**Title:** *“The differing impacts of operational and financial slack on occupational safety in varying market conditions”*

**Abstract:** Operations management scholars have long debated the right level of slack resources required to optimize a production system. Recent research suggests that the right level of operational slack, typically in the form of inventory, is very little but not none. However, this conclusion was reached without considering the role of slack resources in occupational safety, which is a critical oversight since the safety literature predicts that the reduction of operational slack harms workers. To address this gap, secondary data from 3,945 publically listed U.S. firms is used to explore the role of operational and financial slack as well as market factors in occupational safety. The results show that decreasing operational slack harms workers and that this effect is mitigated when firms hold higher levels of financial slack. Furthermore, the external market environment also plays a crucial role in the operational slack – safety relationship.

**Keywords:** occupational health and safety, operational slack, financial slack, market environments, secondary data

**1. Introduction**

The essence of operations management is transforming inputs into outputs in an efficient and effective manner. Being efficient and effective has traditionally meant managing an operation or supply chain with low levels of extra or slack resources and capacities (Eroglu and Hofer, 2011).

Slack is “*the pool of resources in an organization that is in excess of the minimum necessary to produce a given level of organizational output*” (Nohria and Gulati, 1996, p. 1246). Managers focus their efforts on finding the optimal level of slack, which for most firms means less slack. Modi and Mishra (2011) identified that at most 10% of firms would benefit from increasing their level of slack and operations management research on operational slack has generally concluded that reducing slack improves operational performance (to a point) when performance is operationalized as profits, cost, quality, delivery and flexibility (Eroglu and Hofer, 2011; Modi and Mishra, 2011; Kovach *et al.,* 2015). In addition, the increased focus on creating more sustainable operations has highlighted that reducing slack is also associated with more efficient use of resources and less pollution (e.g., King and Lenox, 2001).

The discourse in operations on the optimal level of slack mirrors the long running debate on the relative merits of slack resources in the organizational literature (e.g., March and Simon, 1958; Sonenshein, 2014; Kovach *et al.,* 2015). Slack can provide organizations with opportunities to develop new products and enter new markets or it can be a financial burden and indicative of inefficiencies (Tan and Peng, 2003). The arguments for slack posit that slack resources are a useful buffer (Bourgeois, 1981) that allow a firm to innovate (Nohria and Gulati, 1996), survive environmental changes or supply chain disruptions (Hendricks *et al.,* 2009) and profit (Lawson, 2001). Agency theorists on the other hand argue that managers (i.e., agents) accrue and misuse slack resources because of agency problems (Jensen, 1993). In the operations management literature the debate has generally focused on the potential to reduce costs by removing slack (Eroglu and Hofer, 2011).

We enter this discourse from a different perspective by examining the role of operational slack in terms of the safety of operational workers. Safety regulations and safety management systems are designed to protect workers from harm in the form of injuries and occupational illnesses that occur at work (Pagell *et al.,* 2014); a safe production system is one where workers are not harmed when producing goods or services. The recent focus on creating more sustainable operations has lead researchers to expand the conceptualization of operational performance to explicitly consider safety as a primary operational outcome (Brown *et al.,* 2000; Pagell *et al.,* 2015). Research on the linkages between safety and other operational outcomes suggests that quality and safety often move in tandem (e.g., Brown, 1996; Das *et al.,* 2008) and that safety need not be traded off for other operational goals if appropriate managerial systems are in place (Lo *et al.,* 2014; Pagell *et al.,* 2015). However, industrial accidents are still very common and in many firms there is still a tension between creating a safe production system and achieving other operational goals, such as reducing waste (e.g., Pagell *et al.,* 2015).

The operational literature concludes that slack, if not employed strategically to purposefully decouple processes, is inefficient. Yet, safety researchers have concluded that reducing operational slack harms workers (Das *et al.,* 2008; Love *et al.,* 2015). For instance, econometric research shows that a 1% increase in capacity utilization (a decrease in operational slack) in manufacturing firms in the USA is associated with a .69% increase in workplace injuries (Asfaw *et al.,* 2011). Understanding slack’s relationship with safety may help to explain why there is a tension between safety and other operational outcomes in many firms. Therefore, the critical managerial and policy issue this research addresses is that the literature suggests that the relationship between operational slack and safety could be different from the relationship between operational slack and other operational outcomes.

Safety is a primary metric of operational performance and a basic indicator of the social sustainability of a firm. Hence, efforts to become more operationally efficient may harm the workforce and hinder efforts to make an operation more socially sustainable. Much of the existing debate on slack addresses the question of if slack resources are good or bad for firm economic and operational performance. By considering safety as an operational outcome this research addresses the possibility that the level of slack creates trade-offs between various forms of operational performance. This suggests a more complex relationship between slack and various operational and firm outcomes.

Workers and communities are directly and negatively impacted by poor safety. Safety is then an important operational and societal outcome and if tradeoffs do exist they will matter to managers and a wide range of societal stakeholders. Therefore, this research takes a multi-stakeholder perspective and explores the relationship between slack and worker safety from both the firm’s perspective and from the perspective of regulators as representatives for society.

The present discourse on slack is fragmented with managerial scholars focusing mainly on economic outcomes like quality or profits while safety researchers only examine worker outcomes. Few studies have considered the impact of having little or no slack on safety (Filer and Golbe, 2003). Slack resources can be used to respond to environmental uncertainty, supply chain disruptions, or engage in risky innovation projects (Bourgeois, 1981; Nohria and Gulati, 1996; Love and Nohria, 2005; Hendricks *et al.,* 2009). “*Slack resources include excess inputs such as redundant employees, unused capacity, and unnecessary capital expenditures. They also include unexploited opportunities to increase outputs, such as increases in the margins and revenues that might be derived from customers and innovations that might push a firm closer to the technology frontier”* (Nohria and Gultati, 1996, p. 1246).

Slack then has two dimensions: Excess inputs or resources and unexploited opportunities (Nohria and Gultati, 1996). In this research we explore the input dimension of slack via operational slack and the opportunity dimension of slack via financial slack. “*Operational slack represents the buffer resources available to support the operational activities of a firm and allows firms to better match variations between supply and demand… Excess capacity and inventory (each representing a form of operational slack) help firms effectively manage demand variation for their products*” (Kovach et al., 2015, p. 1). Financial slack is a form of Nohria and Gultai’s (1996) unexploited opportunities in that the ability to take on further debt, deploy retained earnings or sell assets allows a firm to respond to threats and opportunities (Lungeanu *et al.,* 2016).

We posit that one of the reasons for the divergent views of slack in the literature is that operational and financial slack have different organizational roles and lead to different outcomes. We base this contention on the coupling component of *Normal Accident Theory* (NAT) (Perrow, 1981). NAT suggests that in complex environments, a reduction in operational slack leads to higher levels of coupling and accidents. Financial slack might be used to offset the negative safety implications of coupling.

