Safety regulation enforcement and production safety: The role of penalties and voluntary safety management systems

Abstract

Scholars, the government, and the public expect that legal enforcement should be an effective means to prevent a firm's future safety violation behavior in daily productions. However, the literature provides limited insight into whether safety regulation enforcement is effective in helping firms reduce future safety violations. Therefore, this study examined the relationship between occupational health and safety enforcement and a firm's future violation behavior. We carried out a regression analysis based on a panel sample of 2,965 listed United States manufacturers with 4,474 violation records issued by the Occupational Safety and Health Administration. We find limited effectiveness of enforcement. Our results indicate that although past violation experiences are negatively correlated with subsequent repeat violations (violations of the same clause), they are positively correlated with non-repeat violations (violations of a different clause) and the number of overall violations (the sum of both). The factors that can reinforce effectiveness were also explored in this study. Our analyses show that the effectiveness of safety regulation enforcement is significantly enhanced when reinforced by stringent penalties and Occupational Health and Safety Assessment Series 18001 certifications. This study contributes to the literature on the operational safety and policy–operations interaction. We challenge conventional wisdom by proposing that regulatory pressures do not necessarily improve firms' overall social responsibility practices in terms of worker health and safety. We also discuss the implications of this for the occupational health and safety (OHS) management practice.

Keywords: regression analysis; safety; secondary data; sustainability

1. Introduction

Recent high-profile industrial accidents such as the 2013 Rana Plaza Collapse and 2020 Beirut Explosion have prompted public concern about the sustainable operations of firms. One important dimension of sustainable operations is occupational health and safety (OHS) (Kleindorfer et al. 2005).

OHS problems can incur substantial social costs. In the United States (US), over 14 workers lose their lives at work every day (Bureau of Labor Statistics Census of Fatal Occupational Injuries 2019). Such incidences can undermine a firm's reputation, image, cash flow, and productivity (Fan et al. 2014; Lo et al. 2014; Pagell et al. 2019). Improved OHS performance can reduce operational risks (Wolf 2001), enhance product quality (Das et al. 2008), and increase revenue and profitability (Lo et al. 2014).

Nowadays, businesses are mandated to have an OHS management system to ensure their workers' health and safety. Mandatory OHS management systems arise from government legislation and enforcement via inspection and fines (Robson et al. 2007). When operations managers are subjected to productivity pressures, safety practices may be compromised to meet urgent production goals (Brown et al. 2000; Pagell et al. 2020; Wiengarten et al. 2017, 2019). Firms with poorly committed managers often drift away from safety norms and requirements, which may result in damage, injuries, and fatalities (Lo et al., 2014). In the absence of internal volition in firms (Pagell & Gobeli, 2009), government enforcement agencies are expected to be the gatekeepers of safe operations.

However, the effectiveness of government enforcement in improving safety performance of firm remains highly controversial (Pagell et al. 2020). Some studies find that safety inspections reduce workplace injuries (e.g., Levine et al. 2012; Mendeloff & Gray 2005) while others find no significant effects (e.g., Ruser & Smith 1991; Viscusi 1979). In practice, it has been observed that firms continuously violate a variety of safety regulations. For example, Manke Lumber was fined US$87,000 in 2015 for 11 violations that resulted in severe injuries and fatalities among workers (OH&S 2015). Similar cases of multiple violations have occurred even in some highly reputable firms, such as Disney and Home Depot, resulting in US$21,000 and US$150,000 fines, respectively (ISHN, 2013). These cases show that it remains uncertain whether violating firms will limit their future transgressions of safety violations. This study thus examines the influence on firms' future safety violation behaviors of safety regulation enforcement, as an indispensable part of firms' mandatory OHS management systems.

Specifically, we aim to address the first research question (RQ1): *Will firms take corrective action responsibly and seriously to reduce their chances of making similar mistakes (defined as violations of the same clause) in the future?* In the US context, safety enforcement begins with a site inspection by experts from the Occupational Safety and Health Administration (OSHA), and mandatory corrective actions are required for any non-compliance found during the inspection. Answering RQ1 will establish the relationship between a firm's experience with violations and its subsequent repeat violations of the same clause. We also consider whether corrective actions are too narrow regarding the immediate point of correction, rather than leading broader safety improvement efforts to prevent other regulatory violations, which leads to firms' subsequent violations of multiple safety regulations in different clauses. Thus, we aim to answer the second research question (RQ2): *Do improved practices following receipt of a violation notice lead to a wider scope of improvement (i.e., extending to other clauses), or do firms irresponsibly just make quick clause-specific fixes that do not improve their overall safety performance?*

This study also explores the boundary conditions of RQ2. As penalties are used to deter firms from non-compliance with safety regulations, we expand the research scope to examine whether fines can reduce violating firms' subsequent violations. In addition, an OHS management system can be mandatory or voluntary (Robson et al. 2007; Yiu et al. 2019). A mandatory system establishes minimum (legal) safety standards with which operations must comply, whereas voluntary OHS system standards are not directly related to regulations. Voluntary standards arise through the private sector and professional institutes, and aim for continuous improvements in a firm's safety practices (Robson et al. 2007). The Occupational Health and Safety Assessment Series (OHSAS) 18001 has been one of the most popular standards used for voluntary OHS management systems in private sectors (Lo et al. 2014). The literature suggests that the OHSAS 18001 should be integrated with other voluntary management system such as ISO 9001 and ISO 14001 (Oliveira Matias & Coelho, 2002). However, it is unclear whether such voluntary OHS management systems can be well integrated with mandatory ones. We thus ask the third research question (RQ3): *Do firms punished severely and with OHSAS 18001-certified safety management systems better utilize their past violation experiences to improve their future safety performance?*

In this study, we sample listed US firms and violation records issued by the OSHA to examine a series of hypotheses. The analysis results show that a firm's past violation experiences are *negatively* related to its subsequent *repeat safety violations* (to the *same* clauses). Meanwhile, a firm's past violation experiences are *positively* related to subsequent *non-repeat safety violations* (with respect to *different* clauses). This indicates the absence of systematic and wider organizational improvement.

However, the relationship between past violation experiences and subsequent violation behaviors (including both repeat and non-repeat violations) is negatively moderated when enforcement is coupled with stringent penalties and a firm's voluntary safety management system (i.e., OHSAS 18000 certification). We provide evidence that government enforcement efficiency in reducing firms' subsequent violation records is limited. Our results also offer the important implication that firms should integrate their mandatory and voluntary OHS management systems to achieve a more ideal safety performance.

2. Theory and Hypothesis Development

2.1. Mandatory OHS Management Systems and Enforcement

Research has explored various factors that account for OHS performance improvement, including managers' attitudes (Pagell & Gobeli 2009), leadership (de Koster et al. 2011; de Vries et al. 2016), culture (Power et al. 2015), and capital structure (Pagell et al. 2019). Among these factors, the OHS management system is considered a vital antecedent to a firm's OHS performance (Lo et al. 2014; Robson et al. 2007; Wiengarten et al. 2017). The operation of a mandatory OHS management system requires substantial interaction between government agencies and firms. The government first establishes the legal standards that firms' safety practices must meet; firms then operate with compliance to these legal safety standards (Fan et al. 2014). However, operations under a mandatory OHS management system may encounter difficulties caused by goal divergence between regulators and firms. Regulators aim to motivate firms to improve safety performance and thus overall social welfare, while firms need to evaluate the balance between safety practice costs and safety performance in production (Pagell et al. 2020). These divergent goals resulting from a safety–productivity tradeoff may cause violation behavior by firms with regard to safety regulations.

Government enforcement, including via inspections and penalties, is thus vital to ensure that mandated OHS management systems are running well in industries. There are two processes involved in safety violations in the US. The first is companies engaging in misconduct in safety practices and the second is the government detecting such misconduct and issuing violation notices. Corporate fraud is generally difficult to detect by outside stakeholders such as media, governments, and customers (Shi et al. 2017). However, inspections help overcome information asymmetry between regulators and firms and can spot any opportunistic (i.e., non-compliance) behavior of firms. In OSHA's policy, workers are motivated to report such misconduct because their health and lives are at stake. The misconduct in regard to safety practices is easier to observe by operational workers who daily interact in the operational system than by the external parties. Employee complaints are the most common cause of OSHA inspections (OSHA 2016).

Inspections are conducted by well-trained and experienced safety and health compliance officers (OSHA 2018). Given that almost all OSHA visits occur with no notice (OSHA 2018), companies have difficulty hiding misconduct. Citations and fines are issued within six months after any serious hazard or violation of regulations is revealed. Employers are offered the opportunity to appeal against citations to area directors of the OSHA for review. Given the extensive nature of an OSHA investigation, enforcement results can be viewed as a legitimate indicator of a firm's safety performance (Lo et al. 2014; Wiengarten et al. 2017).

