OHSAS 18001 Certification and Operating Performance: The Role of Complexity and Coupling

Abstract

Manufacturing firms are under pressure, from multiple stakeholders, to manage occupational health and safety issues properly, systematically and transparently. While manufacturing firms commonly use internally developed Occupational Health and Safety Management Systems, there is growing pressure to adopt externally certified systems such as the OHSAS 18001. However, there are conflicting views and little empirical evidence of linkages between OHSAS 18001 certification and operating performance seems to have been presented in extant literature. Hence, this paper examines the impact of OHSAS 18001 on operational performance through three theoretical lenses: Institutional Theory, Normal Accident Theory and High Reliability Theory. We also investigate how complexity and coupling moderate the relationship between OHSAS 18001 and operational performance. Based on a sample of 211 U.S. listed manufacturing firms with OHSAS 18001 certification, we find that certification leads to significant increase in abnormal performance on safety, sales growth, labor productivity and profitability and these gains increase as complexity and coupling increase.

Keywords: OHSAS 18001, event study, occupational health and safety, contextual factors

1. Introduction

Manufacturing firms are under increasing pressure from multiple stakeholders to manage Occupational Health and Safety (OHS) issues systematically and improve workplace conditions. For instance, multinationals such as Apple, Cisco and Tata Motors now request that their suppliers obtain Occupational Health and Safety Management System (OHSMS) certification to ensure OHS issues are managed systematically and transparently. Occupational Health and Safety Assessment Series 18001 (OHSAS) is the favored certification system and holders have to be audited by an independent organization. OHSAS certification appears to be following the dissemination pattern of ISO 9001 and then 14001, suggesting that in a fairly short period of time this certification could become the norm.

Brown (1996) and Pagell et al. (2013) both suggest that safety needs to be treated as a key operational priority alongside cost, quality, flexibility, delivery and innovation. Besides some large customers, governments and citizens also expect it in most countries. Safety is a legal and moral expectation that must be met by an organization to maintain its license to operate. Poor safety performance is indicative of an organization that is not meeting the expectations of customers, regulators and other stakeholders. Most safety related incidents occur in operational settings and, therefore poor safety performance is indicative of poorly managed operations; safety is an operational priority.

Operational workers are the ones who suffer the majority of illnesses caused by occupational hazards and accidents in manufacturing settings. Manufacturing sector provides about 9 percent of employment in the United States but it accounts for about 30% of occupational accidents and illness cases (Bureau of Labor Statistics, 2013). However, OHS issues have received little attention in operations management literature (Brown, 1996; de Koster et al., 2011; Pagell et al., 2013). Instead the safety of operational workers is mostly studied in a variety of other academic fields, such as occupational medicine and ergonomics.

An operational perspective of safety is limited and implications of both the safety of operational workers and other operational performance outcomes are relatively less known (for a full discussion see Das et al., 2008 or Pagell et al., 2013). Worse, the literature provides divergent views on how safety is related to other operational priorities and outcomes such as cost and quality.

This paper takes a theory-driven approach to increase our understanding of the operational priority of safety by examining the impact of OHSMS certification (OHSAS 18001) on operational performance outcomes. Specifically, this research asks *what is the general impact of OHSAS 18001 certification on operational performance*. Additionally, because context has been shown to influence operational performance in general as well as the impact of other certifications (Nawrocka et al., 2009; Lo et al., 2013) this research also asks *what is the role of context in the OHSAS 18001 and operational performance relationship*.

Four dimensions of operational performance that OHSAS can impact are explored: safety, sales, labor productivity and profitability. We examine safety since this is what OHSAS certification is intended to improve. Sales angle is also examined because certification is being driven by customers and could impact sales. We examine labor productivity because it is a good proxy for operating effectiveness (e.g., Levine and Toffel, 2010) and because improvements in safety are likely related to labor productivity. We examine profitability, measured as ROA, because ROA is an efficiency based metrics of profits that is reflective of overall operational effectiveness (e.g., Corbett et al., 2005; Swink and Jacobs, 2012). The term financial performance refers to the more traditional indicators of operational performance (profitability, sales, and labor productivity) and safety refers to the worker well being component of operational performance.

The research questions are addressed via a longitudinal analysis of the long-term impact of certification on operational performance. Answering these questions contributes to operations management practice and theory. The results provide managers a clearer understanding of how OHSAS certification implies a safe production system and how that influences other operational performance outcomes such as productivity and profitability. This insight also makes it easier for operational managers to respond to external demands, be they from customers, regulators or other stakeholders, to show they are managing or improving operational workers. The results also make contributions to our understanding of theory by empirically testing the conflicting predictions about changes in operational performance that emerge from institutional theory, normal accident theory (NAT) and high reliability theory (HRT).

2. Theoretical development and hypotheses

OHSAS 18001 is the most popular externally certified OHSMS (Fernández-Muñiz et al., 2012). Since the certification was introduced in 1999, it has diffused rapidly, growing from 8399 certifications in 2003 to 56,251 in 2009 (a compound annual growth rate of 37.46%) (OHSAS Project Group, 2011). Over the same period ISO 14000 certifications grew from 64,996 to 222,974 (and now are at 267,457) and ISO 9000 certifications exceeded a million (International Organization for Standardization, 2012). So whilst OHSAS 18001 is growing rapidly and could eventually become the de-facto safety standard, at present it has found relatively limited acceptance compared to other certifications such as ISO 9001.

OHSAS 18001 certifies that a firm's OHSMS can develop and maintain a safe workplace, protecting workers from accidents and illness (British Standards Institution, 2012). Certification requires firms to identify hazards, assess safety risks and establish and measure safety controls to continuously enhance safety performance (Fernández-Muñiz et al., 2012).

OHSAS 18001 is thus similar to other externally certified management systems such as ISO 9001 and 14001, both of which have been linked to improved firm operational performance (Corbett et al., 2005; Lo et al., 2012).

Despite these similarities, OHSAS 18001 differs from other external certifications and can influence operational performance differently. ISO 9001 and 14001 certifications were often driven by customer demand to create management and quality control systems in firms where few existed. However, most firms do have an OHSMS and many have been actively managing safety for decades, both because of their values and because safety regulation has existed in the United States since the 1930's. OHSAS 18001 then generally augments or replaces existing, and often effective, systems. Equally important is that while ISO 9001 clearly benefited customers directly and ISO 14001 is linked to resource efficiency, extant literature apparently lacks a business case for safety (see Pagell et al., 2013) in general and safety certification in particular.

Three different theoretical perspectives can be used to predict the relationship between OHSAS certification and operational performance. The institutional theory suggests that firms get certified mainly to gain legitimacy, with limited impact on operational performance. NAT (FULL FORM?] and the concept of role overload suggest that firms sacrifice safety for other operational performance outcomes and HRT and the human capital perspective suggest that certification improves all operational performance outcomes.

2.1. Institutional theory

From an institutional perspective, OHSAS certification may help firms to signal legitimacy to major customers (Staw and Epstein, 2000; Suchman, 1995). Previous research shows that ISO 9001 and 14001 were both adopted partially for legitimisation reasons (Boiral, 2007; Qi et al., 2011) and hence it is likely that OHSAS certification will also have a similar effect. OHSAS 18001 is expected to be interpreted as a signal of a firm's commitment to health and safety management. Given the increasing demands for organizations to at least appear to be doing something about health and safety, this could be a powerful driver for certification.

If this perspective is correct, OHSAS certification should improve the firm's sales performance as certification may meet customer's safety requirements (Law et al., 2006). However, if the only benefit from certification is the ability to signal safety, then all other components of operational performance would remain unchanged after certification. Based on this perspective, the process of certification would not alter production processes or the production system's reliability. The primary benefit of certification would be increased sales, once certification is granted.