Globalization and a focus on efficiency have generally meant a reduction in operational slack and more tightly coupled operations. For instance, the inventory to shipment ratio for U.S. manufacturers declined from 1.46 in 1995 to 1.34 in Sep. 2016 (United States Census Bureau, 2012, 2016[[1]](#footnote-1)). Increasing coupling generally improves operational efficiency (e.g., Modi and Mishra, 2011). NAT and research in both the safety and operations domains (Babson, 1993; Love *et al.,* 2015) predict that this increase in coupling will have negative implications for operational workers in the guise of increased stress or a greater likelihood of injury. This prediction is explored via the following research question: *(1) Does increasing coupling by reducing operational slack lead to higher levels of safety violations?*

Financial slack is a means to manage risk and uncertainties (Bourgeois, 1981, 1985). Firms with buffers of financial slack would have the resources to potentially mitigate the negative safety implications of tighter coupling. Increased financial slack would allow a firm to train operational workers, hire safety or ergonomic experts or develop innovative new processes. Hence, we propose that organizations can employ financial slack to counteract the increased coupling that results from reducing operational slack. Thus, we explore the following research question *(2) Can financial slack attenuate the impact of tightly coupled operations on safety violations?*

Regulators have typically examined the relative danger of a firm’s operations to determine the likelihood that workers will be harmed; safety risks are higher in a mine than in a distribution center. Research questions one and two suggest that operational and financial slack may also predict how likely firms are to harm their workers. Previous research suggested that industry or market characteristics such as munificence, dynamism, and complexity are important factors when it comes to identifying optimum levels of slack for specific operational outcomes (Eroglu and Hofer, 2011; Modi and Mishra, 2011; Kovach *et al.,* 2015). Eroglu and Hofer (2011) for example identified that the shape of the inventory-performance (i.e., ROS, ROA) relationship varies across industry. If the optimal level of slack from an economic perspective, is due to market conditions then it is possible that accounting for an industry’s wider market characteristics may help regulators predict which workers are at risk, and design regulation accordingly. We test this notion by addressing the following research question: *(3) Can an industry’s market characteristics intensify the impact of tightly coupled operations on safety violations?*

These research questions are addressed using longitudinal secondary data from OSHA and COMPUSTAT for 3,945 listed manufacturing firms in the United States. The results indicate that decreases in operational slack are significantly related to increases in safety violations and that companies can reduce the negative impact of operational slack by increasing financial slack. In addition, market characteristics moderate the relationship between operational slack and safety violations.

This research makes multiple contributions. First, this research links organizational and safety research on slack. Second, the research expands the debate on slack to a wider range of operational and firm outcomes. Finally, by exploring operational slack, financial slack, market factors and their interrelationship, the research add nuance to the debate on the role of slack resources by treating slack as multi-dimensional and a potential determinant of outcomes of import to multiple organizational stakeholders.

**2. Literature Review**

The role of slack resources in preventing industrial accidents and harm to workers is often explored through NAT and High Reliability Theory (HRT) (Weick *et al.,* 1999). NAT suggests that accidents are inevitable and identifies two important characteristics that make systems prone to accidents: interactive complexity and coupling (Sammarco, 2005). A plant can be viewed as a complex system where numerous workers, machines, and routines interact with each other. Coupling is a measure of the strength of the inter-connectedness between the system components (Perrow, 1981, 1999) and tightly coupled production systems have little or no slack (Sammarco, 2005). NAT predicts that as slack decreases / coupling increases, accidents will also increase.

HRT is often presented as providing a counter argument to NAT because HRT proposes that accidents are avoidable even in complex production environments (Shrivastava *et al.,* 2009). HRT suggests that complex organizations can avoid accidents and harm by: (1) continuous training, (2) the use of redundancy, and (3) numerous sources of direct information (Weick *et al.,* 1999; Hovden *et al.,* 2010). One of the keys to prevention in HRT is redundant or slack resources. HRT and NAT disagree on the inevitability of accidents, but they both posit that one of the keys to preventing accidents is increasing slack / decreasing coupling.

***2.1. Operational slack, coupling and worker safety***

Traditionally OM scholars followed other organizational scholars such as Bourgeois (1989) and treated slack as a means to decouple steps in a production process in efforts to manage uncertainty. However, numerous studies found that decreasing inventory levels and/or an increase in inventory turns lead to significant performance benefits (e.g., Im and Lee, 1989; Crawford and Cox, 1990; Gilbert, 1990; Billesbach, 1991; Huson and Nanada, 1995; Balakrishnan *et al.,* 1996). From these findings many concluded that all operational slack was waste and should be eliminated (Lawson, 2001).

A more complex view of operational slack has developed in the last decade with researchers once more making room for some slack as a means to manage uncertainty and with a recognition that finding the optimal level of slack maximizes economic performance. Hendricks *et al.* (2009) found that a higher level of operational slack lead to a reduction in the negative stock market reaction to a supply chain disruption. Eroglu and Hofer (2011) returned to the question of how inventory buffers impact performance and found that firms can have too few buffers, suggesting a concave relationship between inventory and firm performance. Modi and Mishra (2011) reached similar conclusions finding that resource efficiency (less slack) is positively related to increased financial performance, but that the benefits of reducing slack show diminishing returns. Finally, Kovach *et al.* (2015) explored the performance implications of operational slack in different external environments. They found that in general lower levels of operational slack are related to higher financial performance, but that in unstable environments increased slack improves performance.

Managers can reduce slack in the production system to the point that the system becomes too tightly coupled (Eroglu and Hofer, 2011) or brittle (Modi and Mishra, 2011). However, Modi and Mishra’s (2011) findings suggest that the inflection point were reducing slack no longer improves financial performance is fairly close to the productivity frontier. Depending on the measures of slack and financial performance, at most about 10% of the firms in their sample would see improvements from increasing slack and for some measures of performance the percentage is less. For instance, the inflection point for the relationship between production resource slack and ROA is at the 95.99 percentile, only 4% of the firms in their sample would benefit from increasing this form of slack. Operations management scholars have generally concluded that all things being equal less operational slack is better than more, but that less does not mean none.

These conclusions about operational slack were generally reached by framing performance in financial terms or from the operational perspective of profits, cost, quality, flexibility and delivery. Worker safety may be a measure of operational performance and an indicator of an operation’s social sustainability (Brown *et al.,* 2000; Pagell *et al.,* 2014) but safety has mainly been absent in operations management research on slack.

However, safety researchers have a long history of studying the role of operational slack in safety outcomes. A general conclusion from this literature is that reductions in slack lead to role overload and increased accidents and injuries (McClain, 1995; Barling *et al.,* 2003). Much of this research builds on observations of early adoptions of lean manufacturing (e.g., Babson, 1993) where safety researchers concluded that reductions in slack to make the operations more efficient were also harming the workforce. Lean was mean and by extension all efforts to reduce operational slack to improve efficiency also put workers at increased risk (see Das *et al.,* 2008 and Love *et al.,* 2015 for a full discussion). The safety literature then concludes that decreases in operational slack harm workers.

The conclusions from the safety literature are in line with both NAT and HRT. Removing slack from of the production system increases operational coupling (Kovach *et al.,* 2015) resulting in role overload. Role overload is an indication of increased coupling (NAT) and reduced redundancies (HRT) and will lead to an increase in accidents, illness and safety violations (Sammarco, 2005). Based on these arguments we propose the following hypothesis:

**H1:** A higher level of coupling is associated with an increase in safety violations.

***2.2. The moderating role of financial slack***

An important theoretical and managerial question is whether companies can augment or offset operational slack through financial slack. Financial slack has been repeatedly categorized into unabsorbed slack (also referred to as available slack), absorbed slack (also referred to as recoverable slack), and unborrowed slack (also referred to as potential slack) (Cheng and Kesner, 1997; Tan and Peng, 2003). These categories are important because they specify the ease of recovering and using various slack resources (Nohria and Gulati, 1996).