Any violation can be viewed as the exposure of latent failures in operational systems, which can lead to accidents (Reason 2016). Safety violation is thus a type of corporate misconduct that puts operational workers' health and safety at risk (Pagell et al. 2019). Therefore, we draw from the literature on corporate misconduct to identify theoretical lenses to conceptually develop the link between past safety violation and subsequent violation behavior of firms. Greve et al. (2010) proposed that corporate misconduct can be understood from three perspectives: economic, social, and behavioral. From an economic perspective, rational choice theory views violation behavior as a rational decision that stems from weighing up the costs of violating and complying with a law. From a social perspective, institutional theory considers compliance as a result of firms' conformance to social norms and pressures. From a behavioral perspective, the behavioral theory of firms (BToF) views an adverse event of violation as a behavioral shock that alerts managers to learn from the experience (known as experiential learning). Our hypothesis development is based on these three theories, followed by a discussion of various mechanisms for the impact of safety enforcement on a firm's future violation behavior. Table 1 summarizes the predictions from the three perspectives.

[Table 1 about here]

2.2. Violation Experiences and Subsequent Violation Behavior

Taking an economic perspective and applying rational choice theory, a firm's non-compliance can be viewed as a rational decision resulting from a cost–benefit analysis (Greve et al. 2010; Scott & Nyaga 2019). Market participants often pursue the most profitable way to produce goods. Pursuing productivity as a goal may undermine worker safety (known as productivity–safety tradeoff) and increase social costs (Lo et al. 2014). As a coercer, the government aims to correct such market imperfections, which may have adverse environmental and social outcomes (Scholz & Gray 1997). Government regulations and enforcement thus play an important role in promoting sustainable operations (Tang & Zhou 2012) by establishing basic environmental and safety requirements that all firms must meet. Fines and penalties for violation increase the cost of non-compliance and shape firms' behavior (Scholz & Gray 1997). Therefore, legal enforcement imposes a deterrent effect that prevents employers from putting their workers' health and safety at risk.

After receiving a violation notice, efforts toward corrective action will be influenced by costs incurred by future inspections, including the probability of being detected again and the expected magnitude of any penalty levied (Gray & Shimshack 2011; Taylor et al. 1977). Therefore, firms evaluate the cost of immediate corrective action efforts against the future cost of making no corrections (or the risk of being further penalized). In a stringent enforcement context (e.g., the US), inspectors monitor and ensure that corrective actions are taken appropriately (OSHA 2018). Thus, an enforcement body has a high chance of knowing if corrective action is not taken. Further penalties are then imposed if uncorrected violations are detected (Industry Safe 2019). Thus, after a firm is cited for a violation, it tends to put effort into correction to avoid later, large penalties for uncorrected violation (Mendeloff & Gray 2005). Correction efforts should consequently improve safety performance and reduce future violations.

The second perspective is based on institutional theory. The essential premise of neo-institutionalism is that coercive pressure stemming from political influence and government mandate causes organizations to conform to an established institutional environment (Scott 2013). Government enforcement include coercive pressure to drive organizations to adopt safety improvement practices

(Gray 1983). Governments establish basic safety requirements and ensure that all firms follow them. Penalties imposed for non-conformance aim to ensure submission to coercive pressure (Scott 2013). In the OHS context, receiving penalties can be stigmatizing to a firm, reminding it of the consequences of not complying with the law. Thus, such pressure should increase the likelihood that the firm will comply with OHS regulations in the future.

The third perspective is based on the BToF and organizational learning (Cyert & March 1963). Violation is conceptualized as a 'behavioral shock' alerting managers to latent failures in operations (Mendeloff & Gray 2005; Scholz & Gray 1990). It signals undesirable safety performance of the firm, which forces it to seek new methods to improve the current situation. The learning motivated by failure is also known as a 'problemistic search,' in which organizations challenge old assumptions, take corrective action, and innovate (Sitkin 1992). These searches generally start with a search for local solutions to fix the most direct and immediate problems (known as a local search) (Greve, 2003). A local search can provide firms with explicit roadmaps that efficiently inform them of necessary improvements. For example, if a firm is found to have failed to establish procedures to properly handle and store hazardous materials (clause 1910.39(c)(1)), it can recruit an expert in the area to establish proper procedures. This can reduce the likelihood of repeating that violation in the future.

As discussed above, the rational choice, behavioral shock, and coercive pressure perspectives all predict that violations should reduce the likelihood of violations in the future. Based on the above discussion, we propose a hypothesis for the effect of mandated corrective actions on preventing firms making the same mistake in the future:

H1: *Past safety violation records lead to a smaller number of subsequent repeat violation incidents (involving the same clause).*

The three theoretical lenses lead to a unanimous prediction in relation to RQ1; however, their predictions for RQ2 are mixed. First, the behavioral shock perspective considers that receiving a safety violation can trigger a firm's problemistic local search for improvement, reducing subsequent repeat violations. Therefore, the problems exposed during the violations increase the manager's attention to safety issues. Mendeloff and Gray (2005) suggested that such attention may extend beyond the area being inspected in that the manager explores safety issues besides the one exposed by a government inspection. In this scenario, the local search is expanded to a distant search with a focus beyond the immediate clause that was violated (Iyer et al. 2019). For example, when fixing a missing hazardous material storage procedure issue (the aforementioned clause 1910.39(c)(1)), a firm may take a further step to train employees responsible for maintaining and controlling the hazard. This additional step may help the firm avoid violating clauses 1910.39(c)(4–5) in the future. Thus, improvements in safety performance may not only occur in the area of violation; there may be a system-wide improvement:

H2: *Past safety violation records lead to a smaller number of subsequent non-repeat violation incidents (involving different clauses).*

However, the rational choice perspective views system-wide improvements triggered by a safety violation experience as conditional. From this perspective, improved safety performance may be superficial because the firm's goal is to pursue optimal control in the tradeoff between compliance costs and violation costs (Greve et al. 2010). Firms might consider violation as a rational choice when the fine is less significant than the investment required in safety practices (Greve et al. 2010). Thus, the expected increase in the cost of safety violations should motivate firms to improve future safety performance. Firms may tend toward proactively improving their safety practices only when the cost of penalties outweighs the cost of self-inspection to identify safety loopholes,

Therefore, we argue that a firm's tendency to improve its safety practices beyond the violated clause should be contingent on the penalties it received for past violations. A huge penalty poses extra costs regarding violation/compliance decisions. The penalty reflects the perceived cost of violations in the firm's cost–benefit evaluation. Because the violation can be offset partly by paying fines to the government, the firm may view OHS problems more seriously when the penalty is higher, as the cost of violation is higher. Thus, a stronger penalty drives firms to investigate non-compliance issues more thoroughly. Based on the above discussion, we propose a hypothesis postulating the boundary condition for H2:

H3: *The relationship between safety violation experiences and subsequent violations is more negative when the firm's penalty (fine) for the experienced violation is higher.*

From the institutional perspective, a firm's safety practices are mandated and not necessarily related to its manager's commitment to improving safety performance (Yeung et al. 2011). The firm's corrective action may simply be a response to coercive pressure. Thus, it may settle a violation issue by carrying out corrective action only in relation to that particular clause. This is in line with the view that firms will only fulfill minimum requirements when work is mandated (Clemens & Douglas 2006; Meqdadi et al. 2019). These arguments are also consistent with the view that government coercive pressure alone may not lead firms to make continuous improvements (Rentizelas et al. 2020).

In addition to coercive pressure, normative and mimetic pressure are identified by neo-institutionalism as institutional pressures motivating firms to conform, in general, to the industrial norms and expectations of other social institutions (DiMaggio & Powell 1983), and to adopt operations management practices such as ISO 9000 (Yeung et al. 2011) Normative pressure is associated with professionalization in a certain field of practice (Dimaggio & Powell 1983). Professionalism shared in a given industry establishes a cognitive base for legitimate organizational practice (Larson 1979). Mimetic pressure is associated with imitating others in response to uncertainty (Dimaggio & Powell 1983). When organizations encounter problems with ambiguous causes and unclear solutions, they can develop by themselves by mimicking other organizations' actions (Cyert & March 1963). Thus, mimetic behavior provides a legitimate option for firms' decision makers in the face of uncertainty (Suchman 1995). Unlike coercive pressure, the compliance behavior motivated by normative and mimetic pressures is more actor-proactive in nature (Zhu & Geng 2013). Thus, we investigate whether firms experiencing stronger normative and mimetic pressure have a greater tendency to initiate improvements covering a wide range of aspects following safety violations. Specifically, we are interested in exploring whether regulators can improve their enforcement effectiveness by collaborating with professional bodies. This investigation is in line with the view that mandatory safety enforcement should be incorporated with a voluntary safety management system to achieve an optimal outcome (Fan et al. 2014; Robson et al. 2007).

If firms are certified by voluntary safety management system standards, they come under higher normative and mimetic pressure. This conceptualization is in line with literature on OHSAS 18001 from an institutional perspective (e.g., Lo et al. 2014; Yang et al. 2021). For example, OHSAS 18001 certification can signal that a firm is committed to OHS, which is appealing to its customers, regardless of its actual impact on safety performance (Lo et al. 2014). Operational safety has received increased focuses in nowadays industries, thus firms might feel pressured to adopt and maintain these safety standards. Failure to obtain certification may have an adverse outcome in terms of competitiveness with other firms.