2.2. Normal accident theory: Coupling leads to role overload

Normal Accident Theory (Perrow, 1981; 1984) proposes that accidents are inevitable in complex and tightly coupled systems, regardless of efforts to control them. A system's complexity is driven by the level of variability in interactions, the number of multi-functional processes or jobs, the level of specialization of tasks that can limit awareness of interdependencies and the need to deal with the unfamiliar or the unintended (Perrow, 1984; Shrivastava et al., 2009). A system is viewed as tightly coupled if there is minimal slack between steps, processes can be executed in only one sequence and substitution of labor, supplies and processes is difficult if not impossible and work can only be done in one way (Perrow, 1984; Shrivastava et al., 2009).

Shrivastava et al. (2009) noted that all systems that transform raw materials are relatively complex and tightly coupled. Hence, NAT predicts that in manufacturing organizations accidents are inevitable and the risk of an accident increases as complexity increases or coupling becomes tighter (Wolf, 2001). NAT also suggests that tighter work rules (e.g., standard operating procedures) in tightly coupled environments do not necessarily lower the risk of an accident because unpredictable situations that the rules were not designed for can result in serious consequences (Rijpma, 1997).

The predictions from NAT are in line with conclusions from numerous researchers who have proposed that there is a trade-off between safety and other operational outcomes such as quality or productivity (e.g., Brenner et al., 2004; Ford and Tetrick, 2008; Godard, 2004; Landsbergis et al., 1999; Lewchuck et al., 2001; Parker, 2003; Pate-Cornell and Murphy, 1996; Zohar, 2002; Zohar and Luria, 2005). Safety and other operational priorities are likely to be in conflict because operational workers often feel pressure to take shortcuts that endanger safety to meet production quotas or even to protect their jobs (e.g., Brown, 1996; Brown et al., 2000; McLain, 1995; Barling et al., 2002; de Koster et al., 2011).

From an operational perspective slack resources are often indicative of waste and hence many operational best practices such as lean are focused on removing slack. However, from the perspective of operational workers reductions in slack mean less time to do tasks, creating "role overload" (e.g., McLain, 1995). As production systems become more efficient there is less time for workers to complete their tasks and workers feel pressured to take shortcuts. Slack resources are a critical way to decrease coupling (Wolf, 2001), reducing slack increases coupling. The theoretical explanation for the trade-off perspective is that operational improvements increase coupling, creating role overload which leads to increase in accidents.

Similar logic applies for improving safety. Improving safety takes organizational resources and requires operational workers to spend time on safety, besides production. If this perspective is correct then *if* OHSAS certification leads to improved safety, it must do so at the cost of other operational performance outcomes. Specifically, workers become less productive which then leads to decrease in profits. However, sales are not likely to change since an organization gains some customers who are willing to pay higher price for good safety and lose some who are not. Based on this perspective, organizations pursuing certification see trade-offs between safety and productivity from the moment they begin to pursue certification and these trade-offs continue through and beyond certification.

2.3. High reliability theory and the human capital perspective

The argument that safety is in conflict with other operational performance outcomes is compelling and finds support in both the safety (e.g., Zohar, 2000) and operations literature (e.g., de Koster et al., 2011), but is generally untested. There is an equally compelling perspective in the literature based on the human capital perspective and HRT.

The operations management community has generally concluded that continuous improvement based management systems are the best practice and that they require well-trained and empowered workers. To optimize the production system, human capital needs to be valued and leveraged. Workers who are not safe are not valued and cannot be leveraged.

The human capital perspective fits well with the predictions of HRT which posits that accidents are preventable in highly reliable organizations. These organizations are described as “mindful”, meaning that they make safety a strategic priority, pay careful attention to design and processes, have mechanisms for valuing human capital and have a safety culture (Reason, 1998; Weick et al., 1999). Critically HRT suggests that high reliability benefits *all* operational performance outcomes, not just safety (e.g., Weick et al., 1999); highly reliable organizations can prevent accidents and other failures such as quality defects or late deliveries.

The benefits of high reliability extend beyond safety for numerous reasons. First, in highly reliable organizations workers can believe that the management is taking care of safety, which allows them to focus on their tasks not related to self-protection (Colquit et al., 2011).

A safer working environment fulfills the workers' basic safety needs, allowing the workers to pursue operational goals (Das et al., 2008).

Second, control of processes is fundamental to HRT. Numerous authors (e.g., Shrivistava et al., 2009; Farjoun, 2010) have noted that as complexity and coupling increase the need for control increases, because of the potential for catastrophic failures. Control of transformation processes is also a fundamental component of safety and operations management and increased control of processes means less variance and reduction in non-productive tasks such as rework.

Finally, workplace injuries and illnesses have direct and indirect costs. The direct costs include workers compensation, medical treatment (Loeppke et al., 2007) and insurance premiums (Starr and Whipple, 1984). The indirect costs include overtime wages, labor turnover, new employee training, lost working days (Oxenburgh and Marlow, 2005) and reputational damage (de Koster et al., 2011). Previous studies have highlighted that an OHSMS can be an effective tool to reduce accidents and illnesses among workers leading to lower absenteeism and labor turnover and a general reduction in these costs (e.g., de Koster et al., 2011; Loeppke et al., 2007). From this it can be concluded that improved safety performance should improve a firm's profitability (Robson et al., 2007).

HRT can then explain the literature that suggests that safety and other operational outcomes move in tandem. When a system is safe, i.e. workers trust the management and can focus on their jobs, the production system should be in control, which is a critical condition for outcomes such as quality and costs too are reduced.

This set of predictions can apply to all effective OHSMS, not just OHSAS certification. If all OHSMS improve reliability, then the institutional perspective's prediction that certification is mainly a way to signal should be supported. However, the literature on certification suggests that external certifications have added benefits over internal systems, including an increased awareness of processes, more measurement and control, less room for backsliding since an external assessor must be satisfied on a regular basis and increased training and participation of workers (e.g., Curkovic and Pagell, 1999; Sroufe and Curkovic, 2008).

OHSAS 18001, when properly implemented, inculcates many of the attributes of a high reliability organization and, on average, improves all operational outcomes not just safety. If OHSAS certification is not purely ceremonial then it can provide benefits beyond an internally developed OHSMS. Based on this perspective, organizations pursuing certification can see improvements in at least productivity and safety from the moment they begin to pursue certification and these benefits continue through and beyond certification, leading to improved sales and profits.

Based on the discussion above, we propose:

H1: There is a significant relationship between OHSAS certification and safety performance.

The institutional theory predicts that certification leads to increased sales but does not impact ROA or productivity. NAT predicts that if certification does improve safety then productivity and ROA should decrease, while HRT suggests that improvements in safety occur due to certification with simultaneous improvements in other operational performance outcomes. Following the same logic as in H1, certification is likely not purely ceremonial and should have significant impact on all elements of operational performance, though the direction of the effects is unknown. Table 1 summarizes the predictions each theory makes for each dimension of operational performance.

H2: There is a significant relationship between OHSAS certification and sales growth.

H3: There is a significant relationship between OHSAS certification and labor productivity.

H4: There is a significant relationship between OHSAS certification and ROA.

[Table 1 is about here]

2.4. Contextual factors and the effectiveness of OHSAS 18001 certification

If OHSAS certification is more than a signaling device, then institutional explanations are insufficient to explain the OHSAS certification operational performance relationship. However, both NAT and HRT based explanations can still be useful in predicting the role of context in the certification / performance relationship.

We follow much of the extant literature and present NAT and HRT as competing theories (Wolf, 2001; Rijpima, 2003; Shrivastava et al., 2009). Yet Shrivastava et al. (2009) proposed that once one accounts for "time" the two theories can be complimentary: organizations that are not constantly mindful will over time *drift* (Snook, 2000) from reliable behavior into behaviors that lead to accidents. This means an organization can stay highly reliable as long as it maintains mindfulness and does not drift away from the prescribed behaviors. Maintaining high reliability is however difficult because drift or entropy are typical outcomes in organizations.