Unabsorbed slack represents resources that are readily available and is the most liquid form of financial slack. Greve (2003) defines unabsorbed slack as financial reserves, which an organization maintains by holding cash or other financial instruments. These are financial resources that have been accumulated and can easily be deployed at short notice.

Absorbed slack represents non-liquid resources that the organization has accumulated that go beyond what is necessary for the short-term operation and maintenance of the production system (Greve, 2003). Examples of absorbed slack include employing additional workers or having excess equipment (Greve, 2003; Love and Nohria, 2005). These slack resources are not as flexible or liquid as unabsorbed slack but having absorbed slack provides a firm with some flexibility to handle environmental uncertainties such as changes in demand.

Unborrowed slack represents future resources that could be raised by means such as raising debt levels (Cheng and Kesner, 1997). Unborrowed slack is the least available and re-deployable form of financial slack (Love and Nohria, 2005).

The literature finds that while firms can be safe and productive (Lo *et al.,* 2014; Pagell *et al.,* 2015) many are not; they make trade-offs between safety and productivity tending to favor productivity (Love *et al.,* 2015). In a firm without slack resources solving a safety problem will require taking resources from production. But if a firm has financial slack they can allocate sufficient resources both to being safe and being productive (Bourgious, 1989), mitigating potential conflicts between safety and other operational outcomes. Similarly, firms with financial slack have greater scope to innovate their way out of potential trade-offs between being safe and productive.

For example, role overload is most likely to occur when demand spikes in a tightly coupled production system (McClain, 1995); it is during times of high demand that workers would be most likely to have to choose between being safe and being productive (Love *et al.,* 2015). A firm with little or no financial slack would probably react to a demand spike by increasing pressure on the workers, exasperating the impacts of tight coupling. However, unabsorbed slack could be instantly deployed during a demand spike to hire additional workers or shift some work to contractors. A firm with unabsorbed slack could avoid role overload during demand spikes mitigating the impacts of tight coupling.

**H2(a):** Unabsorbed slack negatively moderates the relationships between coupling and safety violations.

Similarly, Organizations with absorbed slack would already have additional resources at hand to support their workforce. This could reduce the likelihood of safety incidents since these companies have built in buffers to counteract tightly coupled processes.

**H2(b):** Absorbed slack negatively moderates the relationships between coupling and safety violations.

Finally**,** unborrowed slack does allow a firm to respond to environmental shocks, though not be as fast as with more liquid forms of financial slack. Firms with high levels of unborrowed slack would be able to raise funds and then respond in much the same manner as firms with high levels of unabsorbed slack.

**H2(c):** Unborrowed slack negatively moderates the relationships between coupling and safety violations.

***2.3. The moderating role of the market***

Coupling, operational slack and financial slack are endogenous factors that interact at the company level to help determine safety outcomes. Exogenous factors at the industry or market level have also been linked to company behavior and safety outcomes (Fine, 1998; Lo *et al.,* 2014).

Some companies are embedded in market environments that can be characterized by high levels of competition, short product life cycles and / or unpredictable demand patterns. These exogenous pressures may create or exacerbate tensions between safety and other outcomes (Lo *et al.,* 2014) and based on HRT and NAT, could potentially increase the complexity of the firm’s working environment and hence increase the likelihood of workers being harmed.

The external environmental has been frequently categorized into munificence, dynamism, and complexity (Aldrich, 1979). Munificence assesses the market’s ability to support continuous growth (Li and Tang, 2010). A market that is munificent provides opportunities and resources to firms to potentially rapidly grow their market share, follow new opportunities or potentially develop new products or services. Dynamism is a measure of environmental volatility, similar to market uncertainty (Boyd, 1995). Higher levels of dynamism relate to higher levels of uncertainty (Boyd, 1995). Complexity assesses the extent to which a market can be characterized as competitive and heterogeneous (Aldrich, 1979; Dess and Beard, 1984; Li and Tang, 2010). Complexity increases as industry concentration decreases and the number of competitors increase (Li and Tang, 2010).

In our first hypothesis we proposed that higher levels of coupling are positively associated with higher levels of safety violations. A market that is characterized by munificence may, somewhat counter intuitively, accentuate this relationship. Munificence markets are attractive to managers because they provide an abundance of resources and opportunities to grow (Keats and Hitt, 1988). Typically, managerial research links an abundance of resources with an increased ability to invest and or solve problems. However, the safety literature finds that in growing firms and industries accidents increase (e.g., Asfaw *et al.,* 2011). In addition, safety tends to follow the business cycle, with accidents increasing in booms and decreasing in busts (e.g., Davies *et al.,* 2009; Barnes *at al.,* 2016). Researchers suggest that in periods of growth firms increase the utilization of existing equipment and workers reducing slack and or invest in new equipment and hiring new workers increasing complexity (Davies *et al.,* 2009; Asfaw *et al.,* 2011; Barnes *et al.,* 2016). Firms in munificent environments are generally trying to maximize the growth opportunity the environment presents, not investing in safety.

**H3(a):** Munificence positively moderates the relationships between coupling and safety violations.

A dynamic market has been characterized as one with relatively high levels of uncertainty (Boyd, 1995). Palmer and Wiseman (1999) noted that dynamism increases organizational risk because companies have greater difficulties predicting future events such as demand patterns and spikes. One way for companies to respond to dynamism is by decreasing response time and increased accountability (Keats and Hitt, 1988). Similarly, Fisher (1997) argued that uncertain environments require a market-responsive supply chain. This entails short lead-times to be able to quickly respond to unpredictable demand (Fisher, 1997). These dynamic market characteristics put additional strains on a company’s resources and might create tensions between safety and other operational outcomes.

**H3(b):** Dynamism positively moderates the relationships between coupling and safety violations.

Complex markets are characterized by many competitors and significant price pressure (Palmer and Wiseman, 1998). To survive and flourish in complex markets companies need to be efficient and effective. The cost reductions linked to decreasing slack will be especially useful in these markets and the pressure to cut costs might tempt companies to interpret safety rule and regulations more loosely to gain temporary advantages over competitors.

**H3(c):** Complexity positively moderates the relationships between coupling and safety violations.

**3. Method**

Secondary data on US listed manufacturing firms compiled from the Occupational Safety and Health Administration (OSHA)and COMPUSTAT was used to answer the research questions. We followed previous literature and used violations of OSHA regulations to assess a firm’s safety performance (Pagell and Gobeli, 2009; Lo *et al*., 2014). The COMPUSTAT data was used to create the measures of slack, market factors and the controls.

The process started with the OSHA violation database (OSHA, 2015). The U.S. manufacturing sector includes 459 industries, based on four-digit SIC code. Four digit SIC codes have the greatest granularity and firms within the same 4 digit SIC code should share many similarities.