In addition, as with other voluntary management system standards such as ISO 9000, OHSAS 18001 was developed by professional organizations that promote prevailing standardized management practices and share the industry norm of practice (Guler et al. 2002). Certification from the most widely used voluntary safety management system, OHSAS 18001, signals that a firm is committed to continuous improvement in OHS (Lo et al. 2014). Research has shown that widespread diffusion of OHSAS 18001 improves the safety climate and, over time, employees' beliefs and behavior with respect to safety management (Abad et al. 2013). The industrial norms created by OHSAS 18001 also affect managers' attitudes toward establishing safety priorities and policies (Fernández-Muñiz et al. 2012). As certification bodies periodically audit OHSAS 18001-certified firms, these firms undergo normative pressure to conform with voluntary safety management practices.

In practice, a violation experience represents valuable intellectual capital, and learning capability is required for firms to efficiently utilize this capital. Thus, the impact of a violation experience on improvement in safety performance may be contingent on the learning capabilities brought by OHSAS 18001. The literature suggests that a management philosophy of continuous improvement facilitates a firm's sustained learning (Savolainen & Haikonen 2007). With the plan–do–check–act continuous improvement cycle, firms proactively monitor any pitfalls in operations (at the 'check' stage), search for solutions ('act') and improve their operations ('plan' and 'do'). In an OHS context, violations expose latent pitfalls in violating firms' operations. Firms with a policy of continuous improvement are more likely to take corrective action in a more comprehensive manner, leading to improved future safety performance (reduced subsequent violation). Therefore, we postulate voluntary OHS management systems as another boundary condition for H2:

H4: *The relationship between safety violation experiences and subsequent violations is more negative when the firm has OHSAS 18001 certification.*

3. Method

3.1. Samples

We sampled listed US manufacturing firms and developed a firm–year panel data set to examine our hypotheses. The use of panel data has advantages in terms of mitigating endogeneity concerns (Ketokivi & McIntosh 2017) (see also the detailed discussion in Section 4.2). Panel data analysis has also been used in studies where the dependent variable was corporate malfeasance (e.g., Haunschild & Rhee 2004). Safety violation data were collected from OSHA's violation database (OSHA 2017a). The OSHA data has been widely used in safety science research (e.g., Grant & Hinze, 2014; Taylor, 2015). Other financial data were collected from the COMPUSTAT database.

The data collection process began with preparation of a list of the names of all 8,953 manufacturing firms (Standard Industry Classification code (SIC) 2000–3999) obtained from the COMPUSTAT database. We then collected violation data for these firms from OSHA's violation database, which records OSHA inspections of facilities, and whether these led to violations. From each violation record, we were able to obtain the name of the firm that owns the facility. The firm name provides a foreign key to link with the COMPUSTAT database. We could also obtain the facility's address, the violation date, type, and other related information from OSHA's database.

An empirical challenge in merging the data from the COMPUSTAT and OSHA databases was firm name differences between the two. For example, the 'Apple Inc' recorded in COMPUSTAT could be shown as 'Apple Inc.' or 'Apple Computer.'. We thus recruited two research assistants to manually search for these firm names in OSHA's violation database for their violation records. One author verified the matching results to ensure data collection quality.

We compiled the violations of each firm into a yearly sum to create a variable representing the annual number of safety violations, which we used as the dependent variable. If a firm was not engaged in any violation that year, the observation was coded as '0'. This treatment is consistent with the operations management literature investigating safety violations (Lo et al. 2014; Wiengarten et al. 2017). We note that this treatment assumes that a violation in one of a firm's facilities is visible to its other facilities. We argue that this assumption is mostly valid as violation records are publicly available. As our analysis involved a comparison with industry peers, we excluded industries (4-digit SIC) that did not have any violation history within our analysis window.

The analysis window was 2000–14 because of the prevailing use of the voluntary OHS management system OHSAS 18001, developed in 1999. Firms certified by OHSAS would apply a continuous improvement philosophy to manage their OHS (Lo et al. 2014). In 2015, the OSHA introduced the requirement for firms to report all work-related hospitalizations within 24 hours. Previously, employers were required to report only when three or more workers were hospitalized because of the same incident (OSHA 2015). We used violation data only for 2000–14 as dependent variables to minimize differences brought by the 2015 changes to reporting and record keeping. We used a 1-year lag between independent and dependent variables, so our independent list covered 1999–2013. We generated a panel data set consisting of 25,273 observations drawn from 2,965 firms. The average number of observations per firm was 8.52 (years) instead of 15 because some firms became inactive or had missing financial data in our research window. The data set contained 694 firms that had committed at least one violation. In total, 4,474 violations were reported. We used the remaining firms with no violation records as control firms. Adding these control firms introduced a large number of '0' values for our dependent variable, but Cramer et al. (1999) reported that parameter estimation is robust in samples involving large percentages of '0' observations. In the robustness check, we adopted zero-inflated negative binomial regression and found that the excessive proportion of '0' values did not bias our main analysis results.

3.2. Variables

For our dependent variable, we used the rate of subsequent safety violations as a proxy for a firm's safety performance (Lo et al. 2014; Pagell & Gobeli 2009; Wiengarten et al. 2017). This was measured as the firm's annual number of OSHA violations, scaled by its ten-thousand number of employees ('0000) in year *t* (Lo et al., 2014). The violation database categorizes violations into serious, repeat, willful, and other. To test H1 we focused on the number of repeat violations (*repeat violation rate*) to capture specific safety improvements related to past violations. A repeat violation occurs when a firm violates a safety regulation clause(s) it has been cited for violating in the past. For example, Metalico

Rochester, Inc. was cited in 2011 for failing to develop proper safety procedures, which led to the death of an employee. The OSHA classified this as a repeat violation because the company was cited for the same violation in 2010. Under OSHA's citation policy, a repeat citation will be issued within 3 years of the final order date of the previous citation (OSHA 1998). To test H2, we excluded repeat violations from our measurement of the dependent variable because our objective here was to test if past violation experiences are associated with a higher number of subsequent non-repeat violation incidents (of different clauses). For robustness, we also considered both repeat and non-repeat violations to examine effects on *overall violation number*. We treated all other types as equal when calculating the number of violations because the classification was not mutually exclusive (i.e., a violation can belong to many categories). For example, a violation can be serious and willful at the same time. This treatment is consistent with previous studies (e.g., Lo et al. 2014;Pagell & Gobeli 2009; Wiengarten et al. 2017). In our sample, nearly 99% of OSHA visits occurred without advance notice, so the firms could not have indulged in last-minute cover-ups prior to visits. Accordingly, inspections accurately reflect firms' safety performance.

The violation variables were scaled by firm size for two reasons. First, a larger number of employees increases the likelihood of safety incidents. To verify this assumption, we regressed the number of violations (in year t) against the number of employees (natural logarithm transformed, year t–1) through a negative binomial regression. The results show that number of employees is a significant predictor (coefficient = 0.548, z = 40.11, $p < 0.001$). Large firms with number of employees one standard deviation above the mean have 1.322 more violations per year than average-size firms. Given that violation is rare (1.133 per firm per year), the effect magnitude of 1.322 is considerable. Second, the inclusion of the number of employees can also mitigate selection bias in safety violation. Employee complaint (whistle blowing) is the most common cause of OSHA inspection (OSHA, 2016). 22.13% of OSHA inspections in 2019 were prompted by worker complaints (OSHA 2021). A larger number of employees increases the number of watchful eyes over a firm's safety practices, which increases the chances of having whistle blowers and consequently OSHA inspections.

In H1 and H2, we hypothesized a relationship between past safety violation experiences and subsequent safety violation incidents. The variable, *violation experience*, was measured as the total number of violations committed by a firm in all years before a certain year (year *t*). This measure is consistent with that used in studies on organizational learning from failure (e.g., Haunschild & Rhee 2004; Yiu et al. 2014). It captures total past experiences in all years before a safety violation incident in year *t*. In our sensitivity analysis, we replaced this variable with the number of safety violations committed by a firm in 1 year (instead of all years) before year *t* (i.e., in year *t*–1; see Section 4.2).

In H3 and H4, we hypothesized moderating effects for *penalty* and *OHSAS 18001* certification. The average penalty for a firm's past violations should reflect the cost of having violation in the firm's economic evaluation. We calculated the level of safety violation penalties as the total number of fines paid by the firm before year *t* divided by the number of violations committed by the firm.

OHSAS 18001 was developed by professional organizations (e.g., BSI Group) that promote prevailing standardized management practices. Certification establishes industry standards and expectations for operational safety, which removes ambiguity and uncertainty surrounding safety practices. We coded firms in years they were certified by OHSAS 18001 as '1,' otherwise '0' (Wiengarten et al. 2017). We collected the OHSAS 18001 certification data from each firm's official website and annual report, and from media reports (Lo et al. 2014).

