

ABSTRACT

Title of Document: SUPPLY CHAIN STRUCTURE, PRODUCT
RECALLS AND FIRM PERFORMANCE:
INVESTIGATING RECALL DRIVERS AND
RECALL FINANCIAL PERFORMANCE
RELATIONSHIPS.

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This dissertation is a two-essay study on globalization, sourcing structure and product quality and firm performance in global supply chain management. In the first essay, using a unique archival dataset on firms and their suppliers, the role of supply chain strategies in contributing to product safety and quality, as assessed through product recalls are investigated. The second essay investigates the relationship between product recalls and firm performance. Moreover, the moderating effects on the recall-profitability relationship of supply chain as well as recall management strategies are investigated

Essay 1 investigates how a number of supply chain strategies contribute to product recalls. In particular, I examine how the make or buy decision (i.e., outsourcing), the decision to concentrate the supply base (i.e., use few vs. several

suppliers), the use of foreign suppliers (i.e., offshoring), and the extent of global operations, contribute to product recalls. The subject area of product quality and safety failures leading to product recalls is important because product recalls can have a major, negative impact on firm performance. For example, in the event of a product recall, replacement orders may need to be shipped, new suppliers may need to be found and vetted, and marketing expenditures may need to be made to counter negative publicity from the recall. Applying key theories in operations and supply chain management, I find that firms vary greatly in recall propensity and that these variations are related to heterogeneity in outsourcing, offshoring, and supply base concentration.

In the second essay, I revisit the recall-performance relationship. First, I investigate the relationship between product recalls and profitability. Firms may choose to try to avoid product recalls by increasing their expenditures on product quality and inspection services. Or, on the other hand, they may emphasize short term profitability by reducing production and inspection costs, thereby increasing the risk of incurring a product recall. Since firms are expected to balance production and quality inspection costs against the costs associated with product recalls in order to maximize profit performance, the recall-profitability relationship is not clear, a priori. I further investigate the moderating effect of global operations, supply base structure and recall strategies on the relationship between product recalls and profit margins. My theory-based research suggests a curvilinear recall-profit relationship and that this relationship depends on key global supply chain practices and recall management strategies.

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PERFORMANCE: INVESTIGATING RECALL DRIVERS AND RECALL
FINANCIAL PERFORMANCE RELATIONSHIPS.

By

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Dissertation submitted to the Faculty of the Graduate School of the
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Dedication

To Nyanje Makula Bellay for telling me the truth when I could not understand it, for saying you can when I said I could not. Through this work, your name and memories will endure for generations.

To Mariama Bellay, for been both my mother and father.

To Biggie, Nyanje and Nydia; you are my motivation.

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Dissertation introduction

This dissertation links globalization, sourcing structure and product quality and firm performance in global supply chain management. Globalization, both sourcing and markets, has been a popular business strategy within the last two decades. At the same time, product recalls are, according to both media and research sources, on the rise (Hora et al., 2011). The Consumer Product Safety Commission's (CPSC) recordings of recalls have doubled, both in the number of announcements and affected products, over the past ten years. In fact, according to Maruchek et al., (2011), the most globalized industries make the most recalls.

Globalization of firms and its relationship to performance has been of central interest in global strategy studies for a long time but has recently garnered heightened interest (e.g. Qian et al., 2010; Rawley, 2010; Hitt et al., 2006; Lu et al., 2001). Many globalization studies, spanning three decades and across several disciplinary boundaries, focused primarily on the effects of diversification on firm financial performance (e.g. Morck and Yeung, 1991; Tallman and Li, 1996; Delios and Beamish, 1999; Tallman and Yip, 2009; Qian et al., 2010; Kirca et al., 2011 etc.). Several studies, alluding to several management theories like organization learning theories, a resource based perspective and transaction cost economics, have looked into the linkages between global strategies, both sourcing and sales, and performance, albeit with different empirical findings (example Hitt et al., 2006). These studies have, however, largely ignored the supply chain implications and product quality and safety risks of globalization on internationally diversified firms. Indeed, even though globalization remains ever popular as a business strategy, the global market

environment is getting more turbulent and prone to disruptions (Li and Tallman, 2011). As a firm globalizes its operations, the exposure to global risks increases and increases the likelihood of the firm being subject to disruptions and or product quality and safety failures. Both of these events, of course may have a negative impact on the firm's supply chain performance. A firm's financial performance is intertwined with its supply chain and product performances. A supply chain disruption and or a product quality compromise negatively affects a firms financial performance by increasing costs, blurring reputation and goodwill, and reducing revenues or firm values (e.g. Hendricks and Singhal, 2005; Chen et al., 2009 etc.). It is not surprising, therefore, that the empirical results, linking geographic diversification and firm performance that have mainly looked at the broader impact of globalization and performance linkage and ignored the systematic risks of such a strategy, are not free of ambiguity. In fact, these studies have documented many sorts of relationships between globalization and overall firm performance, including a negative relationship (e.g. Lu and Beamish, 2004), a positive relationship (e.g. Qian et al., 2008), and quadratic relationship of both U and inverted-U shapes.

This dissertation aims to investigate the association between globalization and product quality and safety as assessed through product recalls in two essays.

Specifically, in the first essay, the research will look at a firm's sourcing practices and global market reach and how they relate to a firm's product quality and safety glitches that result in recalls. In this essay, we first look at firm level sourcing behavior(make or buy, concentrated or diversified supply base, buy local or buy foreign, and concentrated or diversified international supply base) and how each of these factors

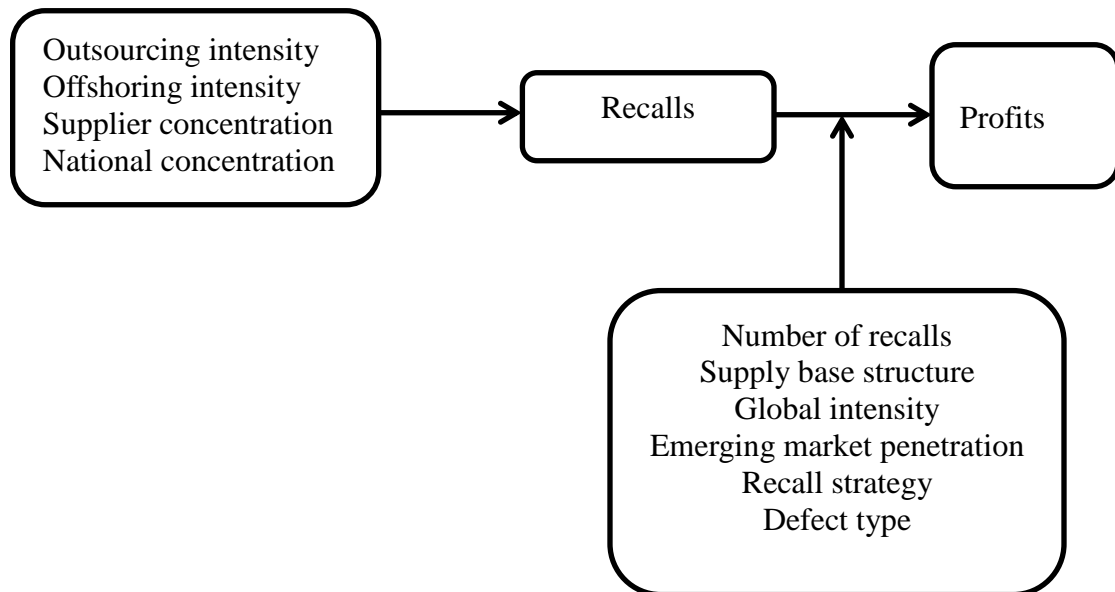
relate to product recalls. Referencing agency theory, contract manufacturing either inshore or offshore may lead to lower quality performance. Having many suppliers and across many countries may make a supply chain very complex. From the transactions cost economics, supply chain complexity is considered to have an effect on supply chain coordination costs and consequently supply chain performance as measured by product conformance.

In the second essay, the research takes another look at the recall-performance relationship. Even though it is of common knowledge that recalls hurt firms, firms have not been able to avoid recalls completely. One question remaining to be answered therefore is: Does the cost of a recall outweigh the cost of a preventing the recall? It is logical to think here that firms may try to balance these two costs in order to optimize financial performance. Where the cost of a recall is greater than the prevention cost, the firm will try to minimize or avoid recalls. On the other hand, if the prevention cost outweighs the recall cost, then the expectation would be that the firm may settle for some recalls and prepare to handle the recall. This is possible in situations of low cost goods, where demand is highly inelastic to quality compromises and in cases where firms have the capacity and capability to handle the recall seamlessly or without impact based on a firm's recall strategy and or the defect type that prompts the recall. Other factors that may affect this are the firm's supply base structure and global market and emerging market presence. In this second essay, therefore, we first reexamine the recall-profit relationship to determine if a recall announcement actually has a debilitating effect on profit. Second, we examine the recall-profit relationship for a possible non-linearity. It is possible that at a low recall

level, the prevention costs outweigh the recall costs such that firms are able to improve profits or remain profitable at a positive recall number. However, at high recall levels, the cost of the recalls outweighs the prevention costs, so that profits are negative in recalls. As argued in the essay, the cost of a recall may depend on specific firm strengths and the structure of the market the firm operates in. A second motive therefore, is to examine possible moderators, specifically global reach, supply base structure, recall strategy and source of product defects on the recall-profit relationship.

The below diagram, Fig. I, summarizes the entire dissertation.

Fig I, Dissertation conceptual model



1.1. Research Questions

This dissertation is contributing to this growing body of knowledge by investigating the linkages between product recalls and strategic sourcing behaviors, and the

linkages between recalls and firm financial performance. Investigated across two the essays, the major research questions are thus:

1. Are product recalls related to a firm's sourcing strategy and structure?
2. Is the product recall-profit relationship moderated by sourcing strategies and structure?
3. Is the product recall-profit relationship moderated by global and emerging market penetration?
4. Is the product recall-profit relationship moderated by the recall strategy and the source of the defect, either design or manufacturing?

1.2. Research Contributions

The paper contributes to the literature in several ways. First, it looks at some potential antecedents of product recalls within the operations and supply chain management context that has been ignored so far. Given that the investigated potential antecedents are highly popular firm strategies, their investigation of their impacts on different aspects of performance is very important. Second, this is the first time the impact of product quality and safety issues that result in recalls on profit margins with emphasis on non-linearities, firms are investigated. Investigating the effect on profit margin is quite important as many other performances are driven by the amount of money a firm generates from its core operations. Previous research on the effects of product recalls has overwhelmingly mainly focused on the effect of wealth of shareholders (example Thirumalai and Sinha, 2011; Jarrel and Peltzman, 1985), marketing effectiveness (Cleeren et al., 2008; Heerde et al., 2007 etc.), with limited works

looking at the effects on brand demand (Heerde et al., 2007; Marsh et al. 2004) ignoring the opposing cost effects: one through the cost of the recall (correcting and replacing the defective product) and the other through savings that might accrue through lower quality and frequency of inspections, and or lower quality and safety expenditures. Third, a potential non-linear relationship between recalls and performance, which has not been investigated before, that enable firms to recall products a certain number of times without concomitant impact on performance is investigated. This is a significant contribution because it partially explains the ever increasing recall incidents. It also redirects some attention to strategies that dampens down any negative effect of inevitable recalls rather entirely focusing on preventive strategies.

Essay 1: Global Sourcing and Quality recalls

1. Introduction

Product recalls are on the rise (Hora et al., 2011), despite quality improvement effort across industries. The Consumer Product Safety Commission's (CPSC) recall announcements, for instance, have doubled over the past ten years, as have the number of individual items recalled. According to one Gallup poll, this spate of recalls has affected public confidence in product safety and the ability of both government and firms to assure safety (Maruchek et al., 2011). Consequently, product recalls have had damaging effects on firm performance. Furthermore, The CPSC estimated in 2009 that safety failures that result in deaths, injuries, or property damages cost the country more than \$800 billion annually. More recently, media reports put a price tag of US \$2 billion on the 2009 Toyota recalls due to lost output and lost sales worldwide (e.g., BBC 2010, Time 2010).