The research is concerned with the role of operational slack in safety outcomes. Therefore, we confined our sample to those industries where there had been violations of OSHA regulation because in industries with no violations there would be no variance on the dependent variable. There was at least one safety violation recorded in 218 of the 459 industries during the period from 1990-2013, so we sampled only from those 218 industries and excluded the remaining 241 industries from the analysis.

Next we collected financial data from the COMPUSTAT database for all of the firms in these 218 industries. The COMPUSTAT data was used to create the independent variables and covers the period from 1989 to 2012 because this data, has a one-year lag to the dependent variable (safety violations). There were 62,937 firm-year observations from the 5,110 firms in these 218 industries.

Finally, we eliminated 1,165 firms with missing data for the independent variables such as the number of employees, leaving 3,945 firms for the analysis: 2,133 with at least one violation and 1,812 with no violations. The 2,133 firms with violations committed a total of 9,497 violations in the time period and 908 of these 2,133 firms had violations in multiple years. The final data set included 40,204 firm year observations from the 3,945 firms. Figure 1 shows the steps that yielded the final data set. Figure 2 illustrates the distribution of violations by industry (based on 2 digit SIC code for simplicity) in the data set.

--- Insert Figure 1 about here ---

--- Insert Figure 2 about here ---

***3.1. Measures***

Safety violation is the dependent variable in the analysis. The OSHA database includes the firm’s name, the date of the violation(s) and the type of violation(s). OSHA classifies violations as serious, wilful, repeat and other than serious (other). Table 1 displays how OSHA defines these classifications. Violations are captured and reported at the plant level, which is where they occur. We subsequently convert this plant level data to the firm level by summing up all violations at all plants in a firm, in a year.

--- Insert Table 1 about here ---

A single OSHA record can have more than one type of violation. For example, a violation can be both serious and repeated. In the analysis we treated all violation types as equal to be consistent with prior literature (Pagell and Gobeli, 2009; Lo *et al.,* 2014). Each violation record was counted as one violation regardless of violation type or if there were multiple types of violation for the record. However, we explore if violation type affects the results as a robustness check.

Safety violationis measured by number of violations a firm committed in one year. Measuring violations in an ordinal fashion is consistent with previous studies that examined the likelihood of other types of corporate malfeasance (e.g., Haunschild and Rhee, 2004). Because a firm’s number of violations may depend on the number of OSHA inspection visits, we calculated our dependent variable by dividing the number of violations by the number of inspections per year. Therefore, we can interpret the dependent variable as a percentage (Short *et al.,* 2016). For simplicity, we refer to safety violations per inspection as safety violations for the remainder of the paper.

Unless otherwise stated, all of the independent variables for a firm-year observation are information from one-year prior (year = *t-1*) to the dependent variable (year = *t*).

We conceptualized operational slack through excess inventory (Kovach et al., 2015). A firm’s inventory buffer is commonly measured as the number of inventory days (Hendricks *et al.,* 2009). Tightly coupled operations have significantly fewer inventory days than loosely coupled operations (Hayes and Jones, 2006), making inventory days a good proxy for the level of operational slack. H1 predicts that tighter coupling leads to a higher number of safety violations. Therefore, we reversed the measure of inventory days for the analysis (reversed inventory days), since fewer days of inventory corresponds to less operational slack and more tightly coupled operations.

In H2(a-c) we hypothesize that financial slack attenuates the relationship between tightly coupled operations and safety violations. Financial slack is conceptualized as unabsorbed, absorbed, and unborrowed slack (Palmer and Wiseman, 1999). Unabsorbed slack was measured by the quick ratio, which is calculated as current assets minus inventories scaled by current liabilities. Absorbed slack was measured as the ratio of selling, administrative, and general expenses to sales (SG&A/sales) (Love and Nohria, 2005). Unborrowed slack was measured by financial leverage, which was calculated as the ratio of debt to equity. And following the same logic as for inventory days, we reversed coded unborrowed slack because a higher level of leverage means a firm has less financial slack (Palmer and Wiseman, 1999).

In H3(a-c) we hypothesize that market factors intensify the positive relationship between tightly coupled operations and safety violations. We followed previous literature and categorized market factors into munificence, dynamism and complexity (e.g., Boyd, 1995; Palmer and Wiseman, 1999; Li and Tang, 2010).Dynamism was operationalized using the standard error derived from the regression of the industry’s annual sales over a 5-year period (Boyd, 1995). Munificence was operationalized using a standardized measure of industry volatility of industry sales growth over a 5-year period (Boyd, 1995). Finally, complexity was operationalized as the Herfindahl-Hirschman Index (HHI). The HHI is calculated by using the sum of the squared market shares of all firms in an industry group. HHI can range between 0 and 1, where scores close to one imply few competitors or dominant competitors with large market shares and less complex markets (Boyd, 1995). We reversed the scale of HHI to measure market complexity.

We included multiple control variables to increase the robustness and generalizability of our results. We first include the lag value of safety violations (*t*-1) to create a dynamic panel data model (Lam *et al.,* 2016) and control for a firm’s recent violation experience. Firms may learn from recent experience reducing the likelihood of subsequent violations (Baum and Dahlin, 2007; Yiu et al., 2014). Firm size, measured as the number of employees (‘000), is included because firms with more employees may have more safety violations. Firm performance, measured as return on assets (ROA), is included because more profitable firms may have more resources. Research and development (R&D) intensit*y,* measured as R&D expense per employee, is included because technological complexity may be associated with safety risks (Lo *et al.,* 2014). The cash-to-cash cycle controls for the firm’s capability to convert resource inputs into cash. We follow Hendricks *et al.* (2009) and calculate cash-to-cash cycle as inventory days plus receivables minus payable days. Production efficiency was controlled by labor productivity measured as operating income per employee (Hendricks *et al.,* 2009) and the ratio of sales to property, plant and equipment *(SOP)* (Modi and Mishra, 2011). We also control for if the firm is OHSAS 18001certified because certification can lead to better safety performance (Lo *et al.,* 2014). Inventory fluctuations are controlled for by inventory volatility because volatile inventory could increase coupling and occupational safety risks (Lo *et al.,* 2014). We calculate inventory volatility as the ratio between the standard deviation of quarterly inventory and the annual mean quarterly inventory (Steinker and Hoberg, 2013; Lo *et al.,* 2014). The ratio is adjusted by the value of *t-1* to eliminate the seasonality factors. We control for firm age because older firms may accumulate production experience and thus have a lower likelihood of violation. We include the number of inspections by OSHA to control for the extent the firm was targeted by the regulator.

The buffer effect of inventory could be diluted if a firm’s production is spread over multiple sites. Thus, we control for a firm’s geographical diversification to address this concern. We calculate the HHI by using the geographic location of a firm’s property, plant and equipment to control for geographical diversification (Berger et al., 2010; Westphal and Bednar, 2005). Lastly, firms that have abundant human resources could potentially mitigate the production pressure on each worker and decrease the likelihood of breaching regulations. We follow Mishina *et al.* (2004) and calculate human resource availability as the industry adjusted ratio of employees to sales.

We also include dummy variables foryear, the state where the firm had their US headquarters, and industry. We include industry as a control because munificence, dynamism and complexity are time-variant market factors. The industry dummy is used to control the unobservable fix effects (or time-invariant effects) from issues such as regulation and the industry’s past safety record. The average variance-inflation factors (VIF) for two ways of conceptualizing industry are low so the likelihood multi-collinearity is also relatively low.

