approach	0.918	1.92	0.93	0.35	3.58
4	TPM	• Standardized work • Production leveling • Maintenance system • Workplace organization	0.862	1.80	0.82	0.30	3.53
5	HRM	• Goal oriented teams • Cross functional work • Organizational design	0.827	1.98	0.81	0.46	3.54

The table presents definitions of the principles GEM uses to evaluate the implementation of the lean from 2009 through 2013 and descriptive statistics for each principle. Each principle contains three to five "modules." GEM has defined and described five maturity stages: 1 ("Basic"), 2 ("Structured"), 3 ("Improving), 4 ("Best-in-Industry"), and 5 ("World-Class"). See Appendix A for additional description of the assessment process. The assessment scores can range from zero to five (a factory is assigned zero if it does not reach the requirements for "Basic" in a module).

TABLE 2
Descriptive Statistics for Selected Variables

Variable Name	N	Mean	Standard Deviation	Min	Max
Dedicated Teams	36	3.86	0.81	1.89	5.00
Performance Reporting	36	3.30	0.95	1.62	4.67
Internal Audits	36	3.04	0.86	1.29	4.50
Financial Rewards	36	1.68	0.69	1.00	3.55
Nonfinancial Rewards	36	2.78	0.99	1.17	5.00
Operational Performance	36	4.16	0.43	3.00	4.80
Size	36	6.59	0.87	4.38	7.88
Union	36	0.78	0.42	0.00	1.00
Product Type	36	0.38	0.49	0.00	1.00

This table reports descriptive statistics for the variables used in our analysis of management control practices, lean implementation, and factory operational performance. Dedicated Teams, Performance Reporting, Internal Audits, Financial Rewards, and Nonfinancial Rewards are measured using a five-point Likert scale from 1 (“Never Used”) to 5 (“Very Frequently Used”). Operational Performance is measure using a five-point Likert scale from 1 (“Substantially Declined”) to 5 (“Substantially Improved”). Please see Appendix B for complete variable definitions.

TABLE 3
Correlations among Selected Variables

	Dedicated Teams	Performance Reporting	Internal Audits	Financial Rewards	Nonfinancial Rewards	Lean Implementation
Performance Reporting	0.73***					
Internal Audits	0.64***	0.72***				
Financial Rewards	0.35*	0.42**	0.39*			
Nonfinancial Rewards	0.59***	0.71***	0.82***	0.36*		
Lean Implementation	0.73***	0.68***	0.64***	0.73***	0.48***	
Operational Performance	0.38*	0.28	0.68***	0.53***	0.27	0.42**

This table reports correlations among selected variables used in our analysis of management control practices, lean implementation, and factory operational performance. Please see Appendix B for complete variable definitions. *** = $p<0.001$, ** = $p<0.01$, * = $p<0.05$, and ^ = $p<0.10$, two-tailed tests of statistical significance.

TABLE 4
Management Control Practices, Lean Implementation and Factory Operational Performance

First stage regression model:

$$\textit{Lean Implementation} = \alpha_0 + \alpha_1\textit{Dedicated Teams} + \alpha_2\textit{Performance Reporting} + \alpha_3\textit{Internal Audits} + \alpha_4\textit{Financial Rewards} + \alpha_5\textit{Nonfinancial Rewards} + \alpha_6\textit{Factory Size} + \alpha_7\textit{Product Type} + \alpha_8\textit{Union} + \varepsilon$$

Second stage regression model:

$$\textit{Operational Performance} = \beta_0 + \beta_1\textit{Lean Implementation} + \beta_2\textit{Factory Size} + \beta_3\textit{Product Type} + \beta_4\textit{Union} + \varepsilon$$

		Two-stage Least Squares		**Bootstrap Standard Errors**	
	Predicted Sign	**Lean Implementation**	**Operational Performance**	**Lean Implementation (50 replications)**	**Lean Implementation (200 replications)**
Lean Implementation	+	-	0.246** (0.104)	-	-
Dedicated Teams	+	0.245* (0.118)	-	0.245* (0.124)	0.245^ (0.129)
Performance Reporting	+	0.272** (0.108)	-	0.272* (0.138)	0.272* (0.126)
Internal Audits	+	0.188 (0.159)	-	0.188 (0.182)	0.188 (0.178)
Financial Rewards	+	0.137 (0.156)	-	0.137 (0.156)	0.137 (0.187)
Nonfinancial Rewards	+	0.333** (0.115)	-	0.333** (0.110)	0.333** (0.138)
Factory Size	NA	0.149^ (0.080)	-0.095 (0.065)	0.149^ (0.086)	0.149^ (0.088)
Product Type	NA	0.078 (0.157)	0.153 (0.123)	0.078 (0.157)	0.078 (0.155)
Union	NA	0.154 (0.179)	-0.241* (0.112)	0.154 (0.185)	0.154 (0.188)
Intercept		-1.681*** (0.462)	4.472*** (0.388)	-1.681** (0.503)	-1.681*** (0.462)
Adjusted R-squared		0.75	0.26	0.75	0.75

This table reports evidence on the relation between management control practices, lean implementation, and factory-level operational performance. *Lean Implementation* is the extent of implementation of the five GEM lean principles—JIT, TQM, CI, TPM, HRM—obtained from the GEM Lean Implementation Audit (see Appendix A for details). *Operational Performance* represents a factory's assessment across six performance attributes. Please see Appendix B for complete variable definitions. Columns 3 and 4 report the results of a two-stage least squares regression. Columns 5 and 6 report results from estimation of the first stage regression model using ordinary least squares regressions with bootstrapped standard errors using 50 replications and 200 replications, respectively. Standard errors in parentheses are adjusted for heteroskadasticity (columns 3 and 4 only). *** = p<0.001, ** = p<0.01, * = p<0.05, and ^ = p<0.10, two-tailed tests of statistical significance.