Product recalls are quality failures of supply chains because the finished product quality is the agglomeration of the individual quality control efforts of each member in the supply chain. While quality management has garnered substantial interest (see for example Sousa and Voss, 2002 for a review), quality failures have been understudied from the supply chain perspective. Among the most commonly adopted supply chain sourcing strategies are outsourcing and offshoring of manufacturing (Hayes, et al. 2005). Almost all industries have seen an increase in outsourcing activity, ranging from business processes and information technology (example Corbett, 2005) to production and manufacturing (Wilhelmsson 2004).

While outsourcing can be motivated by a variety of reasons, cost savings are most often the driving force (e.g., Landis et al., 2005; Insinga and Werle, 2000; Kakabadse and Kakabadse 2005; Cecere, 2005). However, outsourcing may have unintended consequences, such as increased exposure to quality risks resulting from reduced control and visibility in the supply chain (e.g., Doig et al. 2001, Landis et al. 2005, Robinson et al., 2008). A Deloitte study reported that over 60% of its respondents returned some outsourced services back in-house and over 40% said they did not realize the expected benefits from outsourcing due to increased risks (Landis, et al. 2005). On the other hand, it has been argued that product recalls have often been a result of poor design and other factors unrelated to outsourcing. Mattel, for example, has been known for high profile recalls due to lead paint from a supplier of one of Mattel's main contract manufacturers, but a large number of its recalls resulted from its own product design flaw that failed to secure small magnet pieces in its products (Beamish and Bapuji 2008). In spite of the common belief that connects outsourcing with product recalls, no rigorous analysis has been conducted to provide concrete evidence of the existence of this link. This leads to the following research question: are quality recalls associated with the outsourcing or offshoring in supply chains?

Even though a large volume of work has been done on the antecedents of market versus total integration type of governance (example Williamson, 1979 and 1991, Barney, 1999) with focus on direct costs and costs of transactions, little research has been done examining how different governance forms affect product quality in particular. In a broader perspective, Leiblein et al., (2002) suggests an investigation of how these governance strategies affect other performance indicators,

including not only profits but risks as well. As put by Marucheck et al., (2011), outsourcing and offshoring have made supply chains longer and more complex, with increased numbers of hands touching products as they move across the supply chain nodes and across international boundaries. It is plausible that the increased complexity and the lengthening of supply chains as a consequence of outsourcing and offshoring may negatively affect product quality.

In this paper, we first empirically investigate whether product recalls are associated with a firm's global sourcing decisions. Specifically, we examine the relationships between recalls and the extent to which the firm's supply chain is outsourced or offshored. Research has shown that outsourcing may lead to poor quality performance (Hsieh et al. 2002) and offshoring production may be linked to lower quality ratings (Gray et al. 2011). Other recall related literature focuses on conceptual guidance and research directions (example Lyles et al. 2008; Marucheck et al. 2011). However, an empirical connection is needed to be established between outsourcing and offshoring and quality recalls.

A strategic decision that is closely tied to outsourcing and offshoring is supply base concentration. The supply base of a firm may be concentrated among few suppliers and/or across few countries, which may be related to a firm's exposure to supply chain disruptions; quality and safety compromises; and, consequently, to product recalls. We, therefore, examine supply base concentration and its relationship with product recalls. As supply chains have become increasingly global and specialized, supply bases have also evolved. There are two ways in which supply base concentration may be related to product recalls as explained below. First, lack of

supply base concentration (i.e., a dispersed supply base) may be directly related to product recalls. Supply chain visibility and traceability can be much more difficult across many suppliers and across international boundaries as supply chains become diverse and global. Consequently, global supply chains may be more exposed to risks and vulnerable to disruptions (e.g. Rice and Caniato, 2003; Stauffer 2003; Chopra and Sodhi 2004; Tang 2006; Tohmatsu, 2007) increasing the risk of quality and safety failures that triggers recalls.

Second, supply base concentration may moderate the outsourcing/offshoring-recall relationship. Consolidation and concentration of suppliers could reduce searching, monitoring, enforcement, and coordination costs (for example Zhao et al., 2007 etc.)¹. Alternatively, a diverse supply base may lead to more complex supply chains (Choi et al., 2001; Craighead et al. 2007; Bozarth et al. 2009), which can increase uncertainty in the supply chain. Higher uncertainty may have coordination and monitoring implications (Denis et al. 2002; Bodnar et al. 1999). It is plausible that supplier dispersion may enhance the positive relationship between outsourcing and offshoring intensity and recalls due to the increasing transactional complexity and coordination challenges of dealing with multiple suppliers. Shirking, intentional or unintentional, may increase where coordination and monitoring difficulties exist. In contrast, a supply chain with a more concentrated supplier base may be able to contain its complexity and minimize its risks associated with product recalls.

Arguably on the other hand, diversifying the supply base may introduce competition

¹ Supply chain concentration has been found to potentially lead to higher financial performance (Lanier et al., 2010). In addition, more concentrated supply bases have been found to operate with reduced inventory costs (Trevelen, 1987), leading to cost savings (e.g., Guimaraes et al., 2002) and to benefits from scale economies through volume orders (Hahn et al., 1986).

among competing suppliers which may improve performance. However, given difficulties in measuring quality performance, coupled with the fact that there are multiple performance metrics in buyer-supplier relationship, supplier attention may be directed towards more easily measured performance criteria, such as cost and or delivery speed (Holstrom and Milgrom, 1991). This may put quality performance on the back seat offsetting any gains from the inter-supplier competition.

We are looking at three major issues in this paper as it follows from the previous paragraphs. First, we empirically investigate the link between outsourcing and offshoring (outsourcing conducted with foreign companies) and product quality failures as assessed through product recalls. Second, we examine the linkages between consolidation of the supply base to a small number of suppliers and countries and product recalls. We suggest two different relationships between supply base concentration and recalls: a direct effect through reduced exposure to risks and a moderating effect through diminished transactional complexity and coordination challenges. Our findings indicate that both outsourcing and offshoring have significant and positive impact on product recalls. Interestingly, we find that outsourcing to a smaller supplier base may actually lead to fewer recalls. Moreover, diversifying the supply base across many suppliers or international boundaries appears to compound the positive association between outsourcing and offshoring and product recalls.

The rest of this work is organized as follows. A review of literature is presented in the next section, followed by hypotheses developed from the literature and discussed in Section 3; data and research methodologies are outlined in Section 4.

The results are presented and discussed in section 5 with conclusion in the last section.

2. Literature Review

The central goal of this paper is to explain the linkages between supply chain strategies (outsourcing, offshoring, and supply base concentration) and product quality failures as assessed through product recalls. To develop the theoretical underpinnings for the research hypotheses, we draw upon literature on strategic sourcing and quality management, as well as on theory of transaction cost economics and agency theory.

2.1. Quality management and product recalls

Quality management (QM) research has focused on quality programs within a firm or facility and is quite developed (Sousa & Voss, 2002). However, there is a dearth of QM literature focusing on quality issues in a supply chain setting. Consequently, multiple scholars have suggested that attention be directed to extending the QM literature to include a supply chain perspective (for example Robinson & Malhotra, 2005). Notable exceptions are analytical works that have studied relative effectiveness of different forms of managing quality at contract manufacturer or a supplier (example Hart et al., 199; Economides, 1999; Hwang et al. 2006) and empirically (e.g., Forker 1997, Trent and Monczka 1999; Handley and Gray, 2012). However, none of these studies looked at how quality risks of a manufacturer are affected by the decision to outsource to several suppliers or a few suppliers. As it relates to offshore manufacturing, a few studies have indicated that offshore

locations, on average, perform worse in quality (Gray et al., 2011). However, our paper looks at offshore outsourcing as opposed to offshore manufacturing by the same company which Gray et al. (2011) looked at. We are also investigating the effect of manufacturing in a number of countries rather than manufacturing in a single country.

As it relates to product recalls, the popular press has covered well-known quality failures that have resulted in product recalls and have often linked these recalls to outsourced manufacturing. Recently, there has been an increase in empirical research in operations management on product recalls. Marucheck et al. (2011), in an editorial note, summarized the issues and outlined research opportunities in product safety research. They indicated industries that are prone to recalls and areas that have potential for academic research, including supplier relationship management. Thirumalai and Sinha (2011) conducted an empirical investigation of the causes of recalls in the medical devices industry. They found that research firms are more likely to make recalls and that product diversification and past recall experience are negatively correlated with future recalls. Earlier studies also found a negative relationship between learning experience and recalls. Haunschild and Rhee (2004) found that past voluntary recalls had a negative effect on future recalls. Beamish and Bapuji (2008) suggested that outsourcing to China has not primarily contributed to recalls, but rather most recalls are due to design flaws which were created by issues in the home country.

Most of the research into product recalls has been on the impact of recalls on firm outcomes, rather than on the sources or causes of recalls. For example,

researchers have examined the effects of recalls on demand (Crafton et al., 1981; Reilly and Hofer, 1983), on brand equity (Dawar et al., 2000), on marketing effectiveness (Herde et al., 2007), and on wealth of sellers (e.g., Jarrell and Peltzman, 1985; Hoffer et al., 1988; Thirumalai and Sinha, 2011). Despite observed challenges with outsourcing, the QM literature has not provided sufficient practical and theory-based guidance to brand-owning firms that outsource production to secondary or offshore manufacturers, nor have product recalls been associated sufficiently with outsourcing or supply base consolidation strategies.

This paper contributes to the literature by linking explicitly the quality management literature, the outsourcing/offshoring decision, and product recalls. Specifically, this paper investigates the extent to which outsourcing and offshoring, as well as the concentration of a firm's supply base structure, has bearing on product quality as indicated by product recalls. Further, this paper investigates the interaction between supply base structures and outsourcing on product quality failures, largely ignored to date in the literature. This is significant contribution because the decision to outsource goes in tandem with the decision on the number of contract manufactures or suppliers.

2.2. Outsourcing and Offshoring

Outsourcing decisions involve the choice between activities firms conduct themselves and activities firms buy from other firms (outsource) (Stukey and White, 1993). Studies have pointed out that outsourcing creates competitive advantages for firms (e.g., Narasimhan and Das, 1999). The growth in popularity of the practice has led scholars to deem it as a strategic rather than tactical purchasing activity (Kakabadse

and Kakabadse, 2003, Holcomb and Hilt, 2007, Kroes and Gosh 2010). There are quite a few theories across scholarly fields that describe the role outsourcing plays in creating competitive advantage for the outsourcing firm. Kroes and Gosh (2010) note that these theories include agency theory, transaction cost economics (TCE) and the resource based view.

Agency theory explains the motivation to outsource as a tactical move to delegate responsibility to an outsourcing firm leading to lower costs for the outsourcer (Kroes and Ghosh, 2010). The seminal work of Williamson (1975 and 1985) on transaction cost economics suggests that firms will either make or buy depending on the cost of doing business in the market. This theory has been widely referenced as a theoretical basis for many papers on outsourcing. The TCE proposition is that firms will outsource if outsourcing leads to a lower cost of transactions (Holcomb and Hilt 2007). This proposition holds true even when outsourcing introduces other costs, such as governance costs, as long as it leads to overall lower costs (Leiblein, 2003). The seminal work of Barney (1991) suggests that unique resources, capabilities and processes can provide a competitive advantage for a firm. From the outsourcing perspective, the resource base view states that outsourcing involves the decision of whether to use a firm's internal resources or to depend on other firms' resources to create competitive advantage.

Offshoring can be broadly defined as the relocation of some of the manufacturing or production stages to a foreign country. Although, it can happen within the firm's boundaries, as in the case of foreign direct investments, or through

transactions with firms in a foreign country, for our study offshoring is defined as international outsourcing.