Shrivastava et al. (2009) then developed the work of Leveson (2004) and Rasmussen (1997) to conclude *"the higher the ability to control transformation processes, the higher the level of safety in the workplace"* (pg. 1380). Shrivastava et al. (2009) built on both NAT and HRT to note that as complexity increases and coupling gets tighter the need for control increases because of the increased potential for harm. Shrivstava et al.'s (2009) synthesis of NAT and HRT suggests that as complexity increases and coupling becomes tighter the benefits of OHSAS certification increase. We use these syntheses to develop hypotheses for the second research question on the impact of context on the certification / operational performance relationship. Complexity is explored by examining R&D and labor intensity, while coupling is explored by looking at inventory levels and volatility.

Because the benefits of R&D investment take time to arrive (Ravenscraft and Scherer, 1982) and its influence on operations is ambiguous (Hoskisson and Johnson, 1992), R&D intensive firms often encounter uncertainties in meeting customer demands (Palmer and Wiseman, 1999). These uncertainties create complex circumstances for operations, for example, difficulty in scheduling (Prater et al., 2001). Furthermore, the production processes of R&D intensive firms are often technologically complex (Singh, 1997). If production is not outsourced, operational workers at these firms have higher exposure to hazardous circumstances because it is more difficult to take immediate corrective action in complicated processes. This complexity increases the risk of accidents and systems failures (Perrow, 1984; Singh, 1997). In such settings OHSAS 18001's potential to enhance control could be of increased benefit relative to firms with less complex production settings.

Similarly, when labor intensity increases, a firm's operations become more variable and complex (Swink and Jacobs, 2012). Labor intensive firms' production processes are often complicated and not automated and, therefore, these firms rely heavily on workers in their operations. Variability and complexity increase the likelihood of accidents (Perrow, 1984) and high labor intensity increases the potential impact of each of these accidents on the system. OHSAS 18001 helps continuously improve working conditions and leads to lower turnover, lower recruitment and training costs and improved labor productivity (de Koster et al., 2011; McLain, 1995). Additionally, OHSAS 18001 may allow a firm to recruit higher quality workers relative to non-adopters, because skilled workers have more power to bargain for better welfare and working conditions (Cahuc et al., 2006). These benefits are most useful to firms that are relatively labor intensive.

H5: As operational complexity (as measured by R&D and labor intensity) increases the benefit of OHSAS certification also increases.

NAT predicts that as coupling increases the risk of safety failures also increases (Perrow, 1984). One of the primary means of decoupling in a manufacturing setting is the use of inventory buffers for stochastic demand (Minner, 2001) so as to keep the supply chain running when disruptions occur. Inventory creates slack for the workers so that they do not have to react to every change in demand or problem in delivery, allowing them to do their jobs as planned and reducing the odds of *drift*. Inventory is then an indicator of coupling, with low levels of inventory being associated with high levels of coupling. As coupling increases (inventory decreases) the risk of failure increases and hence the value of OHSAS 18001 also increases.

The assumption that more inventory means looser coupling is premised on holding the correct inventory. Firms that are poor at tasks such as forecasting and planning may have the wrong inventory and may make more frequent set-ups, spend time set aside for maintenance on production, do more expediting and have to move more parts in and out of storage. Holding the wrong inventory, as evidenced by increased inventory volatility, is indicative of increased coupling. Figure 1 summarizes the relationships between certification and operational outcomes and the influence of context.

H6: As operational coupling increases (as measured by increased inventory volatility and decreased inventory level), the benefit of OHSAS certification also increases.

[Figure 1 is about here]

3. Methodology

This research used all U.S. listed manufacturing firms for sample (SIC 2000-3999). We collected financial data from Standard and Poor's COMPUSTAT database, industry characteristics data (e.g., labor working hours and wages) from the U.S. Census Bureau (2013) and safety violation data from U.S. Department of Labor.

There is no publicly available database that contains the full list of OHSAS 18001 certified firms. Therefore data regarding OHSAS certification was collected from three sources, companies' official websites, annual reports (from SEC filings) and media reports (from Factiva based on the keywords OHSAS, 18001, Occupational Health and Safety Management System and the company name). This was a multi-step process with built in redundancy. First, one member of the research team searched all three sources for announcements of certification for each of the 8477 listed manufacturing firms. Second, a different research team member verified identified announcements. Third, firms without an announcement were re-checked to ensure all the certified firms had been included in our sample. If we found no OHSAS certification information on a firm's website or in annual or media reports, the firm was considered a non-adopter. For adopters a clear certification date was needed for inclusion in the sample. This research follows the practice of previous certification literature (e.g., Corbett et al., 2005) by only focusing on the first OHSAS certification.

Out of the 8477 U.S. listed manufacturing firms (both active and inactive firms) 374 obtained at least one OHSAS certification between 1999 and 2011. Seventy-eight of the 374 were discarded from the analysis because there was no information on the year of the first certification. Additionally, 85 firms did not have financial data from the period of OHSAS certification (i.e., these firms obtained certification prior to listing on the stock exchange) and these were also discarded. Subsequently, 211 firms were used for the analysis.

Certification patterns in the sample followed the overall trend for OHSAS 18001. From 1999 to 2004, 71 firms (35.6% of the sample) obtained certification. Certification became more popular in more recent years (2005 – 2011) with 140 firms (64.4% of the sample) obtaining certification in this period. OHSAS certification in the sample is then more prevalent in recent years, but in the overall population there are still relatively few firms (especially when compared to ISO 9001 and 14,001) with certification. Proportion of firms obtaining OHSAS certification was the highest in the electronics industry (SIC: 36), with chemical products (SIC: 28) and industrial machinery manufacturing (SIC: 35) being second and third, respectively.

3.1. Event study approach for longitudinal analysis

To explore the causal relationship between OHSAS certification and operational performance, we used a long-horizon event study approach. Consequently, this research defines the event year (year 0) as the year when a firm first acquired OHSAS certification. Furthermore, the long-horizon event study approach requires us to define the base year of the event (i.e., the starting year of the event period), which is the year when the firm was free from the impact of implementing OHSAS 18001. On average it takes from 6 to 18 months to implement a management certification, prior to registration (Corbett et al., 2005; Lo et al., 2012). Thus, we define year -2 as the base year, which means that the firm has yet to start the implementation process. As we are interested in the long-term impact of OHSAS 18001, this research investigates abnormal performance changes over four years from the start of the certification process (Year -1, Year 0, Year 1 and Year 2).

We matched each sampled firm with a portfolio of comparable control firms. Following previous research (e.g., Hendricks et al., 2007), a separate portfolio was created for each firm for each of the financial performance indicators: sales, labor productivity and ROA. Each portfolio was based on three factors: industry, firm size and performance on that specific element of financial performance. Following Barber and Lyon (1996), two-digit SIC code was used to match for industry. To control for size we matched each sampled firm to control firms within 50 to 200% (a factor of 2) of the sample firm's total assets (Hendricks and

Singhal, 2008). For the specific element of financial performance control firms were those with 90% to 110% sample firm's pre-event performance (the firm's sales, labor productivity and ROA in year -2).

Creating a similar portfolio for safety would have been optimal but was not feasible because collecting safety data for all listed firms was beyond our resources. Therefore, the portfolio of control firms used for safety performance is the same portfolio as was used for ROA. ROA was chosen because sales and productivity should contribute to ROA and because ROA is the financial performance metric used in the cross sectional analysis.