We performed a natural logarithm transformation to reversed inventory days, SOP, absorbed slack, unborrowed slack, inventory volatility and firm size to correct their skewed distributions. All of the independent variables and controls are measured one-year prior to the dependent variable. Table 2 presents the descriptive statistics and the correlations between the variables.

--- Insert Table 2 about here ---

***3.2. Endogeneity test***

Endogeneity concerns arise when either reversed causality between independent variables and dependent variable is possible or when there may be unobserved variable(s) that affect both independent and dependent variables. Whilst we have a time lag between our independent and dependent variables we cannot rule out the possibility of endogeneity due to unobserved variables. For example, financially healthier firms might have more slack resources relative to firms in financial trouble, which could also affect their safety performance (De Carolis *et al.,* 2009; Surroca, 2010). From a statistical viewpoint, the concern arises because the independent variables in our model (operational and financial slack) may be endogenous and correlate with the corresponding error term. This may bias the interpretation of the hypothesized effect (Semadeni *et al.,* 2014).

An instrumental variable technique, which uses external variables to split the part of the endogenous variable correlating with the error term, is adequate to address this concern (Wooldridge, 2015). Valid instruments should be correlated with the endogenous independent variables but not with the error term (Wooldridge, 2015). However, it is difficult to select a strictly exogenous instrumental variable (Bardhan et al., 2013). Therefore, we followed previous recent studies using similar dynamic panel data and conducted a generalized method of moments (GMM) analysis to address the endogeneity concern (Lam *et al.,* 2016; Senot *et al.,* 2016; Sodero *et al.,* 2013).

GMM analysis offers some important advantages for our research. First and foremost, the GMM technique does not rely on additional external variables to construct the instruments. Furthermore, GMM uses lagged values of endogenous variables as instrumental variables to reduce the correlation between the endogenous variables and error terms (Roodman, 2009), which overcomes the difficulty of obtaining a strictly exogenous instrumental variable. Sodero *et al.* (2013) concluded that in cases of large sample sizes GMM provides consistent and efficient estimates, even when the panel data is unbalanced.

We use the lagged value of safety violations, operational and financial slack, as instruments for our GMM analysis. We also include the lagged value of the three market factors when instrumenting the endogenous variables to examine the potential impact of interactions between firm- and industry-level data. In addition, we also include the lagged value of the interaction terms as instrumental variables when testing H2 and H3 (Senot *et al.,* 2016).

We perform the Arellano-Bond (Arellano and Bond, 1991) and Hansen test (Hansen, 1982) to examine whether the instrumental variables are effective in addressing the endogeneity concerns. The results of these tests are presented in the following section.

**4. Results**

We used *Stata 14.0* to conduct the GMM analysis to address endogeneity concerns (Arellano and Bover, 1995; Lam *et al.,* 2016). The results are presented in Table 3. In order to test whether or not the lagged values of the endogenous variables are valid instruments (i.e., correlated with the contemporaneous values of these variables and independent of the error terms in the second-stage regressions) we conducted the Arellano-Bond and Hansen tests (Arellano and Bond, 1991; Senot *et al.,* 2016). With regards to the Arellano-Bond test, the first-order autocorrelation (AR1) is significant (*p* < 0.01) while the second-order autocorrelation (AR2) is not significant (*p* >0.1). Thus, the instrumental variables are not correlated with the error terms. In addition, the Hansen test is not significant (*p* > 0.1), and thus also fails to reject the null hypothesis that the instrumental variables are uncorrelated with the error terms. Therefore, our instrumental variables are exogenous and the GMM analysis mitigates concerns about endogeneity bias.

---Insert Table 3 about here---

***4.1. The direct effects of coupling on safety violations***

Model 1, in Table 3 includes all of the control variables. Results of the omnibus test (Chi2 = 675.670, *p* < 0.01) indicate that the control variables significantly improve the fit of Model 1, relative to the null (intercept only) Model.

Model 2 includes all the control variables as well as the hypothesized direct effect of coupling (H1). The impact of reversed inventory days on safety violations is significant (*p* < 0.01) and in the predicted direction (Coefficient = 1.873). The results of Model 2 support H1 by confirming that a higher level of coupling is associated with an increase in safety violations. The GMM analysis shows that the significant effect is not due to endogenous variables.

***4.2. The moderating roles of financial slack and market context***

Our second research question asks whether or not financial slack can attenuate the effects of operational slack. Model 3, examines the moderating effects of the three types of financial slack on the relationship between reversed inventory days and safety violations. Two of the three interaction terms are negative and significant: reversed inventory days X unabsorbed slack (Coefficient = -0.040, *p* < 0.01) and reversed inventory days X absorbed slack (Coefficient = -0.790, *p* < 0.01). Reversed inventory days X unborrowed slack is not significant (*p* > 0.1). Adding these interaction terms significantly improves the fit of Model 3 relative to Model 2 (incremental Chi2 = 1,809.09, *p* < 0.01). Therefore, the results in Model 3 provide support for H2(a) and H2(b) but not for H2(c).

Model 4 examines the moderating effects of the three market factors on the relationship betweenreversed inventory days and safety violations. All three interactions terms are positive and significant: reversed inventory days X dynamism (Coefficient = 0.018, *p* < 0.01), reversed inventory days X munificence (Coefficient = 0.316, *p* < 0.01) and reversed inventory days X complexity (Coefficient = 2.959, *p* < 0.1). The interaction terms significantly improve the fit of Model 4 relative to Model 2 (incremental Chi2 =551.24, *p* < 0.01). The results in Model 4 provide support for H3(a), H3(b) and H3(c).

***4.3. Robustness tests***

The slack variables in the GMM models are transformed into instrumented variables and thus lose their practical meaning. Therefore, we conducted linear regression with maximum likelihood estimation (Lam *et al.,* 2016) to evaluate the practical effects of the antecedents of safety violations (Acemoglu *et al.,* 2008; Lam *et al.,* 2016; Senot *et al.,* 2016). The VIF of the independent variables is 1.311, with the maximum VIF of 1.955. Thus, the likelihood of multi-collinearity affecting our results is relatively low (Cohen *et al*., 2013). The results of this analysis are presented in Table 4.

In Model 2 (Table 4), the coefficient of reversed inventory days is positive and significant (Coefficient = 0.408, *p* < 0.05). The likelihood of a safety violation for all observations (N = 40,204) is 9.24%. Violations are rare and the impact of slack on safety violations needs to be interpreted with this in mind. Increasing inventory days from zero to the mean level of inventory days (83.76) reduces the likelihood of a violation per inspection by 1.807%[[2]](#footnote-2).

In Model 3, the coefficients of reversed inventory days X unabsorbed slack (-0.053, *p* < 0.01) and reversed inventory days X absorbed slack (-0.685, *p* < 0.01) are negative and significant. When we hold reversed inventory days constant, increasing unabsorbed slack from zero to the mean level (2.188) attenuates the effect of reversed inventory days on safety violations by 16.08%[[3]](#footnote-3). Similarly, when reversed inventory days are held constant and absorbed slack is changed from zero to the mean level (0.261), the effect of inventory days on safety violations is attenuated by 24.80%.