Considerable research has looked at the performance of outsourcing and offshoring. In summarizing the literature on IT outsourcing, Lacity et al. (2010) reported that the empirical findings are conflicting. Results from outsourcing and offshoring have been found to be negative, positive, or insignificant. Some papers have found a negative curvilinear relationship between outsourcing and firm performance, using measures such as market share (Katobe et al., (2012) and financial performance (e.g., Grimpe and Kaiser 2010, Kotabe and Mole 2004, Kotabe et al., 2008, Rothermel et al., 2006). While some empirical studies have found that outsourcing leads to lower operational costs (e.g., Jiang et al. 2006) or higher firm value (Hays et al, 2000), others have found no relation to profitability (Jiang et al. 2006, Kimura 2002). In addition, opportunistic provider behavior has been noted in the literature as a concern with outsourcing (e.g., Halcomb and Hitt, 2007, McIvor, 2009).

While these theories and the empirical literature testing the efficacies of outsourcing as a strategy are well espoused, albeit with mixed findings, the literature so far has not looked deeply into the quality implications involved in lengthening and complicating the supply chain through outsourcing and offshoring. Our paper is well positioned to fill this void by linking outsourcing and offshoring to product recalls that emanate from quality failures. Further, as indicated earlier, we are linking the concentration of the suppliers and international diversification of the supply base to quality failures.

2.3. Supply Base concentration

Quite a few papers have been written on the concentration-performance relationship. It has been argued that concentrated supply bases have superior financial performance than more disperse supplier bases (Lanier et al., 2010). In addition, concentrated supply bases have been found to operate with reduce inventory costs (Trevelen, 1987), leading to cost savings (e.g., Guimaraes et al., 2002) and to benefits from scale economies through volume orders (Hahn et al., 1986).

However, not much has been done in linking supply base concentration with quality performance or quality failures that result in recalls. Notwithstanding this dearth of work, the broader literature on the relationship between supply chain complexity and performance can be used to motivate a linkage between supply base concentration and quality management. Complexity constructs defined by many academics have included measures of both supply base concentration and geographic diversification of suppliers. The number of suppliers has been identified as a complexity driver (Choi et al., 2001; Wu and Choi, 2005; Goffin et al., 2006; Bozarth et al., 2009) as well as the extent of globalization of the supply base (Cho and Kang, 2001; Nellore et al., 2001; Bozarth et al., 2009). Supply chain complexity has been shown to have a negative impact on service quality (Milgate, 2001; Vachon and Klassen, 2002) and manufacturing performance (example Bozarth et al., 2009).

Even though these studies have linked complexity to performance, linkages between supply base complexity and quality performance has not been established empirically to the best of our knowledge.

3. Hypotheses development

We draw upon agency theory to develop our hypotheses in this research. Even though the primary theoretical background is provided by agency theory which is used in developing the first two hypotheses, transactions cost economics (TCE) theory is used in developing the second set hypotheses and the intersection between agency theory and TCE is used for the last set of hypotheses.

Agency theory suggests that a combination of information acquisition, interest misalignment, moral hazard, and adverse selection (Fleisher, 1991) drives agency costs such as specifying, rewarding, monitoring, and policing the agent's behavior. Agency theory considers situations where information asymmetry and interest misalignment exists between a principal and an agent (Eisenhardt, 1989). Under this situations, the theory suggests that the agent would try to optimize its own interests at the expense of the principal which often may be suboptimal for the principal (Laffont and Martimort, 2002). In this study, the manufacturer or brand owning firm is considered the principal and the suppliers are considered as the agents. The rationale is that the brand owning firms own the activities that are delegated to the contract manufacturers or suppliers as in our case, and the brand owning firms' management interests are aligned with that of the firm.

This context has been used modestly across disciplinary boundaries in studying inter-firm boundaries and quality conformance. First, several analytic modeling papers have looked at vertical integration in a dyadic relationship and quality performance (example Economides, 1999; Kaya and Ozer, 2009; Lu et al., 2012). The overwhelming proposition is that decentralization can lead to objective

misalignment leading to the suggestions that quality is lower in a decentralized system. Other similar papers focused on moral hazard problem in a dyadic relationship when information asymmetry is present (example Baiman et al., 2000; Balachandran and Radhakrishnan, 2005; Hwang et al., 2006; Chao et al., 2009).

Empirically, there is a dearth of work on quality performance in inter-organizational relationships. Notable exceptions are few works in the service industry. Findings similar to the analytical modeling papers referenced above are noted. The general consensus is that vertically integrated operations provide higher service quality. In the hotel industry for instance, hotel chains operating with more franchises were found to have lower service quality (Michael, 2000). More recently, Hsieh et al. (2010) found that disintegrated courier service providers have more delivery time variability than integrated ones. These papers show that in an outsourcing environment even in the service industry, quality may be lower than in a fully vertically integrated system.

TCE is used as a secondary theoretical background in this study. TCE (Williamson 1979 and 1985) suggests that uncertainty, bounded rationality, and opportunistic behavior create transaction costs and that the primary objective in organizing trade is to minimize such costs within and between firms (Ketchen and Hult, 2007). Market mechanisms perform better with low transactions costs. High transactions costs favor internalization as a governance mechanism (Williamson 1979). Williamson (1985) suggested four forms of transactions costs, including searching, contracting, monitoring, and enforcement costs. Additional transaction costs have been suggested, including coordination costs (Grover and Malhotra, 2003),

defined as the cost of information sharing and transaction risk (Clemons et al., 1993), defined as the risk of shirking responsibilities.

Traditionally, in its primary form, the theory suggests instances in which one of the two extreme governance forms, make or buy, is optimal. The theory has also been used in explaining intermediate governance structures, such as contractual relationships (e.g., Rabinovich et al., 2007). Recently however, application of the normative nature of TCE which suggests that high transactions costs would be associated with low performance levels has been used in studying the relationship between supply chain structures and performance (example Lanier et al., 2010). Specifically as it applies to our study, concentrating a supply base which may reduce supply base complexity, could reduce upstream search, contracting, monitoring and enforcement costs (Zhao et al., 2007; Das et al., 2006; Choi and Krause, 2006; Corsten and Kumar, 2005) as well as coordination costs and transactions risks (Lanier et al., 2010). Choi and Krause (2006) suggests that the number of suppliers and consequently supply base complexity increases the total transactions costs of the focal manufacturing firm and that reducing the number of suppliers for instance, would reduce supply base transactions costs. Using this reasoning, Lanier et al., (2010) for instance find that concentrated supply chains are associated with higher performance defined financially.

These two theories are used to motivate the research hypotheses in this paper. Our contributions to these theoretical literatures come in four forms:

- a. providing empirical evidence for the analytical works as defined by agency theory

- b. providing empirical evidence of the agency theory in the quality domain in the product industry
- c. showing that location of the agents (offshore) exacerbate the agency problem
- d. developing managerial contingencies in an outsourcing environment by intersecting TCE and agency theory in including two key supply base structure moderators

3.1. Outsourcing and Offshoring relationship with product recalls

While quality improvement efforts are critical for best quality performance, there are many factors that work in conjunction to achieve quality excellence (Soussa and Voss, 2002; Nair, 2006). Toyota has historically been considered a quality management leader, for instance, consistently ranked number 1 by customers, both prior to and after the massive recalls in 2009 (<http://www.consumerreports.org>). Toyota is also ranked consistently as an industry leader in quality by professionals (e.g., JD Power and Associates; Kelly Blue Book). However, Toyota's quality management prowess could not prevent the 2009 recalls, and since that time, Toyota has made more than 22 recalls on 2010 and later car models. Despite Toyota's sustained effort to maintain best quality, these recalls suggest that its goals of quality excellence are difficult to attain in an outsourcing environment.

A key argument involves the impossibility of total awareness of quality efforts and actions of its suppliers and the subsequent incentive misalignment that may hinder quality efforts. First, some of the supplier's (as agents) activities that are

critical to quality performance can be difficult to observe by the buyer or manufacturer (as principal). Even though the buyer can monitor a supplier in a number of ways, total control over the supplier's production and procurement processes under outsourcing is almost impossible. In fact, loss of control is inevitable when a firm delegates authority to another organization (Laffont and Martimort, 2002), which encourages supplier moral hazard when the opportunistic supplier shirks its responsibilities. Second, the buyer's quality objectives may not be aligned with those of the supplier's. As demonstrated in the Mattel toy recall in 2007, a supplier, knowing that compromising quality costs the supplier little in terms of reputation while allowing for immediate gains, could have an incentive to deviate from its quality standards, leading to inefficiency associated with moral hazard. Compounding this situation is the difficulty in measuring quality performance as it may often be a composite of multiple individual performance measures. . Where there are many outcomes, effort can be funneled to the outcomes that are easily measurable, such as (Holstrom and Milgrom, 1991) cost or on-time delivery. These arguments from the agency theory suggest that quality may be lower with outsourced production as compared to in-house manufacturing.

Hypothesis 1a. Product recalls are positively associated with a firms' outsourcing intensity.

When outsourcing moves manufacturing offshore to other countries, as firms have increasingly done to take advantage of low costs in labor and other resources, additional issues may exacerbate the moral hazard problem if the problem is present

under outsourcing as we have suggested. Cultural issues, such as different perceptions on governance and legal infrastructural weaknesses in the enforcement of contractual terms, endemic in developing countries that are beneficiaries of most of the foreign outsourcing, are enabling environments for opportunistic behaviors of suppliers (Lyles et al., 2008; Lou 2008). Being far from the market may also help the suppliers to divert blame when there is a quality failure. Therefore, moral hazard may lead to more quality concerns when the supplier is located in a foreign country. Further, effective communication is hindered between the manufacturer (principal) and the suppliers (agents) in an offshore outsourcing situation. Geographic distance, travel distance, language distance and cultural distance each or together may inhibit information flow between the manufacturer and the suppliers increasing information asymmetry (Stringfellow et al., 2007). This increases risks associated with moral hazards. Moreover, in investigating the US pharmaceutical industry, Gray et al., (2011) found that quality risk varies by the location of the manufacturing facility. They found that products manufactured in offshore locations pose higher quality risks than their counterparts produced within the United States, even after controlling for distance and learning effects.

Hypothesis 1b. The positive relationship between outsourcing and product recalls is stronger for offshore outsourcing (offshoring) than domestic outsourcing.

3.2. Supply base concentration and product recalls

The complex and globalized supply chains, resulting from outsourcing and offshoring, often involve a large number of suppliers. Mattel had 37 certified suppliers and hundreds of others in China alone in 2007 (Bapuji and Beamish 2008).

Diversifying the supply base could lead to supply chains with “upstream complexity” (Choi et al., 2001; Wu and Choi 2005; Choi and Krause, 2006; Bozarth et al. 2009). Supply chain complexity can lead to high costs of coordination (Denis et al., 2002), make monitoring much more difficult and costly (Bodnar et al., 1999) and increase information asymmetry (Harris et al., 1982; Myerson 1982). Supply base complexity also may increase supplier risks and reduce supplier responsiveness (Choi and Krause, 2006). From the perspective of TCE on quality, more specifically, supply base complexity may implicitly increase the costs of identifying quality problems, contracting for quality performance, monitoring quality standards, and enforcing quality control programs. When sourcing is widely distributed across a large number of suppliers, individual suppliers may expect higher uncertainties in their supply relationships with the buyer and more likely develop opportunistic behavior in quality improvement effort. In addition, a concentrated supply chain should enable visibility and traceability, leading to early detection of production and supply chain issues.

Another potential driver of product recalls is supplier diversification across geographic regions. Even though there is little literature on the effects of global sourcing on product quality, the broader context of TCE can offer some insights. Geographic diversification of the supply base contributes to the upstream supply

chain complexity (Bozarth et al., 2009) leading to higher transactions costs. Further, nationally diversifying the supply base, in effect, would inhibit inventory visibility and traceability and consequently supply chains would be more exposed to disruptions (e.g. Rice and Caniato, 2003; Stauffer 2003; Chopra and Sodhi 2004; Tang 2006; Deloitte Consulting, 2007). In addition, the effects of such complexity can be compounded through geographic and cultural distances among the member countries. Knowledge transfer needed to attain quality levels across the supply chain; for example, from a parent company to suppliers or subsidiaries, can be hindered by both physical and cultural distances (Gray et al., 2011).