We included several control variables in the models to ensure their robustness. We first included the natural logarithm-transformed number of employees to control for *firm size*, the return-on-assets (*ROA*), and the operating income per employee ratio (*productivity*) to control for firm performance, because a large and profitable firm is likely to have abundant resources to invest in safety practices. We included the number of years in which a firm had no violation records from the start of the OSHA record to the observation year, to control for the firm's safety *operations experience*. We also included a firm's financial slacks because resource-abundant firms are more able to invest in safety precautions. Financial slacks are multidimensional and include *unabsorbed slack* measured as quick ratio (calculated by current assets minus inventory, scaled by current liabilities); *absorbed slack* measured as selling, administration, and general expenses scaled by sales; and *unborrowed slack* measured as financial leverage (debt/equity) (Wiengarten et al. 2017). Firms may face higher safety risks when their operations are complex. We included *labor intensity* (total assets per employee) to control for process complexity in operations (Lo et al. 2014). We included research and development *(R&D) intensity*

(R&D expenses per employee) to control for absorptive capacity because learning is more effective in firms with high absorptive capacity (Tsai 2001). We also included *annual number of inspections* of a firm to control for some firms being targeted more often by authorities. The size of a violation penalty relates to the violation type: willful and repeat violations are penalized more vigorously by the OSHA. Thus, we included the percentage of past willful and repeat violations in the total violations to control for the *type of violation experience*.

We included *industrial safety performance* (4-digit SIC code) to control for OHS pressure from competitors. A firm may encounter higher mimetic pressure when the safety performance of its industry competitors is superior. When a firm receives a notice of violation, it may observe how its industry competitors cope with such violations and intensify its search activities for learning (Madsen & Desai 2010). We calculated industry safety performance as the number of violations in the industry divided by industry size (Guler et al. 2002; Yiu et al. 2014). We excluded the focal firm when calculating this variable and reversed the scale to the industry's average number of violations to measure safety performance. The Panel A of Table 2 presented the variable descriptive statistics.

[Table 2 about here]

3.3. Endogeneity

We noted endogeneity concerns in the treatment of regressing subsequent violations on violation experiences. We thus first followed Davidson and MacKinnon (1993) to use the Durbin–Wu–Hausman test to examine the extent of the issue. Specifically, we regressed our key independent variable, *violation experiences*, on selected instruments, namely number of violations in the industry, industry size, and the violation penalty in the industry. A valid instrument should be an exogenous variable and related to *violation experience.* We argue that the enforcement status of a firm's industry should affect the firm's violation experience; in the meantime, industry-level variables are exogenous to the firm. We derived the residual from the regression analysis and generated a variable *violation experiences_res.* We then regressed our dependent variables, repeat and non-repeat violation rate, on *violation experiences_res* and found its coefficient was significant in both models ($p < 0.01$), which indicates the need to cope with endogeneity issues.

Ketokivi and McIntosh (2017) suggested that endogeneity can arise from two sources: reverse causality and omitted confounding factors. We took advantage of the panel data structure to mitigate endogeneity concerns. We mitigate the reverse causality concern through having a time lag between the independent and dependent variables. Unless otherwise stated, the independent variables have a lag of at least 1 year, *t–1*, behind the dependent variable, *t*.

The confounding factors can be fixed effects or time-variant variables. We included the dummy variables of *year*, *industry*, and *state* of a firm's headquarters to mitigate concerns from fixed effect confounding factors such as industry norms and safety regulations. We included the aforementioned control variables to mitigate concerns about observable time-variant confounding factors (Lu & Shang 2017). For unobservable time-variant confounding factors, we adopted a generalized method of moments (GMM) analysis as a robustness check for their impacts (Wiengarten et al. 2017). Section 4.2.5 provide details of the GMM analysis and show that any bias from unobservable time-variant confounding factors is not a serious concern.

4. Results

4.1. Hypothesis Testing

Because the dependent variable (violations per 10,000 employees) is continuously distributed, we followed Lo et al. (2014) and adopted ordinary least squares (OLS) as the estimator. We also adopted alternative estimators including negative binomial, zero-inflated negative binomial and Tobit regressions for robustness checks. The Panel B of Table 2 presents correlations among the variables in our OLS analysis models. Table 3 presents the results from the OLS analysis with robust standard errors. The maximum variance inflation factor (VIF) of the independent variables was 2.437, indicating that multicollinearity is not a serious concern.

[Table 3 about here]

Model 1 examines H1 with the dependent variable set as *repeat violation rate*. We excluded the control firms with no violation records throughout the research window because these firms cannot possibly have repeat violations. We also conducted a separate analysis including all sample and control firms (Appendix Table A), the results of which are largely similar to our main analysis. In Model 1 of Table 2, the coefficient for past *violation experiences* is significantly negative (−0.0024, $p < 0.05$), which supports H1. The coefficient indicates that with one more past violation experience, a firm's subsequent repeat violation rate would be reduced by 0.0024 per 10,000 employees. Given an average repeat violation rate of 0.0340, there is a decrease of 7% (0.0024/0.034) relative to the mean.

Model 2 examines H2 with the dependent variable as *non-repeat violation rate*. The coefficient for past *violation experiences* is significantly positive (0.0293, $p < 0.01$), providing no support for H2. With one more past violation experience, a firm's subsequent non-repeat violation would increase to 0.0293 per 10,000 employees. Given an average non-repeat violation rate of 1.0992, there is an increase of 3%.

Model 3 includes both repeat and non-repeat violations in the dependent variable (total violation rate). The coefficient for past *violation experiences* is significantly positive (0.0265, $p < 0.01$). Given an average total violation rate of 1.1332, one more past violation experience increases the total violation rate by 2%. This result suggests that having violation experiences is associated with a higher overall violation rate (i.e., the sum of violation of the same clause and of different clauses) in the future. Figure 1 illustrates the marginal effect of violation experiences on repeat, non-repeat, and total violation rates.

[Figure 1 about here]

Further analysis results are presented in Table 4 to examine H3 and H4, given that the effectiveness of enforcement is not ideal in reducing non-repeat and total violation numbers. We used non-repeat violation rate in Model 1 and 2, total violation rate in Model 3 and 4 as dependent variables.

We first examined the moderation effects of penalties in Model 1 and 3; the coefficient of *violation experiences*past penalty* is significantly negative in both Model 1 and 3 (−4.7954 and −5.1207, $p < 0.01$). Based on Model 3, moving the value of *past penalty* by one standard deviation (0.0055) weakens the impact of violation experiences on subsequent violations by 50.84%: −0.5084 = (-5.1207*0.0055)/-0.0554. Thus, H3 was supported.

We examined the moderation effects of OHSAS 18001 in Model 2 and 4. The coefficient of *violation experiences*OHSAS 18001* is significantly negative in both models (−0.0515 and −0.0525, $p < 0.01$). Based on Model 4, the impact of violation experiences on subsequent violations is attenuated by 147.46% for firms certified by OHSAS 18001, compared with non-certified firms,. Thus, H4 is supported.

[Table 4 about here]

4.2. Robustness Checks

4.2.1. Timing of Violation Experiences

We used the violations of a firm recorded by the OSHA in all years before year *t* in our treatment of violation experiences. However, one might argue that the impact of recent experiences would be influential (Ingram & Baum 1997). Therefore, we used the number of violations committed in the most recent 5 years ($t-1$, $t-2$, …$t-5$) as an alternative measure of violation experiences. We present the results in Appendix Tables B and C. The dependent variable in Table B is repeat violation rate in year *t*. We found that the coefficient of violation experiences at $t-1$ is significantly negative in Model 1 of Table B (−0.0046, $p < 0.05$), which further supports H1. We observe a depreciation in the effect from $t-2$ to $t-5$. In addition, the dependent variable in Table C is non-repeat violation rate at year *t*. We find that the coefficient of violation experiences at $t-1$ is significantly positive (0.4617, $p < 0.01$). Thus, these results still fail to support H2. They further support the perspective of rational choice and institutional theory: that firms react superficially to violation notices.

4.2.2. Alternative Measures of Dependent Variable and Estimation Methods

In the main analysis, we retained the original form of dependent and independent variables to maintain their practical meaning. This facilitates the interpretation of results and has practical implications for managers. The variables scaled by the number of employees also accounted for the selection bias caused by employee complaint-induced inspections. However, the dependent variables may suffer from skewness. Thus, we performed logarithm transformations to the violation variables, re-ran the analysis, and present the results in Panel A of Appendix Table D. In Model 1, with the dependent variable of repeat violations, the coefficient is significantly negative (−0.0074, $p < 0.01$). In Models 2, with the dependent variable of non-repeat violations, the coefficient is significantly positive (0.1295 in Model 2, $p < 0.01$). These results are consistent with those in Table 3.