In Model 4, the coefficients of reversed inventory days X dynamism (0.014, *p* < 0.05), reversed inventory days X munificence (0.162, *p* < 0.1) and reversed inventory days X complexity (1.931, *p* < 0.01) are positive and significant. When we hold reversed inventory days constant, increasing dynamism from zero to the mean level (5.118) amplifies the effect of reversed inventory days on safety violations by 12.14%. Similarly, when reversed inventory days are held constant and munificence is changed from zero to the mean level (0.504), the effect of inventory days on safety violations is amplified by 13.84%. When reversed inventory days are held constant and complexity is changed from zero to the mean level (0.305), the effect of inventory days on safety violations is amplified by 99.82%.

---Insert Table 4 about here---

Figures 3 to 7 illustrate the slopes of the significant moderation effects. The figures are based on the values of reversed inventory days and the significant moderators (Jaccard and Turrisi, 2003). The graphs illustrate how the relationship between reversed inventory days and safety violations changes based on having a mean level of moderators, a high level of moderators; defined as 3 standard deviations above the mean, or a low level of moderators; defined as 3 standard deviations below the mean (Cohen *et al.,* 2013). The X-axis is the level of coupling and ranges from 3 standard deviations below the mean to 3 standard deviations above the mean when moving from left to right. According to empirical rule of normal distributions, the range between 3 standard deviations above and below the mean should include 99.7% of the population (Lind *et al.,* 2015). The Y-axis is the probability of a safety violation. These figures help to illustrate the relationship between reversed inventory days and safety violations and show a clear difference between firms with high and low levels of financial slack/market factors.

In Figure 3, moving from a low level of unabsorbed slack to a high level of unabsorbed slack, the slope of reversed inventory days changes from 1.349 to -0.139. The change is significant (Z = -5.262, *p* < 0.01). Similarly, in Figure 4, moving from a low level of absorbed slack to a high level of absorbed slack, the slope of reversed inventory days changes from 1.093 to -0.009. The change is also significant (Z = -3.896, *p* < 0.01).

In Figure 5, moving from a low level of dynamism to a high level of dynamism, the slope of reversed inventory days changes from -0.391 to 1.718. The change is significant (Z = 7.455, *p* < 0.01). Similarly, in Figure 6, moving from a low level of munificence to a high level of munificence, the slope of reversed inventory days changes from -0.010 to 1.353. The change is also significant (Z = 4.821, *p* < 0.01). In Figure 7, moving from a low level of complexity to a high level of complexity, the slope of reversed inventory days changes from -1.203 to 1.206. The change is also significant (Z = 8.519, *p* < 0.01).

These results provide additional support to H1, H2(a), H2(b), H3(a), H3(b) and H3(c). Increases in operational coupling have serious negative consequences for workers. These negative consequences are exasperated by increases in dynamism, munificence or complexity and ameliorated by increases in financial slack.

---Insert Figures 3, 4, 5, 6 & 7 about here---

We also conducted a number of additional tests to determine the robustness of the results. The appendix provides specific details about these additional tests. The overall results are robust to changes in the operationalization of the dependent variable and controlling for the probability of having missing data. Finally, this analysis adds the boundary condition that the results may not hold for the extremely rare acts of wilful violations.

**5. Discussion**

The analysis used longitudinal secondary data, multiple indicators of financial slack, and included multiple robustness checks to answer the three research questions. The answer to the first question; *Does increasing coupling by reducing operational slack lead to higher levels of safety violations* is yes. Increased coupling is generally associated with increases in safety violations. The answer to the second research question; *Can financial slack attenuate the impact of tightly coupled operations on safety violations* is also yes. The shape of the interactions provides the most insight on the relationship between the various forms of slack and safety violations. Figures 3 and 4 indicate that when firms have low levels of financial slack in the form of unabsorbed and absorbed slack, decreasing operational slack leads to an increase in violations. However, firms with high levels of financial slack are able to decrease operational slack without increasing the likelihood of violations. Thus, firms with high levels of financial slack are able to reduce operational slack without harming the workforce while firms with low levels of financial slack are not.

The answer to the third research question; *Can an industry’s market characteristics intensify the impact of tightly coupled operations on safety violations* is also yes. We identified that the probability of having a safety violation due to coupling is significantly increased when operating in markets characterized by relatively high levels of dynamism, complexity and munificence (see Figures 5, 6 & 7). These general findings are robust, except in the cases of wilful violations, and in line with the general predictions of the safety literature and theories such as NAT and HRT.

The results are clear that operational and financial slack need to be considered together because there are strongly significant interactions between the two forms of slack. Furthermore, our results on the role of market factors add nuance to previous findings linking the optimal level of slack to industry (e.g., Eroglu and Hofer, 2011). Our research makes multiple contributions to both theory and practice by linking organizational and safety research on slack, expanding the debate on slack to a wider range of operational and firm outcomes, by treating slack as multidimensional and a potential determinant of outcomes of import to multiple organizational stakeholders, and by exploring industry factors.

***5.1. Theoretical implications***

Previous research typically explored slack from the perspective of there being a right level of slack to maximize economic performance. The present research makes important contributions to this debate. For instance, when the conceptualization of performance is expanded to include social outcomes it is likely that the right level of slack to fully protect the workforce is not the level of slack that will maximize profits. Previous research suggests that in general less operational slack is better for economic performance (e.g. Kovach et al., 2015), yet the current research finds that safety violations increase as operational slack decreases. A company’s level of slack could induce trade-offs between the social and economic components of performance. Future research needs to further explore this potential trade-off.

The research adds to the understanding of the relationship between safety and other operational outcomes. Recent research on the safety of operational workers concludes that firms can be safe and operationally effective (e.g., Lo *et al.,* 2014; Pagell *et al.,* 2015). Our results add nuance to these findings and suggest that for firms to simultaneously protect the workforce and improve efficiency by reducing operational slack, they will need high levels of financial slack. The literature links investments in human capital to improved financial performance and notes that investments in human capital need to coincide with efforts to improve operational efficiency (Longoni *et al*., 2013; Liu *et al*., 2014). Based on our results we would propose that this can only occur if the firm has the financial slack to invest in people. Future research needs to test this proposition.

The results indicate that complexity, dynamism, and munificence are all significant moderators of the relationship between coupling and safety violations. These findings add additional nuance to the understanding of the role of slack resources in operational outcomes. First, they suggest that how industry is conceptualized matters. Typical discussions of the role of industry in safety outcomes focus on the nature of the work, yet our results indicate that market characteristics also matter. Second, the results for munificence should give researchers pause when it comes to assumptions about resource availability. The present results and previous research (e.g. Barnes *et al.,* 2016), suggest that a munificent environment is not good for the workforce. These findings suggest that as our conceptualization of firm performance expands to include environmental and social indicators that assumptions about growth opportunities generally being good will also have to be re-explored.

The final contribution to theory comes from thinking about slack as two dimensional. We applied the theoretical underpinnings of the NAT and HRT to propose relationships between operational slack, financial slack and safety violations. NAT predicts that an increase in operational coupling could result in cutting corners and lead to an increase in safety violations. Our results are in line with NAT and confirm this prediction.