TABLE 5
Robustness of Management Control Practices, Lean Implementation and Factory Operational Performance

Panel A: Alternative Measure of Lean Implementation

First stage regression model:

Lean Factor = α_0 + α_1*Dedicated Teams* + α_2*Performance Reporting* + α_3*Internal Audits* + α_4*Financial Rewards* + α_5*Nonfinancial Rewards* + α_6*Factory Size* + α_7*Product Type* + α_8*Union* + ε

Second stage regression model:

Operational Performance = β_0 + β_1*Lean Factor* + β_2*Factory Size* + β_3*Product Type* + β_4*Union* + $\varepsilon_{i,t}$

		Two-stage Least Squares		Bootstrap Standard Errors	
	Predicted Sign	**Lean Factor**	**Operational Performance**	**Lean Factor (50 replications)**	**Lean Factor (200 replications)**
Lean Factor	+	-	0.192* (0.078)	-	-
Dedicated Teams	+	0.313* (0.152)	-	0.313* (0.159)	0.313^ (0.181)
Performance Reporting	+	0.341* (0.142)	-	0.341* (0.169)	0.341* (0.167)
Internal Audits	+	0.238 (0.204)	-	0.238 (0.239)	0.238 (0.227)
Financial Rewards	+	0.182 (0.205)	-	0.182 (0.203)	0.182 (0.242)
Nonfinancial Rewards	+	0.457*** (0.139)	-	0.457*** (0.135)	0.457** (0.170)
Factory Size	NA	0.211* (0.102)	-0.099 (0.064)	0.211^ (0.114)	0.211^ (0.116)
Product Type	NA	0.152 (0.199)	0.145 (0.125)	0.152 (0.201)	0.152 (0.202)
Union	NA	0.293 (0.218)	-0.254* (0.108)	0.293 (0.225)	0.293 (0.235)
Intercept		-4.775*** (0.563)	4.954*** (0.461)	-4.775*** (0.636)	-4.775*** (0.702)
Adjusted R-squared		0.76	0.27	0.76	0.76

Panel B: Alternative Measure of Lean Implementation and Operational Performance

First stage regression model:

$$\textit{Lean Factor} = \alpha_0 + \alpha_1 \textit{Dedicated Teams} + \alpha_2 \textit{Performance Reporting} + \alpha_3 \textit{Internal Audits} + \alpha_4 \textit{Financial Rewards} + \alpha_5 \textit{Nonfinancial Rewards} + \alpha_6 \textit{Factory Size} + \alpha_7 \textit{Product Type} + \alpha_8 \textit{Union} + \varepsilon$$

Second stage regression model:

$$\textit{Operational Factor} = \beta_0 + \beta_1 \textit{Lean Factor} + \beta_2 \textit{Factory Size} + \beta_3 \textit{Product Type} + \beta_4 \textit{Union} + \varepsilon$$

		Two-stage Least Squares	
	Predicted Sign	**Lean Factor**	**Operational Factor**
Lean Factor	+	-	0.403* (0.167)
Dedicated Teams	+	0.313* (0.152)	-
Performance Reporting	+	0.341* (0.142)	-
Internal Audits	+	0.238 (0.204)	-
Financial Rewards	+	0.182 (0.205)	-
Nonfinancial Rewards	+	0.457*** (0.139)	-
Factory Size	NA	0.211* (0.102)	-0.235^ (0.140)
Product Type	NA	0.152 (0.199)	0.282 (0.268)
Union	NA	0.293 (0.218)	-0.599** (0.244)
Intercept		-4.775*** (0.563)	1.888^ (1.010)
Adjusted R-squared		0.76	0.27

This table reports evidence on the relation between management control practices, lean implementation, and factory-level operational performance. Panel A reports results using *Lean Factor*, which is defined using factor analysis of the five GEM lean principles—JIT, TQM, CI, TPM, HRM—obtained from the GEM Lean Implementation Audit (see Appendix A for details). Columns 3 and 4 report the results of a two-stage least squares regression. Columns 5 and 6 report results from estimation of the first stage regression model using ordinary least squares regressions with bootstrapped standard errors using 50 replications and 200 replications, respectively. Panel B reports results using *Lean Factor* and *Operational Factor*, which is defined using factor analysis of a factory's assessment across six performance attributes. Columns 3 and 4 report the results of a two-stage least squares regression. Please see Appendix B for complete variable definitions. Standard errors in parentheses are adjusted for heteroskadasticity. *** = $p<0.001$, ** = $p<0.01$, * = $p<0.05$, and ^ = $p<0.10$, two-tailed tests of statistical significance.