Hypothesis 2a. Product recalls are negatively associated with the degree of concentration among a firm's suppliers.

Hypothesis 2b. Product recalls are negatively associated with the degree of geographical/national concentration of a firm's suppliers.

As this relationship between supplier concentration and recall is developed from uncertainties and moral hazard issues, it overlaps with the relationship between outsourcing (and offshoring) and product recalls. Both relationships have transaction cost implications on product design, production, and quality management. Specifically, a more concentrated supplier base under outsourcing may ease a firm's effort in coordination, monitoring and enforcement of the quality activities conducted by the suppliers, leading to lower transaction costs involved in such effort. Consequently, supplier concentration may mitigate the negative relationship between outsourcing intensity and quality performance. As Bozarth et al., (2009) argued, the

number of suppliers is associated with increased information and physical flows and greater numbers of relationships to be managed. These high information and physical flows needed in a diverse supply base increases the risk misinformation (information asymmetry) as well as exposure of the product to supply chain disturbances that may compromise quality and safety. Furthermore, the distribution of the suppliers directly affects the visibility of the supply chains, as a large number of small suppliers may make communication and information sharing in the supply chains more difficult, further aggravating the moral hazard problem.

Geographic concentration of suppliers may also moderate how offshoring is associated with product recalls. A supply chain that spans several international boundaries can be more complex than a chain concentrated in one country, for a given number of suppliers (Bozarth et al. 2009; Craighead et al., 2007). Supply base complexity can also lead to high costs of coordination (Denis et al., 2002), making monitoring much more difficult and costly (Bodnar et al., 1999) with higher information asymmetry (Harris et al., 1982; Myerson 1982). Consequently, geographic diversification (concentration) may strengthen (weaken) the negative relationship between offshoring and quality due to higher degree of complexity in business transactions and coordination among suppliers across geographic boundaries.

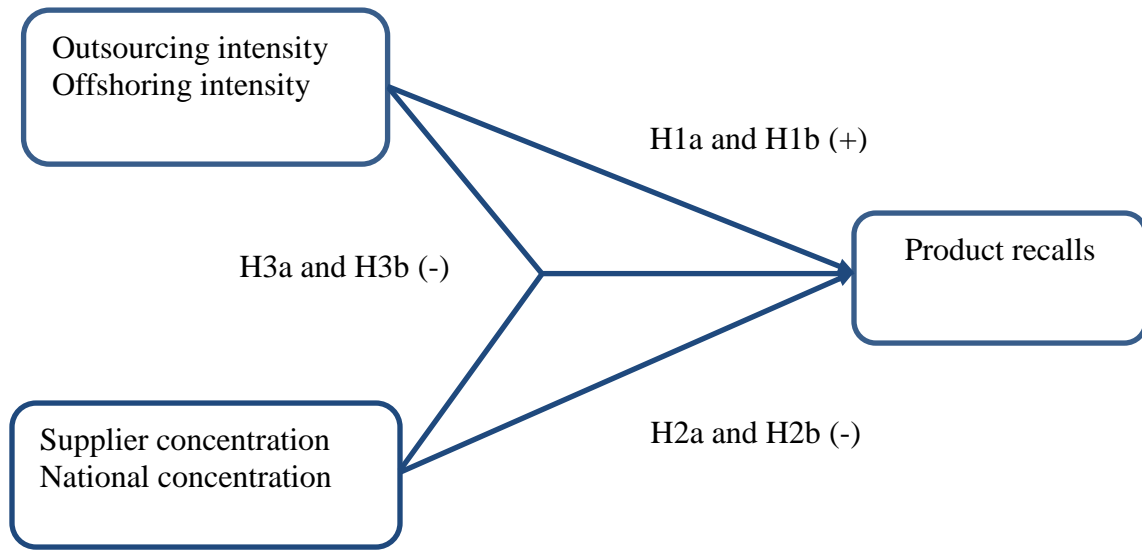
Hypothesis 3a. The positive relationship between outsourcing and product recalls is weaker when the supply base is more concentrated.

Hypothesis 3b. The positive relationship between offshoring and product recall announcements is weaker when the supply base is more concentrated nationally.

4. Model Development and Data

In this section, we develop econometric models to test the above hypotheses. The modeling framework is based on the relationships between product recalls and outsourcing intensity, offshoring intensity, sourcing concentration by suppliers and by geographic locations. Furthermore, additional moderating effects are also examined between supplier concentration, outsourcing, and offshoring. Outsourcing and offshoring intensity are expected to be positively related to the number of recalls (H1a and H1b) and concentration in both suppliers and geographic locations are expected to be negatively related to recalls (H2a and H2b). Also, supply base concentration and national concentration are expected to water down the positive relationship between outsourcing/offshoring and product recalls (H3a and H3b). Figure 1 illustrates this modeling framework.

Figure 1 – Research Model



4.1. The Empirical Model

The dependent variable is the number of recalls, and the explanatory variables are outsourcing and offshoring intensity and supplier and national concentration levels.

An econometric model is proposed that captures these effects. Given that recalls are infrequent for firms and the number of recalls is a count data, it is best to characterize our dependent variable by a Poisson or Negative Binomial distribution.

The regression equation is given below:

$$\begin{aligned}
 \text{Recall} = & \beta_0 + \beta_1 \text{outsourcing} + \beta_2 \text{offshore} + \beta_3 \text{supplier concentration} + \beta_4 \text{national concentration} \\
 & \beta_5 \text{outsourcing} * \text{supplier concentration} + \beta_6 \text{offshore} * \text{national concentration} + \beta_7 \text{prior_recall} \\
 & + \beta_8 R \ \& \ D \text{intensity} + \beta_9 \text{size} + \beta_{10} \text{capital intensity} + \sum_{i=1}^{20} \beta_i \text{industry} + \varepsilon
 \end{aligned}$$

β_1 and β_2 are expected to have positive signs while β_3 through β_6 are expected to have negative signs.

Where:

- Recall is the dependent variable measured by the number of recall announcements per firm per year.
- Outsourcing is one of the key independent variables. It measures the extent to which firms source from outside their firms as oppose to making products in-house.
- Offshore is the second explanatory variable of interest. It measures the extent to which a firm sources internationally; i.e., offshores.
- Supplier concentration is supplier concentration which measures the extent to which a firm’s suppliers are concentrated (or diversified).
- National concentration is concentration of the suppliers of a firm within national boundaries. It captures both the number of suppliers residing in a country as well as the share of costs expended on them by the manufacturing company.
- R&D intensity is a measure of R&D intensity and is a control variable in the model which reflects a firm’s innovative capability and may be associated with a firm’s quality performance. R&D efforts of a firm may reduce the chances of a quality failure, and, hence, lead to lower recalls. On the other hand, higher R&D intensity may also indicate the firm’s focus on innovation and new product development, which may increase the likelihood of errors and thus positively affects recalls.
- Prior recall is a control variable aimed at capturing the effect of learning from quality and safety failures. Recall events may “trigger renewed attention to the weak links in the process and foster research toward improving the existing

operations by bringing new information and resources” (Thirumalai and Sinha, 2011, p. 381). As such, prior recalls made by firms may lead to efforts that mitigate future recalls. On the other hand, prior recalls may just represent poor supply chain management, in which case, one would expect them to be positively related to future recalls.

- Firm size is used as a control variable. Firm size may be positively associated with recalls as larger firms usually have a more diversified product base and are therefore more complex.
- Capital intensity is a control variable that may be associated with firm quality performance. Capital investments includes investments in information technology which may improve visibility of inventory and thus increase the chances of detecting and correcting defects before products reach the market. Capital intensity is therefore expected to be negatively related to product recalls.
- Industry effects are included as control variables in the model. Three-digit North American Industrial Classification System (NAICS) codes are used to classify industry sectors. In North America, industry sectors are classified primarily based on production processes and technologies, both of which may affect product quality and recalls. It is very possible that the nature of activities of an industry will be associated with supply chain disruptions. We include these industry-specific dummy variables to control for otherwise omitted industry-specific attributes that influence product quality and recalls.

4.2. Data and Data sources

To test the hypotheses, we make use of a cross sectional database on publicly traded manufacturing firms, including information on their relationships with suppliers and buyers, the strength of these relationships, and the recalls made by each firm. By using archival data in this analysis, the information gathered is not dependent on survey respondents' perceptions and or attitudes (Goffin et al. 2006).

This investigation is limited to public firms within the US manufacturing sector. The sample uses these firms for a number of reasons. First, the research is about "make or buy" decisions and the sector that faces that decision most often is the manufacturing sector. Other sectors, such as retail, almost always depend on secondary firms for their production needs. No doubt, large retailers, such as Walmart, Target and Babies R Us, play a critical role in the US economy and possess and exercise significant power over supply chain members. However, they are not faced with decisions to make or to buy and, therefore, are not appropriate for this analysis. A second reason is the availability of data on public firms. Since public firms are required to make many disclosures, data are only available for these firms.

Data for this analysis are gathered from three different sources. The main hypotheses revolve around outsourcing and offshoring and their impacts on firm performance as measured by the number of recalls. The performance data comes from two sources. First, the recall data are collected from the US Consumer Product Safety Commission's (CPSC) and US Food and Drug Administration's (FDA) recall announcements. Both the CPSC and the FDA record all recall announcements, voluntary or mandated, of all consumer products, and food, drug and medical devices

respectively. This information includes the quantity recalled, the average price for the recalled products, the type of recall (voluntary or mandatory), and information on whether the faulty product has resulted in any incidences. These data are utilized to obtain the number of recalls each firm makes within our period of observation.

To account for firms with zero recalls, we started by collecting information on all firms in the manufacturing industry using the 6 digit NAICS code from the Compustat data base. Since our explanatory variables are collected from the Bloomberg database (explained further below), the analysis is limited and applicable to only 2010 and 2011, a two year period for which we collected information on firms from the Compustat database. Data is collected on all 6-digit NAICS codes ranging from 3111112 to 3399999, except for 336111, automobile manufacturing, whose jurisdiction on quality and recalls lies outside both CPSC and FDA authorities. This data are then matched with the Bloomberg data by company name to get a unique dataset of 328 firm observations. Recall announcements are then gathered for these 328 firms from both the CPSC and FDA databases. We are therefore able to have firms that made zero recalls within our study period, as well as firms with as many as 4 independent recalls. Descriptive data analysis is given in the next section.

The data for the four explanatory variables capturing outsourcing intensity, offshoring intensity and supplier and national concentration, are compiled from the Bloomberg database. Bloomberg offers data on about 35,000 firms' supply chain relationships. The data map a company to its suppliers, customers, and competitors, and gives an indication of the strength of the relation between any two firms in a dyadic relationship. The supply chain data provided by Bloomberg reveal money

flows between companies on both a customer (revenue) and supplier (cost) basis. Estimates are provided of the percentage of a supplier's revenue that comes from a given buyer, and the percentage of a buyer's cost of goods sold that is spent on a given supplier.

Bloomberg uses three different methods to compile this dataset. The first, termed as the "mathematical method", derives the supply chain relationship from public data as well as from information collected from the companies directly. In the second method, Bloomberg has its own algorithm that is used to quantify relationships based on content analysis such as announcements from manufacturers or their suppliers. Third, Bloomberg also purchases propriety data from other sources. Excerpts of the data description by Bloomberg, as well as a screen shot of the supply chain data, is given in the appendix. Finally, data on the control variables are collected from the Compustat database.

4.3. Measures of Variables and Descriptive Statistics

Recall, the dependent variable is a count variable. The number of independent recalls will be used as the dependent variable to test the hypothesized relationship between sourcing strategy and performance. A total of four core independent variables are of interest in the study. They include outsourcing intensity, offshoring intensity, supplier concentration, and national concentration.