As the number of violations was counted from OSHA's database, the count nature of the data raises concerns about the positive skewness of violation variables. We thus used the original annual number of repeat and non-repeat data (not scaled by number of employees) as alternative measures and adopted a negative binomial regression to conduct a robustness check. The negative binomial estimator is suitable for a regression with counted dependent variables. The analysis results are presented in Panel B. The coefficient of violation experiences is significantly negative for Model 1 with repeat violation number as the dependent variable (−0.0090, $p < 0.05$). The coefficient of violation is significantly positive in Model 2 with non-repeat violation number as the dependent variable (0.0160, $p < 0.01$). These results further support H1 and fail to support H2. Thus, skewness concerns are not significant.

Further, our data analysis contains a significant proportion of '0' values in the dependent variable, as violation is a rare event. This may make the variable over dispersed, and affect the estimation. We thus re-ran the above negative binomial regression using a zero-inflated negative binomial estimator to examine the impacts of having excessive '0' values for dependent variables. The analysis results are presented in Panel C. The coefficient of violation experiences is significantly negative for Model 1 with repeat violation number as the dependent variable (−0.0066, $p < 0.1$). The coefficient of violation is significantly positive in Model 2 with non-repeat violation number as the dependent variable (0.0113, $p < 0.01$). These results indicate that any concerns about the rarity of violations does not falsify the main analysis results.

Last, the dependent variables of violation rate are left-censored at zero as they are counted data. The truncated violation data is another way in which our data set might be zero-inflated. The Tobit regression provides an ideal estimator for handling left-censored data; we examined whether such distribution in the dependent variable would bias our analysis results. We then re-ran the models in Table 3 with Tobit regression, and present the results in Panel D. The coefficient of violation experiences is significantly negative in Model 1 with repeat violation number as the dependent variable (−0.0028, $p < 0.1$). The coefficient of violation is significantly positive in Model 2 with non-repeat violation number as the dependent variable (0.0293, $p < 0.01$). These results indicate that the left-censored distribution does not falsify the main analysis results in Table 3.

4.2.3. Alternative Measures of OHSAS 18001

The current measure of OHSAS 18001 certification followed Wiengarten et al. (2017) to capture whether certification is in effect 1 year prior (t−1) to the dependent variable of annual number of violations (year t). Therefore, the results in Table 4 can be interpreted in terms of whether having OHSAS 18001 certification in place can help firms better learn from previous violation experiences to improve their safety performance in a subsequent year.

However, one may argue that timing is essential for the effect of OHSAS 18001. We thus used the number of years that OHSAS 18001 has been in place in a firm at year t as an alternative measure, and conducted a robustness check. We performed a natural logarithm transformation to correct for the skewness of this variable. This alternative measure accounts for the timing of OHSAS 18001 adoption and the firm's experience of operating with a voluntary standard. Our robustness check finds that the coefficient of the interaction term *violation experiences*OHSAS 18001 experience* is significantly negative (−0.018, $p < 0.01$), providing additional support for H4.

4.2.4. Moderation Effects on Repeat Violation Rate

We used non-repeat violation and total violation rate as dependent variables to examine moderation effects in our further analysis. We conducted additional analyses by replacing the dependent variable with *repeat violation rate* (results in Appendix Table E). We find that all interaction terms are non-significant ($p > 0.1$) for repeat violations, as shown in Table E. Therefore, we conclude that current enforcement is effective enough to reduce future repeat violations. Additional institutional pressure would not further increase its effectiveness. These analyses provide additional support and boundary conditions for our analysis.

4.2.5. GMM Analysis

In our primary models, we developed a panel data set for analysis of the collected data. A panel data analysis has the advantage of being able to mitigate certain endogeneity risks (Ketokivi & Mcintosh 2017). First, our independent variables had a time lag relative to the dependent variables to rule out an alternative explanation of reverse causality. Second, we included the dummy variables of *year, industry*, and *state* to control for unmodeled time-invariant effects such as regulations, seasonal factors related to industry, and law enforcement differences across states. However, the time differences present in the unmodeled variables may raise endogeneity concerns during result evaluation. These concerns might stem from the possibility that unobserved factors affect(s) both independent and dependent variables, leading to alternative explanations. For example, a manager's risk propensity, moral expectations, and management may affect the firm's historical and sequential safety performance. Statistically speaking, such endogeneity concerns arise because the independent variable (*violation experiences*) is correlated with the disturbance term (error term) (Semadeni et al. 2014). This correlation can cause bias in the estimation of the coefficient for the independent variable.

In view of the above, we emulated previous studies using panel data and conducted a GMM analysis in addition to the OLS analysis to examine the risk of endogeneity (Lam et al. 2016; Wiengarten et al. 2017). GMM uses the lagged values of endogenous variables as instrumental variables and reduces the bias caused by endogeneity (Roodman 2009). Instrumental variables are exogenous variables that help split off the part of the endogenous variable that is correlated with the disturbance term (Woodridge 2015). Therefore, instrumental variables should be correlated with endogenous variables but not the disturbance term (Woodridge 2015). Although instrumental variable techniques could mitigate the endogeneity risk, endogenous variables were instrumented so their practical meanings were lost. Therefore, our hypothesis testing and marginal effect discussion are based mainly on the OLS results; the GMM analysis examined whether endogeneity issues from unobserved random variables could falsify our OLS results.

In our GMM analysis, we used the lagged value of *violation experiences* and the interaction terms as instrumental variables (Senot et al. 2016). Appendix Table F presents the GMM analysis results. The dependent variables in Models 1 and 2 are repeat violation rates; those in Models 3 and 4 are non-repeat violation rates; and those in Models 5 and 6 are total violation rates. The results from the Arellano and Bond (1991), Sargan (1958), and Hansen (1982) tests indicate that the lagged values are valid instruments that can address endogeneity concerns in the GMM models. Specifically, in Models 1 and 2, neither the first-order autocorrelation (AR1) nor the second-order autocorrelation (AR2) are significant ($p > 0.1$). In Models 3–6, the AR1 is significant ($p < 0.1$), but not in AR2 ($p > 0.1$). In addition, neither the Hansen nor the Sargan test is significant for all models ($p > 0.1$). Thus, it could be concluded that the instrumental variables were exogenous and not correlated with the disturbance terms, whereas the GMM model mitigated the risk of endogeneity arising from unmodeled random variables.

Models 1 and 3 examine H1 and H2 respectively by including *violation experiences*. The coefficient of violation experiences in Model 1 is negative and significant (−0.0446, $p < 0.01$), whereas in Model 3 it is positive and significant (0.0225, $p < 0.01$). The coefficient of violation experiences in Model 5 is also positive and significant (0.0206, $p < 0.01$). These results are similar to the results in Table 3 and mitigate the endogeneity concern.

Models 2, 4, and 6 examine the moderating hypotheses by including the interaction terms between *violation experiences* and the three moderators. Since the interaction terms were instrumented, potential multicollinearity among the interaction terms was interpreted as mitigated. Therefore, we included the three interaction terms in the same model. The results would remain unchanged if we added the interaction terms separately. All the coefficients of interaction terms are non-significant in Model 2 for repeat violations ($p > 0.1$). The coefficients of *violation experiences*past penalty* (−0.7877, $p < 0.01$), *violation experiences*OHSAS 18001* (−0.0371, $p < 0.01$). These results are similar to the OLS analysis results in Table 4. Last, the coefficients of *violation experiences*past penalty* (−1.0205, $p < 0.01$), *violation experiences*OHSAS 18001* (−0.0379, $p < 0.01$), and *violation experiences*safety performance of industry competitors* (−0.0011, $p < 0.01$) are significantly negative in Model 6. These results are consistent with those in Table 3, lending further support to H2 and H3. Therefore, the GMM analysis results are consistent with those from the OLS analysis, which suggests that the endogeneity risk of OLS analysis is not of serious concern.

5. Discussion and Conclusions

This study has explored the relationship between past safety violation experiences and subsequent repeat, non-repeat, and overall safety violations. It has presented an analysis of a sample set of 2,965 listed US firms with 4,474 violations issued by the OSHA. We found that past violation experience is negatively correlated with subsequent repeat violation incidents, which show a certain level of improvement after a firm’s violation is detected and corrective action is taken. However, past violation experience are positively correlated with subsequent non-repeat violation and overall violation incidents. This shows that firms do not necessarily reduce their number of safety violations as they accumulate more safety violation experiences. However, in our further analysis we found that firms with more severe past violation penalties (fines) and OHSAS 18001 certification display greater tendencies to extensively and proactively learn from their past violation experiences, leading to a reduction in subsequent overall violations.

5.1. Theoretical Contributions

These findings directly contribute to the safety management in operations management domain. Previous studies have substantially investigated the antecedents of firms' safety violation behavior, including lean operations (Longoni et al., 2013), debt pressure (Pagell et al. 2019), operational slacks (Wiengarten et al. 2017), and voluntary OHS management systems (Lo et al. 2014). Unlike those studies, investigating from an internal and organizational perspective, this study has explored the role of government as a powerful external stakeholder in firms' safety violation behavior.