On average, each sampled firm was matched with 28.25 control firms and 97.15% of the sample matched with 5 or more control firms. Following this matching process, we estimated the abnormal change in performance of the sample firms compared to the control group. The formula for calculating the abnormal performance is:

$$AP_{(t+j)} = PS_{(t+j)} - EP_{(t+j)}$$

$$EP_{(t+j)} = PS_{(t+i)} + (PC_{k(t+j)} - PC_{k(t+i)})$$

Where AP is the abnormal performance; PS is the actual performance; EP is the expected performance of the sample firms; PC is the median performance of control firms; t is the OHAS 18001 certification year; i is the base year (i = -2) and j is the ending year of comparison (j = -1, 0, 1 or 2). For the financial performance indicators, we use return-on-assets (ROA) as the measure of profitability, sales growth for sales performance and the ratio of operating income to number of employees for labor productivity. We follow previous research and use the number of violations of safety regulations as a proxy for safety performance (see for instance Pagell and Gobeli, 2009). We collected the violation data from the OHSA Integrated Management Information System (IMIS) database of the US Department of Labor (OSHA IMIS, 2013), which contains information on four types of violations: 1) normal, 2) repeated, 3) serious and 4) others. We followed previous practice (i.e., Pagell and Gobeli, 2009) and treated all violations as equal. Correcting for employment is the normal practice both by government agencies (Bureau of Labor Statistics, 2013) and researchers (Pagell and Gobeli, 2009) to make it clear how likely an employee is to suffer injury at work place. Our measure of safety performance is then a ratio of violations per every 10,000 employees in a given year.

Following Barber and Lyon (1996) and Corbett et al. (2005), we trimmed the datasets, eliminating outliers at each tail of the population of PL CHECK THIS each performance outcome. Furthermore, we conducted the Wilcoxon sign-rank (WSR) test and sign test to examine the abnormal performance. Following common practices (e.g., Hendricks and Singhal, 2008), we mainly discuss the results based on the WSR test, as this test is less influenced by outliers than the parametric *t*-test. However, to verify the result's robustness, we conducted additional parametric *t*-tests for mean values of abnormal performance.

3.2. Cross-sectional analysis of contextual factors

To test H5 and H6 both abnormal safety and abnormal ROA were used as dependent variables. We use abnormal ROA as the dependent variable for financial performance (instead of labor productivity and sales growth) in the cross-sectional analysis because it represents overall operational effectiveness. This is consistent with recent use of a similar approach (e.g., Swink and Jacobs, 2012). To be consistent and comparable to other studies using similar methodologies (e.g., Hendrick and Singhal, 2008), we use the OLS approach to test H5 and H6.

The OLS regression models are specified as follows:

$$AP_k = \beta_0 + \beta_1 (PP_k) + \beta_2 (FSize_k) + \beta_3 (Year_k) + \beta_4 (ISO\ 9001_k) + \beta_5 (ISO\ 14001_k) + \beta_6 (ISize_{kh}) + \beta_7 (Wage_{kh}) + \beta_8 (Union_{kh}) + \beta_9 (Hour_{kh}) + \beta_{10} (RD_k) + \beta_{11} (LI_k) + \beta_{12} (IV_k) + \beta_{13}(IL_k) + e_k$$

Where k refers to the k^{th} sample firm and h refers to the h^{th} industry that the k^{th} firm operates in.

The outcome variable AP_k is either abnormal ROA or abnormal safety performance. RD_k is the firm's R&D intensity, which is the ratio of R&D expense to total assets (Naveh and Marcus, 2005; Russo and Fouts, 1997). LI_k is a firm's labor intensity, which is the ratio of the number of employees to total assets of the firm (Dewenter and Malatesta, 2001). These two indicators are the independent variables for H5. IV_k is a firm's yearly inventory volatility, which is the ratio of the standard deviation of *the* firm's inventory by quarter and its mean quarterly inventory value in the year (Steinker and Hoberg, 2013). IL_k refers to the average inventory scaled by total assets. IV_k and IL_k are the independent variables for H6.

We control for several firm and industry level factors that can impact the sample firms' abnormal performance to ensure the rigorousness of the model. First, more profitable firms have more resources to achieve higher profitability in the future and, therefore, we controlled firms' ROA in Year -2 (PP_k). Second, we control for firm size because larger firms have more resources but may also have more difficulty coordinating employees when implementing OHSAS 18001 (Douglas and Fredendall, 2004). Firm size ($FSize_k$) is the natural logarithm of the number of employees employed by the firm in Year -2 (Kull and Wacker, 2010). Finally, the institutional theory suggests that the motivation for and outcomes of certification can be different for early and late adopters (Westphal et al., 1997; Zhu and Sarkis, 2007). Therefore, we control for the year of OHSAS 18001 certification ($Year_k$). The firm level variables are based on data for Year -2.

It is also possible that the sample firms have adopted an integrated management system which includes ISO 9001, ISO 14001 and OHSAS 18001. Therefore, we created two dummy variables that show whether the firm also received ISO 9001 or 14001 certification during the same period (Year -2 to Year +2). The dummy variables were coded 0 for firms without ISO 9001 / 14001 and 1 for firms with ISO 9001 / 14001.

Industry level control variables were also used in the model. First, we controlled for the size of sample firms' industry *h* ($ISize_{kh}$). There are various proxies for industry size, including industry output (Moomaw, 1988), number of firms (Weiss, 1963) and number of employees (Rushing, 1967). We used number of employees (Rushing, 1967) because our research focuses on workers and worker related outcomes. Second, we controlled for the average production worker's wages in the industry ($Wage_{kh}$), which is the normalized annual wage per production worker. We also controlled for the influence of labor unions in the industry ($Union_{kh}$). Production workers are more likely to be unionized in dangerous industries (Hirsch and Berger, 1983) and unionized workers can collectively bargain with employers to obtain higher risk premiums compared to non-unionized workers. Therefore, firms in industries with high levels of union influence face extra operations and administrative costs (Freeman and Medoff, 1981; Olson, 1981). We use the ratio of the number of workers covered by collective agreements to the total number of workers in industry as the labor union influence indicator. Finally, we use the industry average working-hours of production workers to control for the association between health and safety problems and long working hours ($Hour_{kh}$) (Spurgeon et al., 1997). All industry level control variables are based on data for Year -2.

4. Results

We compared the sample to the relevant industry segments and the control firms on the four operational performance indicators as well as the controls. We conducted paired-sample *t*-tests and the certified firms (0.089 violations per 10,000 employees) had significantly better safety performance compared to the industry two-years (Year -2) prior to certification (0.641 violations per 10,000 employees, $p < 0.001$). Not only was their propensity of violations lower than industry norms, this group also had less variance in violations, suggesting greater control of safety processes and safety outcomes prior to OHSAS certification. However, when compared with the matched control firms' safety performance, there is no significant difference, which indicates that using the ROA control for safety is not a concern. Prior to certification the sample and the matched control firms (based on ROA) had significantly better safety performance than the industrywide performance.

4.1. Results of the event study analysis

The cumulative abnormal performance analysis is presented in Table 2 and the year-to-year abnormal performance analysis is shown in Table 3. We followed conventions in event studies and used the largest sample available for each period and dependent variable (e.g., Corbett et al., 2005, Swink and Jacobs, 2012). The sample varies across tests for two reasons. The primary reason for different sample sizes is missing data. There may be some missing information on one or more of the performance outcome variables in any given period. This problem is more common for firms with more recent certifications (2010 and 2011) because the COMPUSTAT database may not contain Year 1 or Year 2 financial data for firms that were recently certified. The secondary reason for different sample sizes is survivor bias; firms that went out of business or were delisted after being certified in Year -2. Four firms in the sample were delisted over the event horizon. The results for each hypothesis remained the same after removing these 4 delisted firms. The results show the impact of OHSAS certification on all 4 dimensions of the sample firms' abnormal operational performance.