Outsourcing intensity is measured as the percentage of a firm's cost of goods sold (COGS) that are expended on its suppliers as provided in the Bloomberg database. The larger this percentage, the more intense is a firm's outsourcing activity.

$$\text{Outsourcing in intensity (Outsour)} = \frac{\sum \text{expenditure to secondary firms}}{\text{Cost of goods sold}}$$

Offshoring intensity is measured as the percentage of a firm's COGS that is expended on foreign firms. Foreign firms mean firms that are registered or headquartered in foreign countries.

$$\text{Offshoring in intensity (Offshore)} = \frac{\sum \text{expenditure to foreign firms}}{\text{Cost of goods sold}}$$

Both variables measure the extent of relationships with other firms relative to cost of goods sold.

Supplier concentration is measured as the sum of the squares of shares of cost of goods sold expended on each supplier following the Herfindahl-Hirschman Index (HHI).

$$\text{suppliercon} = \sum_{i=1}^N S_i^2$$

where S_i is the share of COGS expended on firm i and N is the total number of suppliers. A value of 1 indicates that a firm has only one supplier and the value of the variable approaches zero as the number of suppliers approach infinity.

National concentration is calculated as the sum of the squares of shares of cost of goods sold by domicile country of the suppliers.

$$\text{Nationcon} = \sum_{j=1}^M X_j^2$$

where X_j is the total share of COGS expended on suppliers in country j and M is the total number of countries in which the firm has suppliers. Similarly, a value of 1 implies that all of a firm's suppliers are domiciled in 1 country.

R & D is measured by a firm's research and development expenditure normalized by sales, while prior recalls is a cumulative measure of recalls prior to the study year.

4.3.1. Descriptive statistics

Firm sourcing characteristics and the distribution of firms by industry are given in

Table 1 and overall descriptive statistics are provided in Table 2.

Table 1 Distribution of firms by industry

NAICS	No. of unique firms	Avg. firm outsourcing	Avg. national concentration	Avg. supplier concentration	Avg. firm recall	Avg. firm prior recall
311	24	0.272	0.342	0.004	0.292	1.160
322	12	0.2000	0.331	0.006	0.083	0.167
325	74	0.235	0.332	0.038	0.324	0.905
332	12	0.230	0.393	0.017	0.250	1.917
333	36	0.406	0.304	0.013	0.306	1.028
334	97	0.630	0.349	0.076	0.092	0.392
335	8	0.108	0.271	0.001	0.250	0.625
336	45	0.550	0.356	0.031	0.133	0.533
337	2	0.009	0.259	0.000	0.500	1.000
339	18	0.285	0.325	0.010	0.278	2.389

From Table 1, it can be seen that firms from the computer and electronics manufacturing sector account for about 25% of the firm-years of observations, while firms from the leather and nonmetallic manufacturing industries are least represented with less than 1% of the observations each. In terms of outsourcing, firms with operations in computer and electronics manufacturing outsource the most (63% of COGS), followed by transportation equipment (55%). On the other hand, firms in the leather industry (<1%), followed by nonmetallic industry firms (1%) have the least outsourcing intensity. With respect to geographic locations (national), most industries are fairly concentrated in terms of their sourcing behavior. The most concentrated are firms in the petroleum industry, sourcing from an equivalent of 3 countries with equal shares, and the least concentrated is the plastics and rubber sector with an equivalent of 10 countries that an average firm sources from. On the contrary, almost all

industries are quite spread out in terms of suppliers. The most concentration of suppliers however, is the computer and electronics industry. The highest recalls are in the furniture industry with an average of 0.5 recalls per firm over the two year period, followed by the chemical industry. In terms of prior recalls, firms classified as “other durables” (which includes toy manufacturing) have the most recalls prior to our observation years.

The mean outsourcing intensity for all firms is 17% of cost of goods sold (Table 2) with a mean of 0.188 recalls per firm year and a maximum recalls per firm year of 4.

Table 2 Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Outsource	328	0.179	0.232	0.000	0.855
Offshore	328	0.087	0.156	0.000	0.553
National concentration	328	0.339	0.139	0.117	0.722
Supplier concentration	328	0.038	0.081	0.000	0.423
Recall	328	0.188	0.535	0.000	4.000
Prior recall	328	0.817	1.741	0.000	12.000
R&D intensity	328	0.063	0.066	0.001	0.330
Capital intensity	328	0.041	0.037	0.007	0.308
Size (Sales)	328	12437	16698	52	108249

5. Results

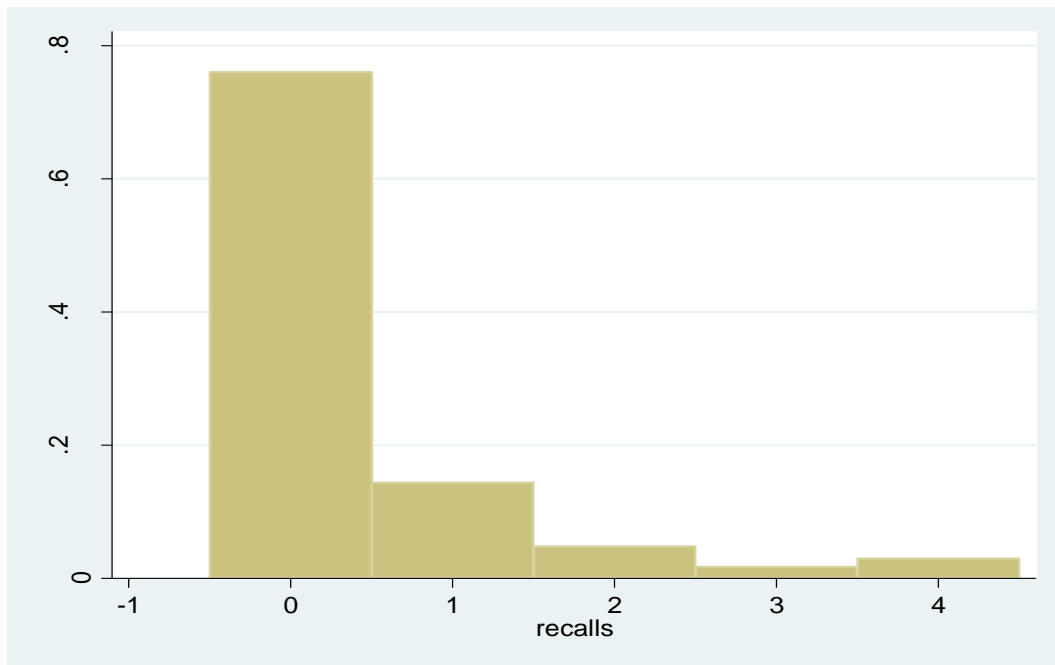
Table 3 provides the correlations between the variable pairs. As expected, there is a positive correlation between both outsourcing intensity and offshoring intensity and recalls. Both country and supplier concentrations have negative correlations with recalls. Interesting, both supply base concentration and national concentration are negatively correlated with outsourcing and offshoring respectively. R & D appears to be positively correlated with recalls as is size as measured by sales.

Table 3. Correlation between variables

	Recalls	outsourcing	offshore	National concentration	Supplier concentration	Capital intensity	R&D intensity	Size (sales)
Recalls	1							
Outsourcing	0.0118	1						
Offshore	0.0253	0.7525	1					
National concentration	-	-0.0311	-0.3175	1				
Supplier concentration	-	-0.3624	-0.2229	0.738	1			
Capital intensity	-	0.0233	-0.0072	-0.0732	-0.0258	1		
R&D intensity	0.0989	0.4706	0.0362	0.1089	0.4497	0.0739	1	
Size(sales)	0.3068	0.4291	0.015	-0.2109	0.0898	-0.0266	-0.0425	1

To reduce heteroscedasticity, all variables, except the dependent variable, are standardized. To control for industry effects, the models are run using both fixed and random industry effects. The estimations using fixed and random effects provide very similar results, so only the random effects model results are presented here. As suggested earlier, because of the discrete nature of the dependent variable, the estimation is best characterized by either a Poisson or a negative binomial distribution. This supposition is supported by the graphical/visual presentation of the dependent variable observations as shown in Figure 2. Figure 2 supports a Poisson distribution. However, the limitations of the Poisson, characterized by only the mean (assumption that the mean and variance are equal), makes the negative binomial a better distribution for this analysis. In fact, the variance of recalls far exceeds the mean, supporting our estimation technique.

Fig. 2; Histogram of recalls



The regression results are presented in Table 4. There are a total of 5 different models. In Model 1, coefficients of the control variables alone are estimated, then outsourcing alone plus the other hypothesized variables are added in Model 2. In Model 3, the outsourcing variable is split into domestic and offshoring to account for the effect of offshoring. The interaction of outsourcing and supply base concentration and offshoring and national concentration are respectively estimated in Models 4 and 5 to limit the effects of multi-collinearity. Overall, all the models have significant Wald Chi-squared statistic. For the model, including the hypothesized relationships but excluding the interaction terms, the Chi-Squared statistic is 92.04 and highly significant at $p < 0.001$. However, all analyses are based on Model 3 for Hypotheses 1a through 2b and Models 4 for the outsourcing-concentration interaction effect and 5 for the offshoring-national concentration effect.

The coefficient for outsourcing is positive and significant in all of the models that include it. This indicates that, as hypothesized, the relationship between

outsourcing and recalls is positive. This result supports the first hypothesis that recalls are positively associated with outsourcing intensive firms. When the outsourcing variable is split to account for offshoring (in Model 3), the outsourcing coefficient however becomes smaller in magnitude and weakly significant. The offshoring variable has a positive coefficient and is significant supporting the second hypothesis. The supplier concentration coefficient is negative and significant. As expected, this indicates that concentrating the supply base is associated with lower recalls. Hypothesis 2a is therefore supported. However, the national concentration coefficient, though the expected sign, is insignificant in all 3 models. There is not enough evidence, therefore, to support Hypothesis 2b. Because of the high correlation between supplier concentration and national concentration, their interaction variables are separately investigated in models 4 and 5. The supplier concentration-outsourcing interaction is significant and negative supporting Hypothesis 3a. This indicates that supply base concentration waters down the negative quality effects of outsourcing. The offshoring-national concentration interaction variable also has a significant and negative coefficient. Hypothesis 3b is therefore supported.

There are some interesting results from the control variables as well. R&D intensity is positively associated with recalls, as indicated by the significant positive coefficient. The results support the notion that higher R&D intensity is an indication of a firm's focus on innovation and new product development. This may increase the likelihood of errors and thus positively affects recalls. There is a possible second intuition for this result. A firm with significant expenditures in R&D may be more

likely to monitor and discover product defects that dictate a recall. Since our database does not differentiate between voluntary and mandatory recalls, firms with high R&D may have greater frequency of voluntary recalls as a consequence of their R&D. The coefficient for Capex (capital intensity) is not significant at any reasonable level and therefore, is found not to have a relationship with product recalls. Larger firms are associated with more recalls as given by the positive and significant coefficient on the size variable. Contrary to expectation, the prior recall coefficient is positive and significant. This contradicts prior findings that previous recalls are negatively related to future recalls.