HRT proposes that an increase in the reliability of the system reduces the likelihood of accidents (Shrivastava *et al.,* 2009). The results suggest that reducing slack and increasing coupling reduces the reliability of the work environment. Removing operational slack from the system puts increased pressure on the workforce. And the results indicate that as volatility, complexity and growth rates increase the need for buffers increases as well. Having operational slack enables companies to smooth over demand uncertainties and volatility. However, once the buffers are eliminated the volatility is directly transferred to the workforce that has to deal with the volatility through extra shifts, increasing work rates or working with machines, materials and processes they are not sufficiently trained for. This reduces the reliability of the operation and puts workers at risk.

However, operational coupling does not occur in a vacuum and our results also suggest that financial and operational slack are different and complimentary. We would posit that financial slack is in essence a very flexible buffer. Inventory and capacity buffers are hard investments and difficult to change or redeploy. They are fairly specific hedges against specific problems. Financial slack is more flexible and because of the ease of deployment can be used to address multiple needs.

From a NAT perspective, this suggests that companies with financial slack can better cope with increased coupling because they can quickly address problems. For instance, if a company with little financial slack reduces inventory and then has a demand surge they are going to be forced to pressurize the workers to respond. However, a company with equal levels of coupling but more financial slack could respond to the same demand surge by hiring temporary workers, emergency outscoring or the purchase of additional capacity.

From an HRT perspective, the results suggest that financial slack can increase the reliability of the operations even when they are tightly coupled. Financial slack gives companies the ability to restore a state of reliability when an external shock trickles down to the operational level. Thus, having financial slack available can reduce the negative safety implications of efforts to increase efficiency.

Slack is two-dimensional and trying to determine the right level of slack to maximize performance is best done with an expansive operationalization of slack. Future research on the role of slack on firm outcomes should explore both operational and financial slack simultaneously. In addition, future research should explore if it is just having access to these resources that matters or if a more cautious or mindful organizational culture (Weick *et al.,* 1999) exists in companies with higher levels of financial slack.

***5.2. Managerial and policy implications***

Our results suggest that on average when companies reduce operational slack they also put their workers at risk of occupational accidents by violating safety regulations. This is an important finding from a managerial perspective because cost effectiveness remains the base competitive priority for many operations and operational capabilities are critical to firm success in difficult economic times when cost cutting is required (Ahmed *et al.,* 2014). Reducing operational slack and its associated costs is then likely a high priority for many firms.

This finding is augmented in dynamic, complex and munificent industries. This is important as it informs managers of the need to be more careful in managing safety in industries that are relatively complex and dynamic. This is intuitive, but the need to place more emphasis on safety in high growth industries need not be. High growth implies a relatively high level of resource availability. But high growth also implies new workers and equipment, more overtime, and or running existing equipment faster; all of which place workers at increased risk of harm. Firms facing these conditions will need more operational slack.

Our results also indicate that financial slack is a viable option to mitigate the negative safety implications of tighter coupling. This is likely of little comfort to a manager facing the pressure to cut costs now, since if they had financial slack the need to cut costs likely would be diminished. Firms with operational capabilities are better able to withstand serious economic downturns, but these capabilities need to be built in periods of growth (Ahmed *et al.,* 2014). Managers facing significant pressure to reduce costs likely know they need to look to their operations. But if they did not previously invest in their operational capabilities, the results of Ahmed *et al.* (2014) suggest that their cost cutting efforts will be less likely to succeed, while the present results suggest that the failure will extend to harming the workers. This suggests that reductions in operational slack are best done when they are least likely to be considered.

These results and the literature suggest that managers of firms with limited financial slack need to explore alternative means of operational performance improvement other than cost reductions. The literature suggests that operational performance can be increased while reducing the level of risk faced by the workforce by focusing on quality (e.g., Das *et al.,* 2008), integrating management systems (Pagell *et al.,* 2015) and empowering the workforce as part of building a culture of safe production (Pagell*, et al.,* 2014). Hence, while the present research is clear in presenting a trade-off between safety violations and reducing operational slack, other research proposes alternative paths to operational performance improvement that need not induce these trade-offs.

Safety is also a societal outcome and the results offer insights to stakeholders such as regulators and insurance companies with an interest in reducing harm to workers. Regulation and workers compensation insurance is often approached from the standpoint of how dangerous is the work. Because certain industries such as mining and construction have more accidents, they have different regulation, see more frequent inspections and tend to pay higher insurance rates. The results give these stakeholders a more expansive way to think about safety risk. At the firm level slack matters and hence regulation and insurance could this into account. For example, insurance companies could set a threshold for financial liquidity and or give discounts for firms with higher than average operational slack in an industry to take into consideration the impact of slack on occupational health and safety.

At the industry level, focusing regulation on issues like how dangerous the work is makes sense to a point. However the competitive landscape is always changing. So while working in a foundry is always dangerous, as the competitive environment changes the relative risk of an industry also changes. And not all of the links between the competitive environment and safety violations are intuitive. Munificence is a market condition that most if not all managers would welcome. But our results and previous research suggest that the economic benefits of munificence are not accruing equally to all stakeholders, an outcome that regulation can address by placing more emphasis on high growth industries and not assuming that firms who are growing will push resources into safety.

**6. Conclusion**

We acknowledge the limitations of our study. First, safety is measured based on violations rather than accidents. Violations are rare, especially relative to accidents so a measure of accidents might produce different results. In addition, we conceptualize a safety violation as an ordinal variable, measuring violations in relation to the number of inspections. We do control for repeat offenders but future research could explore violations in a more nuanced fashion and in so doing might also shed some light onto the role of slack in wilful violations.

Furthermore, the sample is limited to publically listed firms from the United States. Future research should address the role of various forms of slack on worker safety in different contexts and for privately owned firms. Finally, we solely rely on secondary data to explore our research questions. Whilst this has the advantage of adding needed objectivity to sustainability research, it limits us to a relatively high or abstract level of analysis.

Noting these limitations we are confident in the robustness of our results because: 1) the independent variables have a time lag to the dependent variables; 2) our hypotheses are supported by statistically significant results; and 3) we used control variables in the regression models and conducted additional robustness tests to minimize the risk of alternative explanations.

**Appendix**

**Robustness checks**

We conducted additional robustness tests to increase the validity of our results, including the analysis with disaggregated dependent variables, addressing missing data concerns of financial data and further analysis of potential non-linear relationships.

First, we disaggregated the violations into their specific categories to determine if the type of violation influenced the results. In the primary analysis the dependent variable was the number of violations of any type in a given year scaled by the number of inspections. For the robustness check, violations were disaggregated to create 4 variables in terms of: the number of serious violations (mean = 6.54%), repeat violations (mean = 0.35 %), wilful violations (mean = 0.07 %) or other violations (mean = 6.87 %) scaled by annual number of inspections. The dependant variables from Models 3 and 4 (Table 4) were replaced by the disaggregated variables. The slack models in Table B1 show the results for the effect of reversed inventory days moderated by financial slack (analogous to Model 3) and industry factors(Model 4).