[Table 2 and Table 3 are about here]

The sample firms' abnormal safety performance (H1) was significantly better (based on the WSR tests) compared to the control firms in the implementation period (Year -2 to Year 0) at 1% [confidence?] level. OHSAS 18001 increased abnormal safety performance of the sampled firms even though they (and the controls) were performing better than the industry average prior to certification also. This eliminates the possibility that OHSAS certification was only a ceremonial action and provides support for H1.

H2 predicts that OHSAS certification has a significant impact on a firm's sales performance. The results in Table 2 indicate that the cumulative abnormal sales growth from Year -2 to Year 0 was not statistically significant, while the results from both Year 0 to Year 2 and Year -2 to Year 2 were statistically significant. For instance the median (mean) change from Year -2 to Year 2 was 1.95% (2.92%), which was significant at the 10% (5%) level. In this period 56.76% of the sample firms achieved positive abnormal change. Table 3 indicates significant abnormal sales growth in Year 0 to Year 1 but not in years prior to or after certification. In Year 0 to Year 1 the median (mean) change was 2.60% (3.63%), which was significant at the 5% (5%) level. In total 58.18% of the sample firms achieved positive abnormal change in this period. This result suggests that obtaining certification provides the firms opportunities to attract new customers. Consequently, these results indicate that OHSAS 18001 has a positive impact on sample firms' long run abnormal sales performance, providing support for H2.

H3 predicts that OHSAS certification has a significant impact on a firm's labor productivity. This hypothesis is based on actual changes in processes, not just signaling, so the improvement should occur in all periods. The cumulative abnormal labor productivity results in Table 2 are significantly positive in the pre-implementation period and the full event window (Year -2 to Year 0 and Year -2 to Year 2). For instance in the Year -2 to Year 2 period, the median (mean) change was 3.11 thousand (7.18 thousand), which was significant at the 5% (1%) level. In this period 58.74% of the sample firms achieved positive abnormal change. Table 3 shows that the sample firms had significant abnormal labor productivity in the year they started implementation of OHSAS 18001 (Year -2 to Year -1). The median (mean) abnormal increase was 1.58 thousand (2.04 thousand), which was significant at the 10% (5%) level. In this period 56.50% of the sample firms achieved positive abnormal change. Abnormal labor productivity continues to be significant in Year -1 to Year 0 and Year 0 to Year 1. These results suggest that OHSAS 18001 has a significant (and positive) impact on sample firms' long run abnormal labor productivity, supporting H3.

H4 predicts that OHSAS certification has a significant impact on a firm's profitability. Tables 2 and 3 show that the abnormal change of ROA was significantly positive during all year-to-year and up-to-date observation periods. For instance, in the period Year -2 to Year 2, the median (mean) abnormal ROA was 1.41% (1.68%), which was significant at the 1% (1%) level. In this period 58.94% of the sample firms achieved positive abnormal change. These results suggest that implementing OHSAS 18001 has a significant (and positive) impact on sample firms' long run abnormal profitability, supporting H4.

4.1.1. Endogeneity

It is possible that there were other factors affecting changes in operational performance that were not captured through the matching process. Therefore, we conducted additional tests to ensure the relationship between OHSAS 18001 and operational performance improvement is free from endogeneity issues. First, we performed *t*-tests on the sample and control firms' R&D intensity and labor intensity in Year -2. Results indicated no significant differences ($p > 0.1$). Subsequently, we conducted similar tests for all performance indicators in the Year -3 to Year -2 period using the same sample and control firms (see Table 4). With this test we examined whether the impact of OHSAS 18001 on abnormal performance during the event period (Year -2 to Year 2) was actually driven by earlier performance gains (Year -3 to Year -2). Table 4 indicates that there is no significant change in any of the performance indicators in Year -3 to Year -2 period. The performance changes appeared only after the firms started implementing OHSAS 18001 in Year -2. In conclusion, these tests suggest that the causal relationship is not due to a systemic bias in operational performance prior to pursuing OHSAS 18001. Therefore, we believe our sample selection is robust and free from endogeneity issues.

[Table 4 is about here]

4.2. Results of regression analysis

Table 5 shows the correlations between the variables in the regression analysis while Table 6 displays the regression analysis examining the contextual factors under which firms may benefit more from OHSAS 18001. The control models contain the firm and industry level controls, the complexity model includes the controls along with R&D intensity and labor intensity (H5) and the full model includes inventory volatility and inventory level (H6) along with all the other indicators. The results show that firms with higher R&D intensity and labor intensity achieve higher profitability and safety performance after OHSAS certification ($p < 0.05$). Thus, H5 is supported. The complexity variables improve the explanatory power of the abnormal ROA model by 3.1% (based on adjusted R-square) and the abnormal safety performance model by 18.5%.

Inventory volatility is a significant predictor of firms' abnormal ROA, while inventory level is not significant. On the contrary, inventory volatility is not a significant predictor of firms' abnormal safety performance, while inventory level is a significant predictor. These two variables improve the explanatory power of the abnormal ROA model by 3.4% and the abnormal safety performance model by 2%. Hypothesis 6 (coupling) is then supported, but the mechanism by which coupling is increasing (inventory level vs. volatility) determines the relationship with a specific DV.

[Table 5 and Table 6 are about here]

5. Discussion

This research examined the impact of OHSAS 18001 on multiple dimensions of abnormal operational performance, taking contextual factors into consideration. We find that OHSAS 18001 leads to significant increases in abnormal operational performance in terms of safety, sales, labor productivity and profitability. OHSAS certification leads to increased abnormal safety performance for the firms in the sample, even though they had above average safety performance, relative to their industry norm, prior to certification also. When compared to similar firms without certification, these firms also saw increased abnormal financial performance. The results unequivocally show that OHSAS 18001 certification increases both the financial and safety components of abnormal operational performance. These results have important implications for theory and practice.

5.1. Implications for theory

The literature provides three sets of predictions on the operational performance implications of OHSAS certification. Our results provide no support for the NAT based perspective, limited support for the institutional theory and significant support for the HRT based perspective.

The literature suggests that OHSAS 18001, like ISO 9001 and 14001 (e.g., Jiang and Bansal, 2003; Boiral, 2007; Martinez-Costa et al., 2008; Qi et al., 2011), functions mainly as a signaling device. Our results do provide limited evidence of signaling, with certifying firms seeing significant abnormal growth in sales after certification, even though these firms had above average safety performance in their respective industries prior to certification also. The abnormal PL CHECK THIS sales growth only occurs after certification, so improvements in internal processes during the implementation period are likely not driving sales or the increases would have accrued earlier (i.e. Year -1). The bulk of the direct abnormal increase in sales for this sample occurs mainly in the year after certification rather than continuing into the second year, which is also consistent with a signaling hypothesis. Obtaining the actual certification seems to be driving the increase in abnormal sales providing support to the proposition that firms use OHSAS certification as a signaling or legitimisation tool.

However, there are real and lasting increases in all other abnormal operational performance metrics; so institutional theory alone makes poor predictions for this sample. Our results do not allow us to fully discount institutional effects, but they seem to be a small component of why a firm should pursue certification. Studies of other certifications have found that some percentage of firms pursue ISO 9001 or 14001 mainly for institutional or marketing reasons (Boiral, 2007) but there are potentially real performance benefits from certification (e.g., Corbett et al., 2005). This study contributes to the overall certification literature by showing that legitimisation or signaling is generally a component in the behavior of organizations. However, certifications such as ISO 9001/14001 and OHSAS 18001 that are premised on developing production systems with mindful [???] (Weick et al., 1999) processes and cognitions can deliver significant increases in abnormal operational performance.

The results also inform the debate between researchers who posit that safety must be traded-off with other elements of operational performance (e.g., Zohar, 2002) and those who propose that safety and other dimensions of operational performance are complimentary to each other (e.g., Das et al., 2008). Unlike many previous tests (e.g., Das et al., 2008) this research explores the relationship between safety and other operational outcomes using longitudinal data. The results are clear; firms in this sample saw increases in abnormal safety performance that led to simultaneous and subsequent improvements in financial components of abnormal operational performance.