Although a mandatory OHS management system is expected to be implemented by every firm, the literature questions the effectiveness of enforcement to ensure firms operate in compliance with mandatory safety standards (Levine et al. 2012). Unlike most studies in the field investigating the impacts of inspections on firms' workplace injuries (e.g. Haviland et al. 2010), this study has taken a fresh perspective to understand a firm's violation experiences and their impacts on subsequent violation behavior. Our findings are intuitive in that they show that these experiences help reduce future similar mistakes, while it is counterintuitive to find that violation experiences increase future non-repeat and overall violations. We provide several plausible explanations for this phenomenon. Our literature review found that a similar phenomenon has been observed in failure cases involving product recall (Haunschild & Rhee 2004) and minor operating incidents (Tong et al. 2021). Despite the fact that legal enforcement may improve firms' operational systems, Haunschild and Rhee (2004) found that the lessons learned from previous mandated product recall experiences can be shallow and symbolic, leading to no fundamental improvement in firms' product safety routines and practices. Therefore, it is possible that mandated improvements enforced by government authorities may simply be adaptive and reactive within a limited scope (Scholz & Gray 1997). Our findings are also in line with the proposition of organizational myopia: that is, adaptive corrective actions could cause firms to overlook the big picture and other potential failures (Levinthal & March 1993). This is especially the case when adaptive improvements are mandated by external parties (Haunschild & Rhee 2004).

The findings of limited improvement driven by enforcement add value to our investigation of the factors that enhance enforcement effectiveness. From an economic perspective, if the expected penalties are smaller than the investment required to explore potential hazards, the deterrent effect of violation would be insufficient to motivate proactive improvement (Greve et al. 2010). The public and scholars have long criticized OSHA penalties as too low (US Government Printing Office 2008; Viscusi 1979). Our findings show that an increase in violation penalty may enhance the effectiveness of enforcement. This finding is in line with a recent study's finding that penalties can reduce firms' environmental violations (Wang et al. 2019).

This study also responds to the call for investigation of the integration between mandatory and voluntary OHS management system (Fan et al. 2014). Our findings suggest that safety enforcement, as a vital part of a mandatory OHS management system, are more effective in firms with OHSAS 18001 certification. This study also extends the research field of voluntary OHS management systems. The literature shows that OHSAS 18001 certification has a direct positive impact on a firm's safety performance, such as its safety climate (Fernández-Muñiz et al. 2012), and number of safety violations (Lo et al. 2014) and accidents (Heras-Saizarbitoria et al. 2019). This study has taken a different perspective to explore the indirect effects of OHSAS 18001. Specifically, this study found another path by which OHSAS 18001 can improve firms' safety performance, by working with safety enforcement.

5.2. Implications for Managers

The literature identifies superior improvement effects from additional experiences of errors (e.g., Catino & Patriotta 2013) and accidents (e.g., Haunschild & Sullivan 2002; Hofmann & Stetzer 1998). However, consistent with the notion related to organizational myopia (Levinthal & March 1993) and the shallow learning effect from mandated product recall (Haunschild & Rhee 2004), our results show that adaptive corrective action in response to past violations hinders the proactive exploration of other hidden hazards in the system. Table 3 shows that adding one violation to the mean of *violation experiences* (from 3.2898 to 4.2898) increases the mean violation rate per year by 0.0265.

Our results have implications for managers in that violation experiences can be valuable ways for them to learn proactively and to improve safety performance with the possession of OHSAS 18001 certification, which might promote normative and mimetic pressure from outside professional parties. Based on our results from Model 4 (see Table 4), firms with OHSAS 18001 certification are 147.46% more likely to reduce subsequent violations (coefficient = −0.0169) than firms without it (coefficient = 0.0356). Therefore, managers should see the merit of integrating a voluntary OHS management system with the current mandatory OHS management system.

5.3. Implications for Regulators

We found that the presence of institutional forces drives broader improvement triggered by past safety violations. First, our results suggest that increasing the violation penalty forces firms to prevent future violations to avoid incurring penalties. In 2016, the OSHA increased the maximum penalty of all types of violation by 78.16%, from US$70,000 to US$124,709 (OSHA 2017b). Based on our results in Model 3 of Table 4, if the average penalty (currently only US$1,700 in our sample) could be increased by the amount in US$54,709; we also estimate that the violation rate can be attenuated by 505.23%. However, most heavy penalties that are close to the maximum are willful and repeat violation cases, which are quite rare. Considering the penalty alone, our results suggest that the average penalty for each violation should be increased to beyond US$10,828 to create a negative correlation in the relationship between past violation experience and subsequent violation behavior (i.e., making past violation experiences reduce subsequent violations).

5.4. Limitations and Future Research

We implemented various measures to increase the robustness of this research. First, we included relevant control variables in our models to address concerns regarding alternative explanations. Second, we introduced time lags between the independent and dependent variables, which rules out reverse causality concerns. Third, we applied GMM for data analysis to mitigate the endogeneity concerns from unobserved variables. However, this study also has several limitations that need to be addressed in future research. Our sample was collected in the US, where safety regulations are comprehensive. In addition, the use of secondary data limits us in terms of exploring the role of safety climate and culture on a firm's safety violation. Future research might combine secondary and primary data to address this point. Further, we focused on a firm's violation experience instead of operational accidents. Workplace accidents may cause lost worktime, so could be a more impactful alert for managers to improve safety practices. Future research could collect occupational injury data and examine its impact on firms' subsequent violation behavior. Further, our sample includes only listed firms, which have abundant resources to ensure strong safety practices. The analysis results may have been different if small and medium-size enterprises (SMEs) had been included in the analysis. SMEs have less complex organizational structure and fewer resources for managing safety. Future research might sample both listed and private firms and examine the generalizability of our findings. Moreover, this study investigates the role of the helping hand provided by a voluntary OHS management system in mandatory OHS management systems. Future research might compare effectiveness between the two systems. Last, this study has focused on organizational responses to failure experiences in the safety context, whereas future research may explore learning from successful experiences. Because safety failure experiences are normally limited to high-reliability organizations such as nuclear plants and air carriers, researching successful experiences may help identify further implications for these organizations. This study has focused solely on experiential learning. Future research might explore the role of social learning in mitigating safety violations.

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Tables

Table 1. Prediction of Relationships between Violation Experiences and Subsequent Violations from the Rational Choice, Institutional and Behavioral Shock (BToF) Perspectives

Theoretical lens	Conceptualization of OHS violations	Prediction direction	Mechanism	Scope of improvement	Support
Rational choice	Rational decision after evaluating cost of compliance *vs*. cost of violation	Reduce	Corrective actions are monitored; cost of not taking corrective action is high	Limited to the field of violation	H1 and H2a
Institutional theory	Failure to conform to coercive pressure from government	Reduce	Corrective actions prompted by conforming to coercive pressure from government	Limited to the field of violation	H1 and H2a
BToF	Behavioral shocks signaling latent problems in operations	Reduce	Problemistic search: proactive learning for improvement caused by behavioral shock	Expands beyond the field of violation	H1 and H2b

Table 2. Panel A: Variable Descriptions and Descriptive Statistics

	Variable	Mean	Std. deviation	Measure
1	Repeat violation rate (per 10000 employees)	0.0340	1.0508	Annual number of repeat violations per 10 thousand employees
2	Non-repeat violation rate (per 10000 employees)	1.0992	14.2866	Annual number of non-repeat violations per 10 thousand employees
3	Total violation rate (per 10000 employees)	1.1332	14.2574	Annual number of overall violations per 10 thousand employees
4	Operations experiences	13.2249	5.5197	Number of years with no violations recorded
5	Inspection (times)	0.3178	1.3977	Annual number of OSHA inspections
6	RD intensity (thousand USD)	34.3521	108.1755	R&D expenses per number of employees
7	ROA	–0.1426	3.0978	Operating income/total assets
8	Productivity (thousand USD)	–7.4225	530.6779	Operating income per employee
9	Absorbed slack (thousand USD)	1.208	29.7886	SG&A expenses/sales
10	Unborrowed slack	2.5144	0.2073	Financial leverage = debt/equity (natural logarithm transformed); untransformed mean: 12.3592
11	Unabsorbed slack (thousand USD)	2.4318	8.0437	Quick ratio = (current assets – inventory)/current liabilities
12	Labor intensity (thousand USD)	380.058	908.7652	Total assets per employee
13	Firm size (log)	–0.0981	2.4123	Natural logarithm-transformed number of employees (thousand); untransformed mean: 907
14	Violation types in past experiences	0.0204	0.1744	Percentage of past willful and repeat violations in the firm's total violation experiences
15	Safety performance of industry competitors (times)	–2.5618	4.5434	Reversed scaled of (number of violations in the industry – focal firm's number of violations)/industry size
16	OHSAS 18001	0.0561	0.2301	Whether the firm has an OHSAS 18001 certification in place in the focal year
17	Past penalty (million USD)	0.0017	0.0055	Average penalty for a firm's past violations
18	Violation experiences (times)	3.2898	12.3233	Total number of violations a firm committed in all years before the focal year