Comparing the analysis for serious, other and repeat violations in Table B1 to the results for Model 3 and 4 reveals that the results remain unchanged. Thus, the robustness check confirms the overall conclusion that financial slack can attenuate the negative impacts of reduced operational slack; while dynamism, complexity and munificence can amplify the negative impacts of reduced operational slack. However, wilful violations are not predicted by operational slack or the interaction of operational and financial slack/industry factors. Wilful violations are extremely rare events, the likelihood of having a wilful violation from one inspection is only 0.07%. Also, while no firm should violate safety regulations, a wilful violation is an intentional act of commission. The other types of violations are acts of omission that arise from ignorance or neglect. Wilful violations by their nature are different from the other types of violations, and based on the robustness checks, our results have a boundary condition that does not include wilful violations. Future research on wilful violations then seems an important avenue for informing both policy makers and managers.

Second, our observation size drops from 62,937 to 40,204 because of missing data. Therefore, we conducted a two-stage analysis to check whether these missing data affect our results (Allison, 2001). We generate a binary variable Missing data to indicate whether the observation has missing value(s) for the variables used in Table 4. We then conduct a probit analysis using Missing data as the dependent variable and firm size, firm age, number of violations committed as independent variables (Lavie, 2007). We also include the dummy variables of year and industry in the analysis. The results (Table B2) show that the firms with more employees, younger firms, and the firms having more violations will have a higher likelihood of having missing data. We then generate the inversed Mill’s ratio from the probit analysis and add it into the Models in Table 4. The hypotheses testing results remain unchanged, indicating that the non-respondent bias does not seem to affect our analysis.

Finally, an increase in operational slack may increase the complexity of firm, and leading to higher risks of safety violations (Rijpma, 1997), implying the potential curvilinear relations between coupling and safety violations. To test this relation, we included a squared term of reversed inventory days (reversed inventory days squared) into model 2. Results show that the squared term is significant (coefficient = -0.127, p < 0.05) (Table B3), indicating a reversed parabolic relation. Future research may study the non-linear relations between coupling and safety violations.Figure B1illustrates the curvilinear relationship considering intercept and controls as a constant. The figure shows that when operational coupling reaches about three standard deviations above the mean, a continued increase of coupling can reduce safety violations.

Figure B1: Curvilinear relation graph

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table B1: Regression results of disaggregated violation types | | | | | | | | | | | | | | | | |
|  | Serious violations | | | | Other violations | | | | Repeat violations | | | | Wilful violations | | | |
|  | Slack Model | | Industry  factor model | | Slack Model | | Industry  factor model | | Slack Model | | Industry factor model | | Slack Model | | Industry  factor model | |
| Reversed inventory days | 0.578 | \*\*\* | 0.570 | \*\*\* | 0.725 | \*\*\* | 0.590 | \*\*\* | 0.034 |  | 0.013 |  | 0.001 |  | -0.004 |  |
| (0.156) |  | (0.213) |  | (0.171) |  | (0.233) |  | (0.032) |  | (0.045) |  | (0.015) |  | (0.020) |  |
| Reversed inventory days\*Unabsorbed slack | -0.029 | \*\* |  |  | -0.046 | \*\*\* |  |  | -0.003 | \* |  |  | 0.001 |  |  |  |
| (0.014) |  |  |  | (0.015) |  |  |  | (0.002) |  |  |  | (0.001) |  |  |  |
| Reversed inventory days\*Absorbed slack | -0.473 | \*\*\* |  |  | -0.621 | \*\*\* |  |  | -0.057 | \*\*\* |  |  | -0.018 |  |  |  |
| (0.139) |  |  |  | (0.159) |  |  |  | (0.023) |  |  |  | (0.012) |  |  |  |
| Reversed inventory days\*Unborrowed slack | 0.040 |  |  |  | -0.147 |  |  |  | 0.006 |  |  |  | 0.017 |  |  |  |
| (0.092) |  |  |  | (0.093) |  |  |  | (0.017) |  |  |  | (0.009) |  |  |  |
| Reversed inventory days\*Dynamism |  |  | 0.020 | \*\*\* |  |  | 0.010 | \* |  |  | 0.003 | \* |  |  | 0.000 |  |
|  |  | (0.007) |  |  |  | (0.006) |  |  |  | (0.002) |  |  |  | (0.000) |  |
| Reversed inventory days\*Munificence |  |  | 0.111 | \* |  |  | 0.138 | \*\*\* |  |  | 0.017 | \* |  |  | 0.010 |  |
|  |  | (0.066) |  |  |  | (0.066) |  |  |  | (0.009) |  |  |  | (0.006) |  |
| Reversed inventory days\*Complexity |  |  | 1.088 | \* |  |  | 1.021 | \* |  |  | 0.065 |  |  |  | 0.020 |  |
|  |  | (0.567) |  |  |  | (0.586) |  |  |  | (0.109) |  |  |  | (0.036) |  |
| Chi^2 | 6073.305 | \*\*\* | 6079.548 | \*\*\* | 5435.083 | \*\*\* | 5432.145 | \*\*\* | 865.483 | \*\*\* | 867.199 | \*\*\* | 184.575 | \*\*\* | 182.760 | \*\*\* |
| Note: \*\*\*,\*\*,\* indicates significant at 0.01,.0.05 and 0.1 levels; N=40204; all control variables are included but not shown; Standard errors in brackets. | | | | | | | | | | | | | | | | |

|  |  |  |  |
| --- | --- | --- | --- |
| Table B2: Probit estimation of missing data | | | |
| Dependent variable: whether the firm have missing data at year t (1=yes;0=no) | | | |
| Data at year t-1 | | Coef. | |
| Firm size (Natural logged number of employee) | | -0.244 | \*\*\* |
| (0.004) |  |
| Firm age (Natural logged firm age) | | -0.088 | \*\*\* |
| (0.012) |  |
| Number of violations | | 0.022 | \*\* |
| (0.011) |  |
| Intercept | | -0.269 |  |
| (0.893) |  |
| Year | | Included |  |
| Industry | | Included |  |
| Chi^2 | | 10556.370 | \*\*\* |
| R-square | | 0.2409 |  |
| N | | 51631 |  |
| \*\*\*,\*\* indicates significant at 0.01 and 0.05 level, Standard errors in brackets. |  |  |  |

|  |  |  |
| --- | --- | --- |
| Table B3: Test for curvilinear relation, N = 40204 |  |  |
| Dependent variable: Violation per inspection % at year t | | |
|  | Model 5 | |
| Variables, at year t-1 | Coef. | |
| Intercept | 11.049 | \* |
| (5.911) |  |
| Reversed inventory days | -0.589 |  |
| (0.431) |  |
| Reversed inventory days squared | -0.127 | \*\* |
| (0.053) |  |
| N | 40204 |  |
| Chi^2 | 8181.570 | \*\*\* |
| \*\*\*,\*\*,\* indicates significance at 0.01, 0.05, 0.1 level, two-tail test. All control variables are included but not shown. Standard errors in brackets. | | |

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1. U.S. Census Bureau, Statistical Abstract of the United States: 2012, Table 1018; U.S. Census Bureau, Full Report on Manufacturers’ Shipments, Inventories and Orders, Sep. 2016, Table 7. [↑](#footnote-ref-1)
2. 0.408\*ln(83.76) [↑](#footnote-ref-2)
3. 2.188\*(-0.053)/0.721. 0.721 is the coefficient of direct effect of reversed inventory days in model 3. [↑](#footnote-ref-3)