This does not mean that the observations made by authors such as Brown (1996) who noted that in some settings workers feel forced to take safety shortcuts to meet production quotas and or protect their jobs are wrong. Instead, these results are in line with recent theorizing (Shrivsstava et al., 2009; Farjoun, 2010) and results such as Pagell et al. (2013) which show that when firms have mindful [precautionary or something like that?] processes and cognitions they can create systems that ensure control and are reliable, allowing improvements in all operational performance outcomes relative to firms that do not have such systems.

The findings also have important implications for the use of NAT and HRT in operations management research. While our results do not support the proposition that firms make trade-offs between safety and other operational performance outcomes, the results for Hypotheses 5 and 6 do show that NAT can provide useful predictions. The results indicate that OHSAS 18001, while effective in all settings, is more effective in more complex or tightly coupled contexts. The firms that NAT suggests have the greatest risk of failure also earn the most benefits from certification.

These results align well with the syntheses of HRT and NAT. Our results suggest that complexity and coupling are useful in predicting when the increased control that certification facilitates will be most beneficial. NAT has previously been used to predict when safety failures are most likely to occur. We suggest that operations management researchers might be better served by using the coupling and complexity components of NAT to predict when and what types of operational controls would be most effective to reduce / prevent safety failures.

The proposition that increased control reduces safety failures, which is imbedded in HRT, should be familiar to operations management researchers. Our results also provide additional support to that argument. While we do not show that all future failures can be eliminated by certification, we do provide evidence that adopting many of the processes and cognitions associated with HRT can reduce the number of failures and increase operational effectiveness. These cognitions and processes are common to many certifications suggesting that these processes can form a core of best operational practices.

5.2. Implications for practice

The findings verify that OHSMS certification does not induce a trade-off between safety and financial performance. The empirical evidence provides a relevant reference for senior managers of manufacturing firms who are considering OHSAS certification, even in firms with effective internally generated safety management systems. Management can expect that certification will lead to increased abnormal operational performance, especially when the firm has complex or tightly coupled operations.

Not only does the study show that OHSAS 18001 certification has positive benefits for operational performance, the results also reveal the pattern as to how OHSAS 18001 certification is linked to increased abnormal performance. This pattern helps to explain how certification allows firms to improve their processes and signal their achievements to the market. Specifically, abnormal sales increases are associated with certification, not the increases in abnormal safety and productivity that occur due to the improvement in processes. However, abnormal productivity and safety increases accrue throughout the event window. From a managerial perspective our results suggest that as soon as the implementation process begins the firm can expect to see increases in productivity and safety relative to uncertified peers, but that these changes do not translate directly into increased sales until the firm is certified.

The benefits of certification accrue to all organizations, but are stronger for those in complex or tightly coupled settings. The contingent nature of certification's operational performance benefits provides important insights for practitioners and the organizations that develop standards. Managers who are not yet facing stakeholders' pressure to adopt OHSAS

18001 can assess their own level of complexity and coupling to get a better sense of the likely benefits of certification. Standard development organizations (e.g., BSI and ISO) may consider tailoring OHSAS to various settings. We would hope that managers of labor intensive firms are aware of the benefits of protecting their workforce. But managers at R&D intensive firms do not have such obvious signals and may be more likely to miss the benefits OHSAS 18001 provides. Similarly, managers might not make an association between inventory level or volatility and safety. Standard setting organizations can help this process along by adapting the certification to these settings.

Presently, OHSAS certification is relatively rare and is sought mainly on a voluntary basis by firms who are already performing better than industry norms in terms of safety. As OHSAS 18001 becomes more common its relative performance implications could change. The ability to generate sales growth from certification will then dissipate as the standard disseminates. But we posit that as the standard becomes more widespread the safety and productivity benefits evidenced in our sample will remain or even increase. As certification becomes the norm, firms with poor safety performance will be forced to get certification and given their relatively poor starting point performance wise they may see larger safety and productivity benefits than the early adopters in this sample.

Finally, the results provide another piece of evidence for managers trying to navigate the conflicting literature on the relationship between the safety and financial components of operational performance. OHSAS 18001 inculcates practices and cognitions that are in line with operational best practices such as a focus on processes and a continuous improvement philosophy. Recent research (e.g., Das et al., 2008; Pagell et al., 2013) posits that when firms that adopt systems that ensure safety and productivity, multiple dimensions of operational performance can be simultaneously improved. Firms who proactively manage safety as a key component of operations via the processes imbedded in OHSAS 18001 or something similar need not trade-off safety for other elements of operational performance.

While the results are robust, this study too, like all studies, suffers some limitations. The major limitation of this study is that the sample includes only U.S. listed firms who have reported certification. However, the effectiveness of a management practice such as OHSAS 18001 might vary in countries with different cultural contexts (Kull and Wacker, 2010) or where government regulations are quite different. Moreover, listed firms are usually large firms that typically have basic OHSMS systems in place; a supposition that seems confirmed by the above average safety performance of the sample. Thus, the findings could be different for small firms. The measures of complexity and coupling are also limited and future research should look at different and more encompassing measures of both, such as complexity of product design and work-in-progress inventories between key operations. Finally, firms in export-oriented economies (e.g., China, Ireland and India, etc.) may pursue OHSAS certification mainly to fulfill customer requirements with no intention of improving working conditions. Therefore, the impact of certification might be dependent on the motivations of the certifying firms.

6. Conclusions

This research sought to answer two questions. First, *what is the general impact of OHSAS 18001 certification on operational performance?* The results show that OHSAS certification yields significant benefits in terms of safety and financial components of abnormal operational performance, even for firms operating in environments with stringent safety regulations who already had above average safety performance relative to their industry. The second research question asked was *what is the role of context in the OHSAS 18001 operational performance relationship*. The results show that as complexity and coupling increase the benefits of certification also increase. OHSAS certification leads to significant increases in abnormal operational performance and these benefits accrue most to firms with highly complex or coupled production systems.

The results also clarify the theoretical confusion surrounding the relationship between safety certification, safety performance and other operational performance outcomes. The institutional theory perspective suggests that certification may be pursued mainly as a signaling device. The results provide some support for this contention with all significant increases in abnormal sales growth occurring after certification, even though the firms had above industry average safety performance prior to certification also. However, the results also show significant increases in abnormal performance in terms of safety, ROA, sales growth and productivity meaning that certification has more than ceremonial benefits.

The existence of increased abnormal safety and economic performance also provides insights into the ongoing debate on the relationship between safety and financial elements of operational performance. The results show no evidence of trade-offs which is more in line with HRT than NAT. However, the results show that the complexity and coupling components of NAT do provide good predictions as to when increased control, in the guise of OHSAS certification, is most beneficial. Therefore we follow Shrivastava et al., 2009 and suggest that rather than treating HRT and NAT as conflicting theories, operations management scholars would be better served by building on the predictions of NAT to determine where enhanced control, be it in the guise of OHSAS certification, statistical process control, training or something else, will be most valuable to prevent failure.

OHSAS certification is unique in that firms pursuing certification should be replacing existing OHSMS and hence a-priori there is no reason to expect certification to improve operational performance. However, the results are broadly in-line with previous studies of other forms of certification, suggesting that certified management systems that inculcate the processes and cognitions associated with HRT generally improve operational performance.

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Responses to reviewer 5 comments

Reviewer #5: D-13-00070R2

OHSAS 18001 Certification and Operating Performance: The Role of Complexity and Coupling

The author(s) have covered many of the issues raised in my second round review. At this point, my suggestions focus on relatively minor areas that need to be adjusted for consistency and style.