Table 4. Regression results for negative binomial random effects model

	Model 1 (Standard error)	Model 2 (Standard error)	Model 3 (Standard error)	Model 4 (Standard error)	Model 5 (Standard error)
R&D intensity	0.397**(0.136)	0.440***(0.136)	0.434***(0.134)	0.534***(0.157)	0.499***(0.147)
Capital intensity	-0.007(0.181)	-0.056(0.183)	-0.061(0.182)	-0.040185(0.204)	-0.116(0.210)
Firm size (sales)	0.384***(0.100)	0.420***(0.128)	0.440***(0.119)	0.550***(0.142)	0.481***(0.123)
prior recall	0.471***(0.076)	0.479***(0.076)	0.482***(0.076)	0.402***(0.074)	0.408***(0.074)
outsourcing (aggregate)	-	0.601**(0.275)	-	0.629**(0.787)	-
Outsourcing (domestic)	-	-	0.057*(0.034)	-	.-
offshore (offshore outsourcing)	-	-	0.549**(0.251)	-	0.568*(0.291)
Supplier concentration	-	-0.674*(0.353)	-0.603**(0.226)	-0.969*(0.537)	-
National concentration	-	-0.080(0.158)	-0.132(0.172)	-	-0.405(0.305)
Outsourcing*supplier concentration	-	-	-	-0.573**(0.276)	-
offshore*national concentration	-	-	-	-	-0.322**(0.163)
Number of observations	328	328	328	328	328
Number of industries	10	10	10	10	10
Mean observations per industry	31.6	31.6	31.6	31.6	31.6
Model Wald Chi-Squared	61.19	91.35	92.04	91.93	90.92
Model Probability (>chi-squared)	0	0	0	0	0

*, **, and *** denote 10%, 5% and 1% significance levels for two-tailed tests, respectively

6. Discussions, research implications and limitations

6.1. Conclusions and limitations

6.1.1. Direct relationships

Product recalls are on the rise. Toyota for instance, recently made the largest automotive recall in history on the 10th of October 2012 and this followed the recall associated with pedals and floor mats in 2009. It cannot be overemphasized that the most globalized industries, both in terms of sourcing and market reach, are most associated with recalls. The combination of product recalls and increased globalization has resulted in the juxtaposition of these two trends. There is however, no established theoretical relationship between outsourcing and product recalls and there is even some empirical evidence that there is no relationship. The main contribution of this paper therefore, is to investigate the relationship between the extent of outsourcing/ the extent of offshoring and product quality/ safety performance, as assessed through recalls. In addition, we examine the moderating effect of supply base and national concentration on the outsourcing-recall relationship.

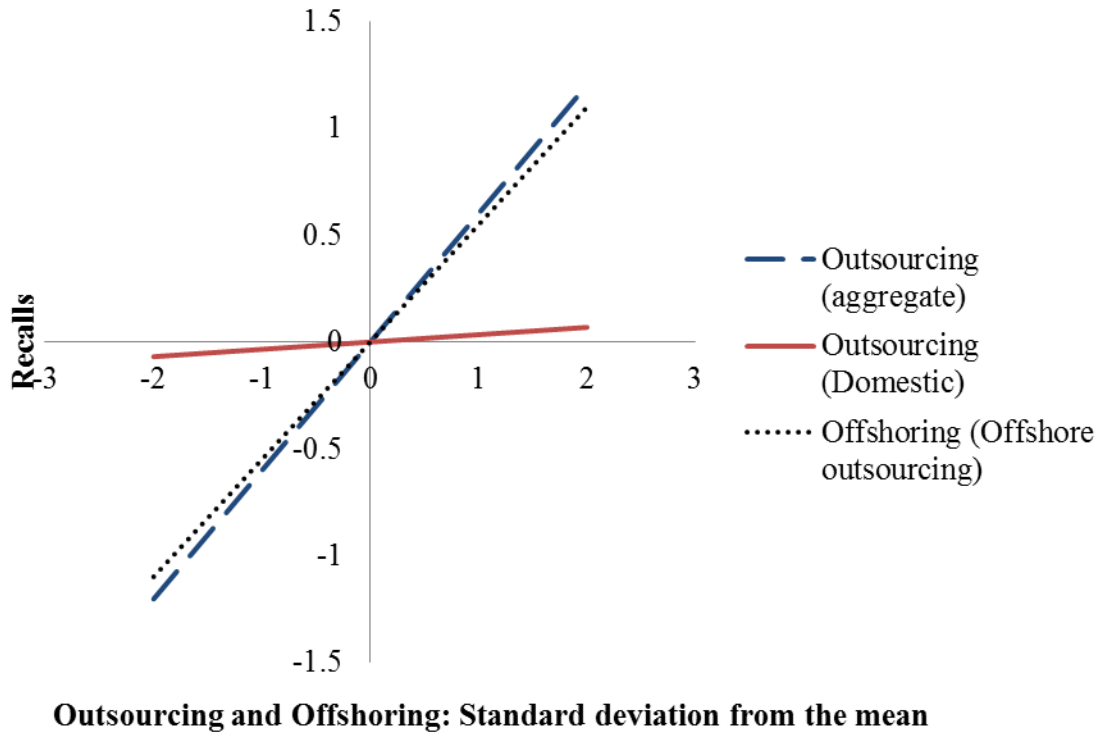
A major contribution of this paper is the focus on both outsourcing and offshoring, distinguishing between them and hypothesizing their effects separately. The separation of outsourcing from offshoring helps in identifying the sources of quality issues in an outsourcing environment. This distinction separates this study from a number of other studies on vertical integration and manufacturing outsourcing. This is a theoretical contribution as it implicitly suggests that the moral hazard problem is exacerbated by transactions across international borders. Our findings that

most of the quality issues emanating from outsourcing are driven by offshore-outsourcing (offshoring) provides an interesting insight and a major contribution to the research stream.

Second, our empirical results show that outsourcing is associated with lower quality and safety performance. This finding is in line with well-known operations management theories, such as, knowledge transfer, transactions cost economics, and agency theory. Knowledge transfer indicates difficulties in transferring knowledge across firm boundaries. There may be difficulties in alignment among firms in the supply chain resulting in quality and safety failures. Transactions cost economics indicates supply chain complexity will increase with extensive globalization. This will result in difficulties in managing over the entire supply chain and lead to quality failures. Agency theory links opportunistic behavior with the delegation of authority (example outsourcing) leading to quality and safety failures that result in recalls. Offshoring, as expected, is positively associated with product recalls; that is, offshoring intensity is associated with more recalls. As argued in the hypotheses development, outsourcing to offshore suppliers engenders the moral hazard problem that may follow outsourcing. In fact, when the variable is split to account for offshoring, it appears that most of the negative quality performance is generated by outsourcing to offshore suppliers. The quality problems in outsourcing, are, therefore, more driven by outsourcing to offshore locations than just outsourcing. This finding is demonstrated in Fig. 3 estimated from the results in Model 3. It can be seen from Fig. 3 that domestic outsourcing has a smaller slope (almost flat) indicating a very

small relationship to recalls. On the other hand, Offshoring almost equals the total outsourcing slope.

Fig. 3. Product Recall and Outsourcing: Aggregate, Domestic and Offshoring



A second motivation of the research was to investigate the association between supply base concentration and recalls. Referencing transactions cost economics theory and literature on supply chain complexity, we hypothesized that diversifying a firm's supply base may be associated with greater numbers of product recalls. This finding reinforces prior research showing that concentration within a supply chain may be associated with superior firm performance as measured by other metrics as cost, profits, and inventory (example Lanier et al., 2010; Trevelen, 1987; Guimaraes et al., 2002) and extends current knowledge by linking concentration to

quality performance. A direct relationship between national concentration and quality was however not found.

6.1.2. Moderating effect of supply base and national concentration

The most important of our contributions to the literature is the finding that diversification of both supply base and national location enhances the relationships between outsourcing and quality and offshoring and quality, respectively. To clearly illustrate this, we look at the marginal impact of changes in offshoring and outsourcing environment on the number of recalls. From the Model 4 results, the equations below can be used to obtain the effect of outsourcing on recalls at the mean levels of all other variables.

$$\begin{aligned}
 \text{Recall} &= 0.629\text{outsourc} - 0.573\text{outsourc} * \text{suppliercon} \dots\dots\dots(2) \\
 \text{Differentiating with respect to outsourcing} \\
 &= 0.629 - 0.573\text{suppliercon}
 \end{aligned}$$

At the mean levels of supplier concentration for instance (that is $\text{suppliercon} = 0$), the marginal effect of outsourcing intensity on recalls is 0.629. This means that a standard deviation change in outsourcing intensity is positively associated with 0.629 recalls.

At high supplier concentration level ($\text{Suppliercon} = 1$; one standard deviation above the mean)

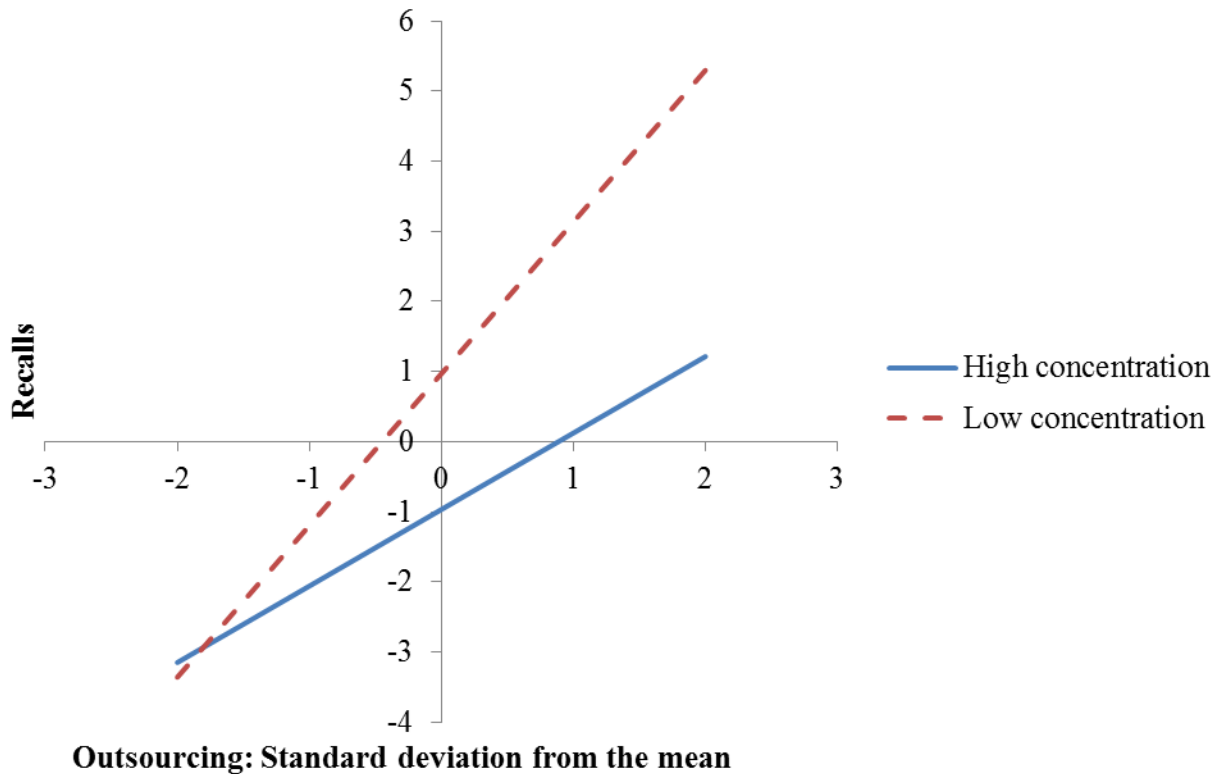
$$\text{Recall} = 0.629 - 0.573 = 0.056 \text{ recalls}$$

At low supplier concentration level (Suppliercon = -1; one standard deviation below the mean)

$$\text{Recall} = 0.629 + 0.573 = 1.202 \text{ recalls}$$

These results imply that for firms with a supply base with a concentration level that is one standard deviation above the mean value, a standard deviation change in outsourcing is only positively associated with 0.056 recalls. However, for a firm that operates in a diversified supply base of one standard deviation below the mean concentration level, a standard deviation change in outsourcing is positively associated with 1.2 recalls. This moderating effect of supply base concentration is illustrated in Fig.4.