Table 2. Panel B: Pearson Correlations (* denotes statistical significance at 0.05 level)

		1	2	3	4	5	6	7	8	9
1	Repeat violation rate									
2	Non-repeat violation rate	–0.0645*								
3	Total violation rate	0.0091	0.9973*							
4	Operations experiences	–0.0246*	–0.0347*	–0.0366*						
5	Inspection (times)	0.0510*	0.0170*	0.0208*	–0.2490*					
6	RD intensity (thousand USD)	–0.0091	–0.0035	–0.0042	0.0149*	–0.0589*				
7	ROA	0.0026	–0.0004	–0.0002	0.0180*	0.0163*	–0.0745*			
8	Productivity (thousand USD)	0.0023	–0.0039	–0.0037	0.0337*	0.0139*	–0.2155*	0.0841*		
9	Absorbed slack (thousand USD))	–0.0011	–0.0018	–0.0019	–0.0026	–0.0080	0.0804*	–0.1228*	–0.0535*	
10	Unborrowed slack	–0.0059	0.0033	0.0028	0.0367*	–0.0997*	0.1037*	0.0465*	–0.0222*	-0.0086
11	Unabsorbed slack (thousand USD)	–0.0005	–0.0025	–0.0025	0.0093	–0.0357*	0.1001*	0.0087	–0.0147*	0.0011
12	Labor intensity (thousand USD)	–0.0036	–0.0101	–0.0103	0.0628*	–0.0163*	0.2097*	0.0166*	0.4670*	0.0094
13	Firm size (log)	–0.0051	–0.0499*	–0.0504*	0.0036	0.2483*	–0.2570*	0.1301*	0.1024*	-0.0576*
14	Violation types in past experiences	0.0290*	0.0189*	0.0211*	–0.1370*	0.1716*	–0.0322*	0.0086	0.0081	-0.0042
15	Safety performance of industry competitors (times)	–0.0013	–0.0026	–0.0026	0.1513*	–0.1331*	0.0143*	–0.0087	–0.0060	0.0080
16	OHSAS 18001	–0.0070	–0.0156*	–0.0162*	0.0665*	0.0217*	–0.0336*	0.0189*	0.0273*	-0.0081
17	Past penalty (million USD)	0.0400*	0.0147*	0.0177*	–0.1026*	0.1892*	–0.0700*	0.0213*	0.0180*	-0.0102
18	Violation experiences (times)	0.0236*	0.0252*	0.0270*	–0.2813*	0.6986*	–0.0679*	0.0190*	0.0165*	-0.0093

		10	11	12	13	14	15	16	17
11	Unabsorbed slack	0.4497*							
12	Labor intensity	0.1017*	0.1631*						
13	Firm size	–0.2741*	–0.1247*	–0.0597*					
14	Violation types in past experiences	–0.0583*	–0.0196*	–0.0084	0.1044*				
15	Safety performance of industry competitors	0.0635*	0.0237*	–0.0434*	–0.1166*	–0.0883*			
16	OHSAS 18001	–0.0869*	–0.0302*	0.0313*	0.3330*	0.0475*	–0.0166*		
17	Past penalty	–0.0890*	–0.0331*	–0.0127*	0.1877*	0.2387*	–0.0567*	0.0605*	
18	Violation experiences	–0.1171*	–0.0411*	–0.0152*	0.2854*	0.2256*	–0.0973*	0.1033*	0.2197*

Table 3. Regression Analysis of Safety Violations

	Model 1 (N = 8294)			Model 2 (N = 25273)			Model 3 (N = 25273)		
	DV (H1): Repeat violation rate (of the same clauses)			DV (H2): Non-repeat violation rate (of different clauses)			DV: Total violation rate		
Independent variable	Coef.		S.E.	Coef.		S.E.	Coef.		S.E.
Operations experiences	–0.0045		0.006	–0.0650	**	0.0250	–0.0673	**	0.025
Inspection	0.0497	**	0.011	0.0063		0.0470	0.0566		0.047
RD intensity	–0.0004		0.000	–0.0010		0.0010	–0.0010		0.001
ROA	0.2723	+	0.158	0.0317	**	0.0110	0.0329	**	0.011
Productivity	0.0001		0.000	0.0001	*	0.0000	0.0001	*	0.000
Absorbed slack	0.0009		0.016	–0.0014		0.0010	–0.0015		0.001
Unborrowed slack	–0.3915		0.361	–0.4168		0.8400	–0.4242		0.839
Unabsorbed slack	0.0363		0.032	–0.0035		0.0070	–0.0031		0.007
Labor intensity	0.0000		0.000	–0.0002	**	0.0000	–0.0002	**	0.000
Firm size	–0.0541	**	0.017	–0.4614	**	0.0710	–0.4730	**	0.071
Violation types in past experiences	0.0958		0.068	0.8396	+	0.4940	0.9421	+	0.492
Safety performance of industry competitors	0.0018		0.002	0.0014		0.0160	0.0037		0.016
OHSAS 18001	0.0407	+	0.024	0.2653	*	0.1340	0.2679	*	0.134
Past penalty	5.1549		4.854	28.0712	**	10.3850	33.5683	**	11.113
Violation experiences	–0.0024	*	0.001	0.0293	**	0.0060	0.0265	**	0.006
F-test	1.25	**		7.45	**		8.27	**	

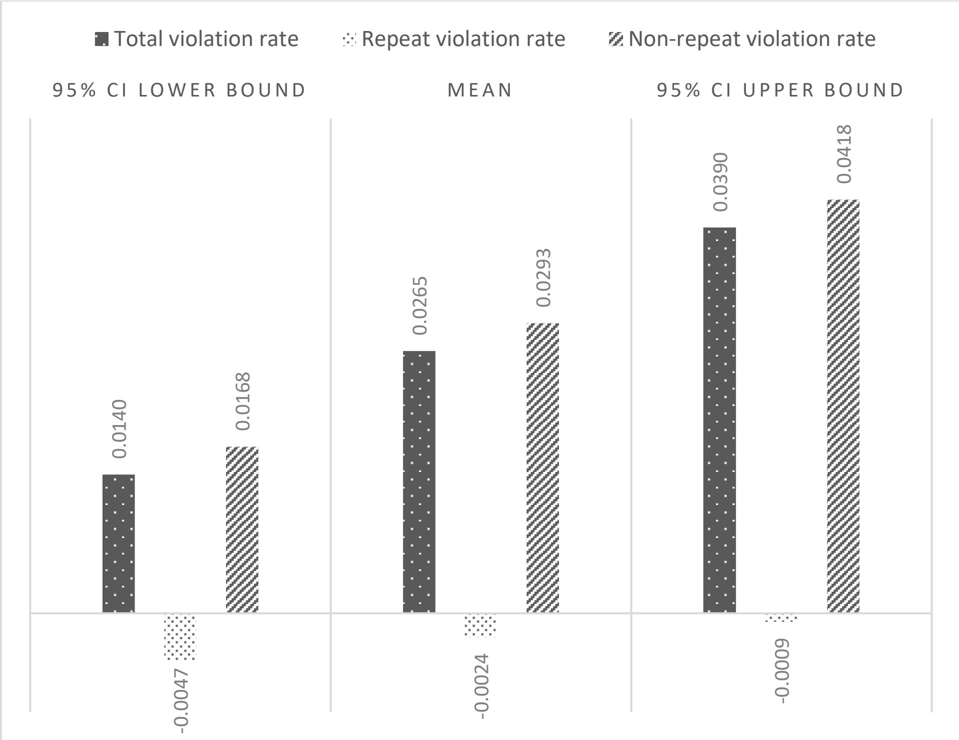
Note: DV, dependent variable; two-tailed tests with dummy variables of year, industry, and state included; 0.0000 indicates <0.0001; violation rate = number of violations per 10,000 employees. **, *, and + denote statistical significance at 0.01, 0.05, and 0.1 levels.