- p. 4, last sentence of Introduction. This sentence seemed very awkward. I suggest rewriting to: "The results also make contributions to our understanding of theory by empirically testing the conflicting predictions about changes in operational performance that emerge from institutional theory, normal accident theory (NAT) and high reliability theory (HRT)."

Response: Thanks for your suggestion. We have revised it based on your suggestion.

- p. 4, growth rates. The normal approach is to convert a multi-year growth rate into CAGR.

Response: We have revised the growth rate of OHSAS 18001 into CAGR.

- p. 7. Could one argue that coupling might force workers to focus efficiently on the tasks (rather than lazily move between tasks), and force the firm to employ more rigorous work rules? Doing so would improve performance, and rules would reduce complexity. These ideas seem to be developed on p. 9 (complexity and control), but outside the context of coupling.

Response: We believe we cannot propose this argument because, regarding the discussion on coupling in p. 7, based on the Normal Accident Theory, first, coupling might NOT force workers to focus efficiently on the task since there will be a mindful *drift* over time (discussed in p. 12) . Second, more rigorous work rules (i.e., standard operational procedures) might lead to serious consequences in situations they have not been designed for (Rijpma, 1997). Thus it will not improve performance and the additional rules would in fact increase complexity when the situation is unpredictable. Therefore, under Normal Accident Theory, the controlling of tasks through tighter work rules does not lower the chances of accidents. Therefore, based on this discussion, we have elaborated this point in the second paragraph in page 7 to address this AE's concern.

Rijpma, J. A. (1997), Complexity, Tight–Coupling and Reliability: Connecting Normal Accidents Theory and High Reliability Theory. Journal of Contingencies and Crisis Management, 5: 15–23

- p. 10 (bottom) - 11 (just before H1). It seemed that these two paragraphs simply restated the hypotheses, which followed immediately thereafter. I suggest deleting these paragraphs, moving Table 1 after H4, and Figure 1 after H6.

Response: The two paragraphs have been removed. Figure 1 and Table 1 are relocated as suggested.

- First sentence after H1. Increased sales can result in increased ROA because fixed costs are distributed over more units, thereby improving ROA. Of course, this depends on several factors, such as sales expenses, relative capital intensity, etc.

Response: We have addressed this possibility of how sales impact ROA and the reasons why we believe it will not have significant impact on our results in the footnote.

6. p. 12, last sentence of second paragraph. I'm not sure that either drift or entropy are technically "normal states". "Typical outcomes" might be a better phrase.

Response: Thanks for your suggestion. We have revised it.

- p. 12. The two paragraphs beginning with Shrivastava can be combined.

Response: Thanks for your suggestion. We have revised it based on the same.

- p. 14, second line after H5. "controlling coupling" Do you mean "decoupling"?

Response: Thanks for your suggestion. We have revised it accordingly.

- p. 14, third paragraph. "loser" should be "looser".

Response: Thanks for your suggestion. We have revised it based on your suggestion.

- p. 19, formula. I believe that the dependent variable should be APk because PS was used earlier on p. 17-18 to refer to "actual performance".

Response: Thanks for your suggestion. We have revised it accordingly.

- p.22-23. All of the results are reported in present tense. It is more typical to use the past tense, given that the work has been completed.

Response: Thanks for your suggestion. We are using past tense in the results section in this revision.

- p. 23. No need to spell out "dollars".

Response: Thanks for your suggestion; we have revised it and removed the word “dollars”.

- Table 2. "cumulated" should be "cumulative".

Response: Sorry for the typo, we have revised it now.

- Tables 2 and 3. Please indicate (probably in a footnote) which statistic is being reported for each measure, e.g., Wilcoxon signed rank z-statistic, t-statistic, etc. (This was done in Table 6.)

Response: Thanks for your suggestion; we have revised the tables with additional footnotes.

- Table 6. Are all of the delta-R2 statistically significant? If so, please indicate with the appropriate number of asterisks.

Response: Yes, they are statistically significant. We have included the incremental f-test results and the number of asterisks in Table 6.

A few minor points about style.

I think that the paper has several important messages and contributions. However, I struggled with the readability and flow of several sections of the manuscript. For example, the paper has an excessive use of "And…" to begin sentences. While this stylistic device can emphasize interesting connections when used on an occasional basis, my quick count indicated 17 occurrences (including two on the first page). I suggest that this usage be reworked.

Response: All the "And .." uses have been checked and revised accordingly.

Verb tenses (past, present and future) also tend to be inconsistent. For example, the second paragraph (p. 2) uses present tense to refer to prior research. (An aside: I also think that Brown, as well as Pagell et al., "demonstrated" or "argued for", rather than "suggested".) The historical government data reported later on p. 1 also is in the present tense. Later, the last paragraph of the Introduction uses both present and future tenses to refer to managerial understanding and application (here I suggest present is most appropriate). Finally, commas should be inserted in many sentences to parse out introductory phrases or clauses.

As a final pass, I recommend that the author(s) use a professional editor to tighten and sharpen the clarity of the writing.

Response: Thanks for your suggestion. We have invited a professional technical writer to help us sharpen the writing and make the verb tenses become more consistent.

Figure 1: The research framework

Table 1 Predictions on the relationships between OHSAS 18001 certification and operational performance

	Safety (H1)	Sales Growth (H2)	Labor productivity (H3)	ROA (H4)
Institutional theory	No change	Improves	No change	No change
NAT and role overload	Improves	No change	Decreases	Decreases
HRT and human capital	Improves	Improves	Improves	Improves

Table 2 Results of sample firms' cumulative abnormal performance

	Pre-certification (Year -2 to Year 0)				**Post-certification (Year 0 to Year 2**			
	N	Median	Percentage	Mean	N	Median	Percentage	Mean
Safety Performance [a, b]	194	-0.00	41.23%	-0.21	163	-0.00	39.26%	-0.03
Statistic		-2.67**	3.14**	-1.67+		-1.69+	2.93**	-0.84
Sales Growth	180	0.63	51.67%	-0.31	148	2.10	56.08%	2.66
Statistic		0.27	0.53	-0.29		1.69+	1.58	1.96+
Labor Productivity	177	2.26	58.19%	4.82	143	-0.09	49.65%	2.62
Statistic		2.39*	2.11*	3.09**		-0.69	0.00	1.39
ROA	194	0.82	58.24%	1.04	163	0.71	54.60%	0.83
Statistic		2.83**	2.23*	3.39**		1.801+	1.097	2.168

Note: Z-statistics for WSR test (median) and sign test (percentage), t-statistics for *t*-test (mean)
Percentage indicates the percentage of firms achieving positive abnormal changes in safety performance, sales growth, labor productivity and ROA; **, *, + note a statistically significant difference from 0 at 0.01, 0.05 and 0.1 levels, respectively (two-tail).
[a] The percentage of negative safety performance between sample and control firms in the pre-certification, post-certification and the full event window period are 22.09%, 20.86% and 30.67%, respectively.

[b] The absolute number of violations in the pre-certification, post-certification and the full event window period are -41.80, -4.89, and -32.60 per 10,000 employee, respectively.

Table 3 Results of sample firms' year-to-year abnormal performance

	Year -2 to Year -1				**Year -1 to Year 0**				**Year 0 to Year 1**		
	N	Median	Percentage	Mean	N	Median	Percentage	Mean	N	Median	Pe
Safety Performance [a, b]	211	-0.00	30.81%	-0.12	194	-0.00	30.41%	-0.08	180	-0.00	31
Statistic		-2.26**	3.25**	-1.12		-2.90**	3.60**	-1.97+		-1.78+	3.
Sales Growth	197	1.48	54.31%	0.31	180	0.86	51.67%	0.97	165	2.60	58
Statistic		0.55	1.29	0.28		0.47	0.60	0.59		2.35*	2.
Labor Productivity	192	1.58	56.50%	2.04	177	1.97	57.63%	2.53	160	2.10	56
Statistic		1.79+	1.66+	2.03*		1.68+	1.95+	1.71+		2.05*	1.
ROA	211	0.42	55.92%	1.01	194	0.73	56.19%	0.73	180	0.54	58
Statistic		2.93**	1.65+	2.43*		1.89+	1.65+	2.03*		2.30*	2.