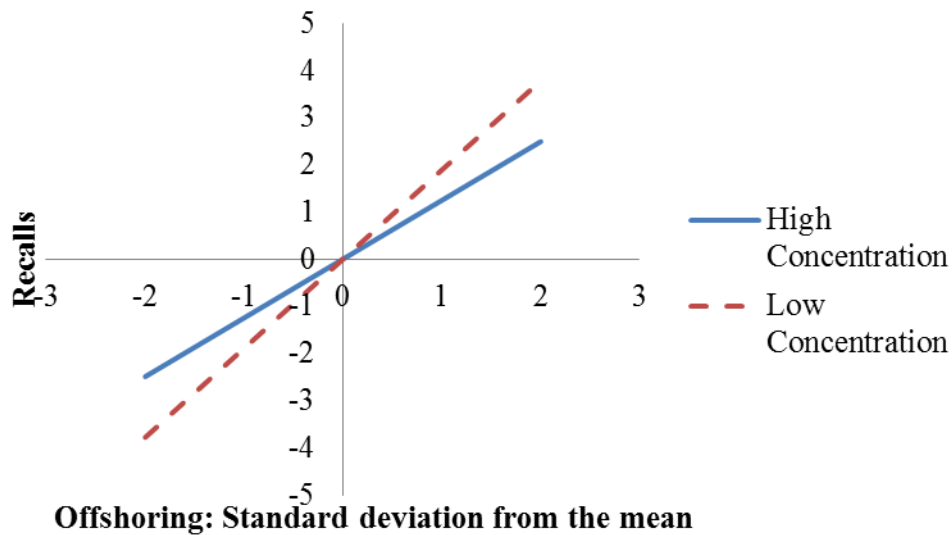
Fig. 4. Product Recall and Outsourcing: The Moderating Role of supply base concentration



Clearly, from Fig. 4, there is a stronger relationship between outsourcing and recalls for less supply base concentrated firms (firms with one standard deviation below the mean concentration) as illustrated by the higher slope (dotted line).

The moderating effect of national concentration on offshoring can be similarly estimated and is demonstrated in Fig.5 below from the Model 5 results. It is important to note here that national concentration does not appear to have any direct relationship with recalls. However, when interacted with offshoring, the result is significant and positive as expected.

Fig. 5. Product Recall and Offshoring: The Moderating Role of national concentration



6.2. Managerial implications

One important managerial implication of our study is that both outsourcing and offshoring may be associated with unintended consequences, such as product non-conformance with standards that may lead to recalls. This consideration should

therefore be taken into account with any cost saving decisions that result from outsourcing.

A second finding in this paper is the relationship between supply base concentration and product recalls. This finding also has an important managerial implication. Recently, large firms have been diversifying their supply bases as a risk mitigation strategy. For example, Flextronics was the sole EMS supplier for the Xbox. However, Microsoft added Wistron and Celestica as suppliers in 2004 (Hoyt and Lee, 2006) in order to diversify supply risk. While doing so, Microsoft may be adding to potential quality issues. While national diversification of the supply base does not appear to have any relationship with quality failures that result in recalls, it exacerbates the quality issues associated with offshoring. Managers should therefore pay attention to the number of countries they are sourcing from as sourcing decisions are taken.

Moreover, attention should be drawn to the finding that having fewer suppliers may reduce the negative quality effects as firms outsource. This is important because not only does concentration of the supply base reduce the exposure of the supply chain to disturbances but also limits difficulties associated with transactions and coordination needed for effective relationship management in an outsourcing environment. Firms may be able to reap the cost benefits associated with outsourcing and be able to limit the quality effects by concentrating their outsourcing behavior among few suppliers.

6.3. Research Implications

There are a number of important research and managerial implications of our findings. An important research implication is that outsourcing may have both direct and indirect effects on firm performance. The direct effect is through cost savings. Indirectly however, outsourcing may be associated with product recalls counteracting the direct cost savings. Perhaps, this is one explanation as to why research on outsourcing-performance relationships has inconsistent findings. There is potential for future research in this direction. The literature has pointed out cost savings as the main driver of outsourcing. It may be possible to attain the cost savings resulting from outsourcing whilst maintaining good quality if certain conditions are present; that is, firms may take actions that keep recalls at a minimum but still rely on secondary firms for their manufacturing. The investigation of such moderating relationships on the outsourcing-recall relationship is a future direction of this research stream. As it relates to the findings associating offshoring to recalls, future research should look at attributes of specific offshore locations to determine what is responsible for the difference in quality. Such attributes include geographic locations of the suppliers, physical as well as cultural distances, and physical, institutional and infrastructural development of the suppliers' foreign bases.

This study also only looked at supply base concentration ignoring the length of the supply chain. There is the potential that the length of the supply chain also adds to its complexity and therefore may compound the negative quality effects of outsourcing. Addition in this area could be an important contribution to the research stream.

6.4. Research Implications

There are quite a few limitations to the study. First, data limitations restrict the study to only a two-year time period. A study using a panel dataset may better allow for the investigation of causal factors. Second, our study is limited to publicly traded firms. A study that can include private firms is desired to add further insights to the subject area since a reasonable number of recalls are made by private firms. Third, the Bloomberg database, which is the source for the explanatory variables, has data mainly on large firms. Adding small firms to the analysis may improve the generalization of the findings. The outsourcing measure must be used with caution. The Bloomberg data indicates the firms' headquarters which is used to operationalize the outsourcing variable. However, it is not clear where these firms produce their outputs.

Essay 2: Product Recall and Firm Financial Performance in the Consumer Product Industry

1. Introduction

Anecdotal evidence has suggested that product recalls can have devastating effect on firms' performance. For instance, Toyota recalled its vehicles in 2009 and 2010 because of serious problems with accelerator pedals and floor mats. The recalls resulted in costs in billions of dollars due to loss of sales, litigation fees, and image restoration campaigns. This effect was felt not only in the US but across the globe where Toyota has substantial presence in markets and supply chains (Sanchanta and Takahasi, 2010). In total, Toyota suffered an estimated loss of US\$2 billion from worldwide (for example BBC 2010, Time 2010) from these recalls. Similarly, recalls by Mattel/Fisher Price in 2007 because of the use of lead-based paint by its paint suppliers and detachable magnets received significant media attention. Mattel suffered losses of approximately \$30 million, almost 50% of a whole quarter's operating revenues of the company (Bloomberg, 2007).

The limited prior research of product recalls in operations and supply chain management is driven by growing need for safer products, globalization of production, increasing complexity of products, and more monitoring by government agencies (Berman 1999). One would believe that, given the associated costs of recalls and closer scrutiny by consumers and government, firms would strive to avoid further recalls. In fact, prior research has shown that product recalls may serve as lessons from which firms can learn and, hence, are negatively related to future recalls

(Haunschild and Rhee, 2004; Thirumalai and Sinha, 2011). However, anecdotal evidence also points to the contrary. For instance, Mattel/Fisher Price made over 13 different recalls affecting millions of products between 2008 and 2011, subsequent to the infamous 2007 recalls discussed above.² Toyota up to the end of 2012, made around 22 different recalls on 2010 and later models of vehicles,³ since the pedal related recalls in 2009. As stated in the media, since 2000, there has been a steady increase in the number of product recalls in the automobile, food, and pharmaceutical industries (for example, The New York Times 2011). The United States Consumer Product Safety Commission (CPSC) recorded approximately 221 recall cases in 1988 (Smith et al., 1996) and 8 million products and, in the last four years ending in 2011, the commission has recorded an average of 366 recall announcements with an average of 50 million affected products per year⁴.

With increasing recalls despite the costs, the impact of recalls on firms' financial performance becomes an important topic of interest. The broad aim of this paper, therefore, is to investigate this impact in the consumer product sector.

1.1. Recall Performance Relationship

Product recalls have been persistent in spite of the high costs and the negative effects in the long term (Berman, 1999), and therefore its relationship with the firm's financial performance may be complicated. The costs associated with product recalls can be direct, such as the cost of managing the reverse logistics, restitution, and legal expenses due to litigation (Berman, 1999; Rupp, 2004; Tang, 2008), or indirect such

² Calculated from the registered CPSC recalls

³ Calculated from the registered recalls by NHTSA

⁴ Calculated from the registered CPSC recalls

as loss of sales revenue and market value, (Jarrel and Peltzman, 1985; Thirumalai and Sinha, 2011) and brand image (Herde et al., 2007). However, ensuring product quality, maintaining the right supply chain partner mix, and coordinating and monitoring the supply chain so as to obviate recalls would also require financial investments and, hence, higher costs. The recall-performance relationship is, therefore, not as straightforward as has been presented in the extant literature. Where the cost of avoiding a recall outweighs the cost of the recall, itself, firms would prefer to have some recalls. The reverse should also be expected. Balancing between the two types of costs, firms may arrive at an “optimal” number of recalls: with a small number of recalls, all things being equal, the cost of avoiding a recall would be higher than would be the cost of absorbing a recall. As the recalls increase to a greater number, the cost of the recalls would be substantially higher. It is therefore to the best interest of the profit maximizing firms to endure a small number of recalls without incurring the higher cost associated with avoiding all recalls. By the same token, as recalls increase, the costs of avoiding recalls become justified with the damage of recalls, short- and long-term, direct and indirect, likely increasing faster. This reasoning does not call for elimination of recalls as has been implied by the extant literature, but optimization of performance and preparedness for the “inevitable recall” as put by Berman (1999).

1.2. Recall Performance relationship moderators

The impact of recalls on firm performance may be affected by a variety of factors. Market reaction (demand or sales), as has been argued, depends on how well the

recall is anticipated and the cost expectations of the recall (example Dawar and Pillutla, 2000), and to react to the negative reaction, firms take actions that would have impact on financial performance. The heterogeneous nature of firms also plays a significant role in how recalls may be associated with firms' financial performance. Firms implement sourcing and distribution strategies, such as global reach and emerging market penetration, which have direct quality implications with financial effect. In addition, individual recall characteristics, such as recall strategy and defect type, may also contribute to how recalls are associated with firms' financial performance. One objective of this research, therefore, is to investigate the roles of supply chain strategies (outsourcing and offshoring), distribution characteristics (global market reach and emerging market penetration), and specific recall characteristics (time to recall, proactive vs. reactive recalls, design vs. manufacturing problem source, and domestic vs. foreign made recalls) in either exacerbating or dampening the effect of product recalls on a recall company's financial performance.

1.2.1. Product recalls and financial performance relationship

moderators: Distribution extensity

The extent of globalization and emerging market penetration may moderate the effect of product recall on financial performance. This is because both product recalls and globalization are associated with risk exposure of a firm, and therefore impacting on firm financial performance by way of neutralization of such risks. Furthermore, penetrating in the emerging markets adds new uncertainty to the longer supply chains and unpredictable markets typically found associated with globalization, and may significantly moderate how quality recalls are related to firms' financial performance.

Furthermore, quality standards and expectations vary across national boundaries. This may neutralize the recall financial performance relationship as individual country effects may offset one another. On the other hand however, a successful recall may be more difficult in a highly globalized market because of the complexity of global markets. This would make the recall more expensive with higher financial consequences.

**1.2.2. Product recalls and financial performance relationship
moderators: sourcing attributes**

Sourcing characteristics may also moderate the recall financial performance relationship. Managing product recalls can be a reverse logistics management challenge as the products are logistically routed through all or part of the reverse supply chain for repairs, refund, or disposals (Hora et al., 2011). As argued earlier, product recalls affect a firm's finances through costs expended on managing the reverse logistics and reductions in revenue from loss of sales. Supply base structures, such as outsourcing and offshoring or supply base concentration intensity, may affect the finances of a firm during a recall through both the direct costs effects and the indirect revenue effects. Outsourcing and offshoring or supply base diversification make supply chains longer and more complex, with increased numbers of hands touching products as they move across the supply chain nodes and across international boundaries (Marucheck et al., 2011). Complex and long supply chains may be associated with higher costs of recalls compared to simple or an in-house manufacturing system for the following reasons. First, a simple supply chain engenders traceability, allowing for early detection, and, subsequently, for timely

correction of product failures. Second, the physical cost of the reverse logistics may be higher in longer supply chains, as the recalled product may need to be sent back up the supply chain for repair. Both of these actions would incur higher costs than would an in-house manufacturer.

On the other hand, the reaction to recalls on the demand side (as in sales and sales revenues) may partly depend on the expectation of quality failures such as recalls (Dawar et al., 2000). A firm's good reputation in product quality may attenuate the market reaction to recalls made by that firm⁵. However, a good reputation also builds expectation among potential buyers of a product (Shapiro, 1983), and may therefore aggravate the negative market reaction to the recall of the product (Rhee and Haunschild, 2006).