Table 4. Analysis of Reducing Safety Violations

N = 25273	Model 1			Model 2			Model 3			Model 4		
	DV: Non-repeat violation rate						DV: Total violation rate					
	Moderating effect of penalty			Moderating effect of OHSAS			Moderating effect of penalty			Moderating effect of OHSAS		
Independent variable	Coef.		S.E.	Coef.		S.E.	Coef.		S.E.	Coef.		S.E.
Operations experiences	–0.0637	**	0.025	–0.0668	**	0.025	–0.0660	**	0.025	–0.0692	**	0.025
Inspection	0.0068		0.048	–0.0201		0.048	0.0571		0.048	0.0297		0.047
RD intensity	–0.0009		0.001	–0.0010		0.001	–0.0010		0.001	–0.0010		0.001
ROA	0.0314	**	0.011	0.0319	**	0.011	0.0326	**	0.011	0.0331	**	0.011
Productivity	0.0001	*	0.000	0.0001	*	0.000	0.0001	*	0.000	0.0001	*	0.000
Absorbed slack	–0.0014		0.001	–0.0015		0.001	–0.0015		0.001	–0.0015		0.001
Unborrowed slack	–0.4213		0.840	–0.4172		0.840	–0.4290		0.839	–0.4247		0.839
Unabsorbed slack	–0.0036		0.007	–0.0035		0.007	–0.0032		0.007	–0.0031		0.007
Labor intensity	–0.0001	**	0.000	–0.0002	**	0.000	–0.0002	**	0.000	–0.0002	**	0.000
Firm size	–0.4661	**	0.071	–0.4677	**	0.071	–0.4781	**	0.071	–0.4795	**	0.071
Violation types in past experiences	0.9814	*	0.501	0.9037	’+	0.495	1.0935	*	0.499	1.0075	*	0.493
Safety performance of industry competitors	0.0017		0.016	0.0026		0.016	0.0040		0.016	0.0049		0.016
OHSAS 18001	0.2669	*	0.134	0.6832	**	0.145	0.2697	*	0.134	0.6943	**	0.145
Past penalty	55.2416	**	12.363	28.1153	**	10.375	62.5822	**	13.305	33.6132	**	11.105
Violation experiences	0.0564	**	0.008	0.0383	**	0.007	0.0554	**	0.008	0.0356	**	0.007
Violation experiences*Past penalty	–4.7954	**	0.668				–5.1207	**	0.689			
Violation experiences*OHSAS 18001				–0.0515	**	0.006				–0.0525	**	0.006
F-test	7.56	**		7.58	**		8.37	**		8.42	**	

Note: DV, dependent variable; two-tailed tests with dummy variables of year, industry, and state included; 0.0000 indicates <0.0001. **, *, and + denote statistical significance at 0.01, 0.05, and 0.1 levels.

Figure 1. Marginal Effect of Violation Experience (1-unit change) on Repeat, Non-Repeat, and Total Violation Rate



Appendix (online supplement)

Table A. Repeat Violation Analysis, Full Sample Set

N = 25273	Model 1		
	DV: Repeat violation rate		
Independent variable	Coefficient		S.E.
Operations experiences	–0.0023		0.002
Inspection	0.0503	**	0.011
RD intensity	0.0000	+	0.000
ROA	0.0012	*	0.001
Productivity	0.0000	*	0.000
Absorbed slack	0.0000		0.000
Unborrowed slack	–0.0074		0.024
Unabsorbed slack	0.0004		0.001
Labor intensity	0.0000	+	0.000
Firm size	–0.0117	**	0.003
Violation types of past experiences	0.1025		0.065
Safety performance of industry competitors	0.0023		0.002
OHSAS 18001	0.0026		0.008
Past penalty	5.4970		3.953
Violation experiences	–0.0028	**	0.001
F-test	1.2600	**	

Note: DV, dependent variable; two-tailed tests with dummy variables of year, industry, and state included; 0.0000 indicates <0.0001; **, *, and + denote statistical significance at 0.01, 0.05, and 0.1 levels.

Table B. Impact Depreciation of Violation Experiences on Repeat Violations

	Dependent variable: Repeat violation rate														
Variables (at year *t*)	Model 1: Violation experience at *t*–1			Model 2: Violation experience at *t*–2			Model 3: Violation experience at *t*–3			Model 4: Violation experience at *t*–4			Model 5: Violation experience at *t*–5		
	Coef.		S.E.	Coef.		S.E.	Coef.		S.E.	Coef.		S.E.	Coef.		S.E.
Violation experiences	–0.0046	*	0.002	–0.0012		0.003	–0.0021		0.003	–0.0006		0.003	–0.0006		0.003
Incremental Log-likelihood	453.655	**		410.062	**		386.718	**		365.87	**		258.528	**	
N	7,679			6,995			6,321			5,666			5,031		

Note: All control variables included but not shown for simplicity; two-tailed test；0.0000 indicates <0.0001. **, *, and + denote statistical significance at 0.01, 0.05, and 0.1 levels.

Table C. Impact Depreciation of Violation Experiences on Non-Repeat Violations

	Dependent variable: Non-repeat violation rate														
Variable (at year *t*)	Model 1: Violation experience at *t*–1			Model 2: Violation experience at *t*–2			Model 3: Violation experience at *t*–3			Model 4: Violation experience at *t*–4			Model 5: Violation experience at *t*–5		
	Coef.		S.E.	Coef.		S.E.	Coef.		S.E.	Coef.		S.E.	Coef.		S.E.
Violation experiences	0.4617	**	0.137	0.1295	+	0.071	0.2023	*	0.081	0.2227	**	0.083	0.2465	**	0.084
Incremental Log-likelihood	97.72	**		88.92	**		86.72	**		85.85	**		75.82	*	
N	22,735			20,356			18,125			16,041			14,077		

Note: All control variables included but not shown for simplicity; two-tailed test；0.0000 indicates <0.0001. **, *, and + denote statistical significance at 0.01, 0.05, and 0.1 levels

Table D. Alternative Measurements of Dependent Variables and Estimation methods

Panel A: Regression Analysis of Safety Violations (Logarithm Transformed)

	Model 1			Model 2		
	DV: Repeat violation (Log)			DV: Non-repeat violation (Log)		
Independent variable	Coef.		S.E.	Coef.		S.E.
Violation experiences (log)	–0.0074	**	0.002	0.1295	**	0.004
F-test	3.33	**		72.82	**	

Panel B: Negative Binomial Regression Analysis of Safety Violations

	Model 1			Model 2		
	DV: Annual repeat violation number			DV: Annual non-repeat violation number		
Independent variable	Coef.		S.E.	Coef.		S.E.
Violation experiences	–0.0090	*	0.004	0.0160	**	0.002
Chi^2	568.25	**		4839.78	**	

Panel C: Zero-inflation Negative Binomial Regression Analysis of Safety Violations

	Model 1			Model 2		
	DV: Annual repeat violation number			DV: Annual non-repeat violation number		
Independent variable	Coef.		S.E.	Coef.		S.E.
Violation experiences	–0.0066	+	0.003	0.0113	**	0.001
Chi^2	234.08	**		1974.92	**	

Panel D: Tobit Regression Analysis of Safety Violations

	Model 1			Model 2		
	DV: Repeat violation rate			DV: Repeat violation rate		
Independent variable	Coef.		S.E.	Coef.		S.E.
Violation experiences	–0.0028	**	0.001	0.0293	**	0.011
Chi^2	167.97	**		210.59	**	

Note: DV, dependent variable; two-tailed tests with all control variables included; 0.0000 indicates <0.0001; violation rate = number of violations per 10,000 employees; N = 25273; **, *, and+ denote statistical significance at 0.01, 0.05, and 0.1 levels.

Table E. Moderation Analysis of Safety Violations DV: Repeat Violation Rate

N = 8294	Model 1			Model 2		
	Moderating effect of penalty			Moderating effect of OHSAS		
Independent variable	Coef.		S.E.	Coef.		S.E.
Violation experiences	–0.0012		0.001	–0.0023	+	0.001
Violation experiences*Past penalty	–0.2219		0.175			
Violation experiences*OHSAS 18001				–0.0009		0.001
F-test	1.2300			1.2300		

Note: Two-tailed tests with all control variables included; 0.0000 indicates <0.0001; violation rate = number of violations per 10,000 employees; N = 25273; **, *, and + denote statistical significance at 0.01, 0.05, and 0.1 levels.

Table F. GMM Analysis

	DV: Repeat violation rate						DV: Non-repeat violation rate						DV: Total violation rate					
	Model 1			Model 2			Model 3			Model 4			Model 5			Model 6		
Independent variable	Coef.	S.E.	*p*	Coef.	S.E.	*p*	Coef.	S.E.	*p*	Coef.	S.E.	*p*	Coef.	S.E.	*p*	Coef.	S.E.	*p*
Violation experiences	–0.0446	0.017	0.007	–0.0282	0.022	0.203	0.0225	0.001	0.000	0.0269	0.001	0.000	0.0206	0.001	0.000	0.0255	0.001	0.000
Violation experiences*Past penalty (H2)				–3.8614	3.114	0.215				–0.7877	0.141	0.000				–1.0205	0.135	0.000
Violation experiences*OHSAS 18001 (H3)				0.0111	0.020	0.580				–0.0371	0.001	0.000				–0.0379	0.001	0.000
Chi^2			0.000			0.000			0.000			0.000			0.000			0.000
AR1			0.221			0.219			0.025			0.029			0.029			0.035
AR2			0.414			0.364			0.604			0.612			0.586			0.581
Hansen test			1.000			1.000			1.000			1.000			1.000			1.000
Sargan test			0.149			0.296			0.200			0.247			0.186			0.311

Note: DV, dependent variable; two-tailed tests with all control variables included but not shown for simplicity; 0.0000 indicates <0.0001; *p*-values provided for assessing instrument validity.