Note: Z-statistics for WSR test (median) and sign test (percentage), t-statistics for *t*-test (mean).
Percentage indicates the percentage of firms achieving positive abnormal changes in safety performance, sales growth, labor productivity and ROA; **, *, + note a statistically significant difference from 0 at 0.01, 0.05 and 0.1 levels, respectively (two-tail).
[a] The percentage of negative safety performance between sample and control in the period Year -2 to Year -1, Year -1 to Year 0, Year 0 to Year 1 and Year 1 to Year 2 are 15.16% , 12.89%,15.00% and 16.64%, respectively.
[b] The absolute number of violations in the period Year -2 to Year -1, Year -1 to Year 0, Year 0 to Year 1 and Year 1 to Year 2 are -25.32, -15.52, -5.4 and 16.3 per 10,000 employee, respectively.

Table 4 Results of systematic bias tests

	Year -3 to Year -2			
	N	Median	Percentage	Mean
Safety Performance	204	0.00	26.07%	0.02
Statistic		1.46	0.28	-0.51
Sales Growth	192	0.56	52.82%	1.44
Statistic		0.99	0.79	1.12
Labor Productivity	186	0.92	53.44%	1.28
Statistic		1.44	0.87	1.44
ROA	204	0.34	52.45%	-0.23
Statistic		0.67	0.63	-0.51

Note: Z-statistics for WSR test (median) and sign test (percentage), t-statistics for *t*-test (mean).
Percentage indicates the percentage of firms achieving positive abnormal changes in safety performance, sales growth, labor productivity and ROA.

Table 5 Correlation of the variables in regression analysis

	Mean	Standard deviation	ROA	Violation	Size	Year of adoption	R&D Intensity	Labor Intensity	ISO 9000
ROA (%)	13.78	0.06							
Violation	0.01	0.02	-0.130^{+}						
Size	3.20	1.39	0.048	-0.072					
Year of adoption	2004.80	2.50	0.054	-0.068	0.038				
R&D Intensity	0.05	0.04	0.094	-0.096	-0.078	-0.143^{+}			
Labor Intensity	3.92	2.44	-0.006	0.038	-0.146	-0.246**	0.147^{+}		
ISO 9000	0.03	0.17	0.024	-0.053	-0.200	-0.003	0.180*	-0.043	
ISO 14000	0.25	0.43	0.045	0.239**	-0.015	-0.041	-0.072	-0.040	-0.191*
Inventory Volatility	0.28	0.51	-0.003	-0.027	-0.045	-0.234	0.004	-0.167	-0.061
Inventory Level	0.12	0.06	-0.008	0.082	0.232**	0.034	-0.054	0.325**	0.001
Size (Industry)	12.19	0.69	-0.043	0.073	0.055	-0.008	0.017	-0.044	0.092
Wage Level (Industry)	0.69	0.98	0.013	-0.055	0.051	0.015	-0.044	0.158	-0.116
Length of Working Hour (Industry)	0.13	0.93	0.066	-0.036	0.009	-0.174*	-0.008	0.080	-0.252**
Labor Union Influence (Industry, %)	15.32	10.51	-0.201*	-0.024	0.187*	0.022	-0.026	-0.036	-0.371**

Note:
N=163
**,*,+ indicate statistically significant at 0.01, 0.05, and 0.1 levels, respectively (two-tail).

Table 6 Estimated coefficients from regression analysis for the indicators in Year -2

	Dependent Variable: Abnormal ROA (Year -2 to Year 2)			**Dependent Variable: Abnormal Safety Performance (Year -2 to Year 2)**		
	Control Model	**Complexity Model**	**Full Model**	**Control Model**	**Complexity Model**	**Full Model**
Intercept	-7.391^{+} [-1.841] (4.014)	-8.798* [-2.205] (3.990)	-11.704** [-2.883] (4.060)	8.315 [0.978] (8.504)	8.902 [1.154] (7.714)	11.029 [1.356] (8.134)
Prior performance	-0.042 [-0.567] (0.075)	-0.053 [-0.715] (0.074)	-0.059 [-0.819] (0.073)	0.656^{+} [1.740] (0.377)	0.563 [1.630] (0.346)	0.421 [1.203] (0.350)
Size	-0.007* [-1.974] (0.003)	-0.005 [-1.561] (0.003)	-0.005 [-1.440] (0.004)	0.007 [1.011] (0.007)	-0.001 [-0.144] (0.007)	0.003 [0.419] (0.007)
Year of adoption	0.004^{+} [1.850] (0.002)	0.004* [2.207] (0.002)	0.006** [2.885] (0.002)	-0.004 [-1.019] (0.004)	-0.005 [-1.191] (0.004)	-0.006 [-1.391] (0.004)
ISO 9000	-0.016 [-0.560] (0.028)	-0.024 [-0.845] (0.028)	-0.015 [-0.552] (0.028)	0.069 [1.150] (0.060)	0.074 [1.340] (0.055)	0.069 [1.261] (0.055)
ISO 14001	-0.003 [-0.288] (0.012)	-0.001 [-0.049] (0.011)	0.002 [0.210] (0.011)	-0.003 [-0.125] (0.025)	-0.015 [0.652] (0.022)	-0.010 [-0.417] (0.023)

Size (Industry)	0.002 [0.260] (0.007)	0.001 [0.138] (0.007)	0.001 [0.131] (0.007)	0.026+ [1.714] (0.015)	0.028* [2.080] (0.014)	0.024+ [1.710] (0.014)
Wage Level (Industry)	-0.002 [-0.320] (0.005)	-0.001 [-0.191] (0.005)	-0.002 [-0.302] (0.005)	0.007 [0.681] (0.011)	0.002 [0.193] (0.010)	0.004 [0.349] (0.010)
Union Influence (Industry)	<-0.001 [-0.246] (0.001)	<0.001 [0.516] (0.001)	<0.001 [0.446] (0.001)	-0.001 [-1.268] (0.001)	-0.002+ [-1.968] (0.001)	-0.002* [-1.987] (0.001)
Length of working hour (Industry)	0.004 [0.745] (0.006)	0.008 [1.414] (0.006)	0.007 [1.246] (0.006)	0.004 [0.313] (0.012)	0.002 [0.150] (0.011)	0.007 [0.647] (0.011)
R&D intensity		0.262* [2.333] (0.112)	0.255* [2.303] (0.111)		-0.343** [-2.691] (0.127)	-0.302** [-2.316] (0.131)
Labor intensity		0.004+ [1.830] (0.002)	0.005* [2.271] (0.002)		-0.007** [-3.485] (0.002)	-0.009** [-3.975] (0.002)
Inventory volatility			0.026** [2.754] (0.009)			-0.021 [-1.029] (0.021)
Inventory level			-0.029 [-0.372] (0.078)			0.345* [2.071] (0.166)
R^2	5.6%	9.7%	14.1%	6.9%	25.5%	28.4%
Incremental R^2		4.1%	4.4%		18.6%	2.9%
Adjusted R^2	0.1%	3.2%	6.6%	1.7%	20.2%	22.2%
Incremental adjusted R^2		3.1%	3.4%		18.5%	2.0%
Incremental F-test		3.43*	3.79*		19.38**	2.54+

Note: **,*,+ indicate statistically significant at 0.01, 0.05, 0.1 levels, respectively (two-tail).
Prior performance: ROA at Year -2 in abnormal ROA model; Violation rate at Year -2 in abnormal violations model.
t-statistics in the bracket; standard error in the parenthesis.
N = 163