It is logical to think, therefore, that the extent of outsourcing, off-shoring, and supply base concentration, all expected to have a relationship on the costs of reverse logistics and quality expectations, would moderate the recall financial performance relationship.

1.2.3. Product recalls and financial performance relationship moderators: recall specific characteristics

A third set of potential moderators includes attributes of each individual recall. Specifically, two aspects of individual recalls, recall strategy and product defect type, are investigated. Recall strategies have been broadly categorized into a proactive or a

⁵ For instance, the early works of sociologists like Goffman 1956 and Zucker 1977, enhanced by more recent ones like Scott 2001 provide the bases to argue that reputation is likely to serve as a resource that cushions negative reactions to recalls.

passive form of strategies (Siomkos and Kurzbard, 1994; Chen et al., 2009; Hora et al., 2011). Some firms follow a proactive strategy when filing a product recall. That is, when a product flaw is detected by either the firm or the quality and safety regulatory agencies, the firm cooperates with the agency and issues a recall early. These recalls are usually reported before any customer complaints or safety incidents. On the other hand, following a passive (reactive) recall strategy, the firm may delay the recall or attempt to shift responsibilities to other firms. Such a recall is usually filed after many consumer complaints or reports of incidents, injuries, or deaths are documented by the firm or the regulatory authority.

Recall strategies firms follow may affect the firms' short-term financial performance associated with recalls. On one hand, a proactive strategy may have positive consequences on consumer perceptions about a company's quality standards and how it values its customers. Because of this positive perception, a fast response to a quality or safety flaw in a product may help mitigate the negative impact of the quality or safety failure on the firm's financial performance (Siomkos and Kurzbard 1994). The implications are that the firm accepts responsibility and is perceived to handle the recalls responsibly. Dawar and Pillutla (2000) find that the negative effect on brand equity are attenuated when a firm accepts the responsibility for its product recall and moves early enough to correct the flaws. A proactive strategy may also be seen as an indication of a firm's concern for its customers, which is important to restore the trust and value its customers place to the firm. Furthermore, a proactive recall might be directly related to the cost of the reverse logistics. A fast recall stops the distribution of the flawed product while limiting the number of the products to be

recalled, preventing incidents that may require litigation, and shortening the length of the reverse chain. All these may lead to a lower cost of managing the recall as compared to a reactive recall strategy.

On the other hand, a proactive recall may serve as a signal for a serious defect to the market (Chen et al., 2009) and may be interpreted as a desperate measure for the firm to protect itself from further exposure to the recall. This may cause apprehension in the market about the firm and its products, subsequently affecting purchase intentions and aggravating the effects of product recalls on financial performance. Furthermore, because firms tend to react passively to product recalls (Dawar and Pillutla 2000; Chen et al., 2009), proactive recalls may attract unwanted extra attention, resulting in more reactions (Chen et al., 2009).

The types of defect associated with recalls, such as design flaws or manufacturing quality issues may further compound the impact of the recalls on a firm's finances. Defect types have been identified by prior studies with an overwhelming portion of the defects falling in the categories of design and manufacturing problems (Beamish and Bapuji, 2008; Lyles et al 2008; Hora et al., 2011). Following these studies, this research focuses on these two types of defects in investigating the relationship between product recalls and firms' financial performance. More specifically, manufacturing defects include the use of wrong raw materials, such as lead base paints in toys, and defects emanating from the manufacturing process, such as inadequate welding together of components (Beamish and Bapuji, 2008). Examples include the 2007 Mattel recalls of toys for high levels of lead. Design problems may be present in the product development stage, long before

the start of the manufacturing process. As in the case of Mattel, an example is the falling magnet toy recalls of 2007. The size of the magnets, the positioning that enables detachment of the magnet, and swallowing by children of the detached magnets are design flaws.

Recalls because of design flaws may negatively affect the firm's finances more than that of a manufacturing defect for the following reasons. First, as discussed earlier, difficulty in traceability may compound the negative financial effect of a recall, and prior studies have suggested that traceability of manufacturing defects may be a lesser challenge than that of design defects (example Hora et al., 2011). Second, manufacturing is more often outsourced, while design processes are likely kept in-house (Beamish and Bapuji, 2008). As a result, contract manufacturers tend to be blamed for manufacturing defects, which reduces the responsibility and financial punishment of the focal firms. However, for a design flaw, the firm, or the brand owner, is usually considered the culprit and subsequently punished by the market.

To better understand product recalls, this study empirically examines the effects of recalls on firm's financial performance. It contributes to the operations management literature as follows:

- It is among the first works to suggest that recalls may not be all bad for a company's profit margins. The research suggests that there is an optimal level of recalls at which profits peak.
- It highlights the importance of global strategies such as sourcing from foreign suppliers and intensification of a firm's global sales.

Specifically, in addition to their direct relationships with profit margins, such strategies are found to also moderate the effect of recalls on profits.

- Sources of defects associated with recalls as well as strategies followed in initiating and managing recalls are also investigated. The recall-profit relationship is also found to depend recall strategies and defect types.

The rest of this work is organized as follows. The next section, Section 2, reviews the related literature, which is followed by hypotheses developed from the literature in Section 3; data and research methodologies are outlined in Section 4. The results are presented and discussed in section 5 with conclusion in the last section.

2. Literature Review

Product recall firm performance relationship is the most studied aspect of product recalls across several disciplinary boundaries. Researchers have looked at the recall effect on demand (Crafton et al., 1981; Reilly and Hofer, 1983), on wealth of sellers (Jarrell and Peltzman, 1985; Hoffer et al., 1988; Thirumalai and Sinha, 2011 etc), on sales (Finkelstein, 2005), on brand equity and image (Dawar and Pillutla, 2000), on customer-brand relationship (Aaker et al., 2004), and on advertising effectiveness (Herde et al., 2007).

The earliest studies on the product recall/ performance linkage looked at demand reactions as well as stock market reactions to product recalls. Not surprising, these studies, specifically looking into automobile recalls, found a negative relationship between product recall and short term demand (Crafton et al., 1981; Reilly and Hofer,

1983). These results are supported by the suggestions of Finkelstein (2005) that sales are negatively impacted by recalls, and there is a negative stock market reaction to recalls (Jarrell and Peltzman, 1985; Pruitt and Peterson, 1986; Hoffer et al., 1988). More recent studies suggest insignificant to modest relationships between recalls and stock market price gyrations but confirm these classical findings for high magnitude recalls (Thirumalai and Sinha, 2011).

Other performance metrics have been used and the overwhelming findings are that recalls have a negative effect on brand equity and on brand image (Dawar and Pillutla, 2000), on customer-brand relationship (Aaker et al., 2004), and on advertising effectiveness (Herde et al., 2007).

More recently, moderators of the recall-performance relationship have been gathering interest. Thirumalai and Sinha (2011) found that the extent of market reaction depends on product scope, debt, and market value. Other findings along this line include firm reputation (Rhee and Haunschild, 2006) and advertising.

Starting with the seminal work of Jarrell and Peltzman (1985), the literature linking a recall event to the wealth of shareholders have unequivocally found a negative impact of a recall on stock market prices (see also Hoffer et al., 1988; Chu et al., 2005; Chen et al., 2009 and Thirumalai and Sinha 2011). However, as stated earlier, the extent of the reactions may be watered down or exacerbated by other events or recall firm specific attributes. Along these lines, Rhee and Haunschild (2006) found that more reputable firms suffer more from product quality compromises that result in recalls than less reputable firms. Apparently, this

unintuitive result follows the expectation reasoning. Reputable firms are expected to produce high quality products and recalls are less expected from them than less reputable firms.

Other firm characteristics have also been found to influence the extent of capital market reaction to product recalls. Product diversity and capital structure (more capital intensive) of firms have been found to lessen the negative reaction to recalls.

An outsourcing and off-shoring intensive firm as well as global and emerging market intensive firm may have a different cost of a recall as well as different expectation of quality as compared to firms that insource production. Therefore, it stands to reason that the intensity of market reactions to product recall may vary not only by sourcing strategy, but also by the extent of global reach in general and emerging market penetration in particular. It is, therefore, a bit surprising that no prior work has looked at these possible moderating effect on the relationship between recall incident and firm financial performance and capital market reaction. This paper moves to fill this void in the literature.

3. Hypotheses development

In this section, the recall profit relationship is developed followed by the hypothetical moderating effects of global and emerging market penetration, supply base structures, and recall specific factors.

3.1. Product recall profit relationship

Recalling a product may negatively affect the financial performance of a firm in three direct and directly ways (Hendricks and Singhal, 2003). The direct effect includes the cost of the recall accrued through managing the reverse logistics, the cost of replacing the defective product, and any inventory unsold after the recall. The second direct effect involves lowering the recall firm's revenues through loss of sales of the recalled product and any spillover effect to other products of the recalling firm. The third, indirect, effect, involves damages to the firm's reputation and credibility. Empirical studies have found mixed results. In investigating the livestock industry, for instance, Marsh et al. (2004) suggested that recall events significantly affect demand, and that such demand response is relatively small. Even those who investigated the stock market reaction to product recalls, argued as a better way to capture both the direct and indirect effects of recalls (for example McWilliams and Siegel, 1997, Subramani and Walden, 2001), found inconsistent results. Some found a negative reaction by the stock market to a recall announcement (e.g Jarrel and Peltzman, 1985) and others found little or no such effects (Hoffer et al., 1988). At the aggregate levels, Thirumalai and Sinha (2011) found no significant relationships. In addition, the impact on sales or demand is consistently negligible except for high magnitude recalls. Enhancing quality performance is not costless (Lundval and Juran, 1974; Giffi et al., 1990; Hendricks and Singhal, 2000; Dresner and Xu, 1995; Steven et al., 2012). The costs involve investments that include items such as training costs, cost of implementing new information, redeployment of resources, and other capital investments to improve quality and safety (Hendricks and Singhal, 2000).

Consequently, ensuring product quality, maintaining the right supply chain partner mix, coordinating and monitoring the supply chain so as to obviate recalls would require financial investments and hence higher costs. This view was first suggested by Lundval and Juran (1974) and Juran and Gryna (1980). In developing the cost of quality concept, Juran and Gryna (1980) argue that there is a tradeoff between prevention and failure costs and, consequently, suggest that the optimal conformance quality level implies a positive proportion of defective products.

Considering the fact that revenue (demand) reactions to product recalls are modest as indicated by the various empirical works mentioned earlier, coupled with the cost implications of avoiding recalls, it is reasonable to argue that firms may be able to attain higher financial performance with a positive number of recalls, especially where the cost of prevention outweighs the cost of non-conformance. However, the cost of recalls, which includes the cost of the reverse logistics and or replacement of defective products as well as the effects on revenue and firm reputation, may increase disproportionately as a firm intensifies recalls (both in number and magnitude) as compared to the cost of preventing the recall. Even though firms may be able to attain higher financial performance level at some positive recall level, the costs of the recall may outweigh any potential cost savings from lack of preventive investments as a firm intensifies its recall activities. Our first hypothesis therefore is given as:

Hypothesis 1. The relationship between recalls and profitability is non-linear, with the slope positive at sufficiently low levels of recalls but negative at sufficiently high levels of recalls.

3.2. Moderating influence of globalization and emerging market penetration on recall profit relationship

Firm specific attributes, resources, and strategies may moderate the recall-performance relationship. The cost of a recall to a firm comes from two sources; the cost of the reverse logistics and replacement cost and the market (customers and shareholders) reaction to the recall. Market reaction, has been argued depends among other factors, on the prior expectations of the firm's performance (example Dawar and Pillutla, 2000). Therefore, given the heterogeneous nature of firms both in terms of resource strengths and reach, the impact of a recall on the firm's profitability and its recovery abilities would be varied (Thirumailai and Sinha, 2011). Also, firms operate in different market structures and market structure has been found to moderate customers' reactions to firm strategies (example Steven et al., 2012)⁶. Below, we identify two global strategies that affect the severity of a recall event on a firm's profitability. Further, we explore the possibility of a moderating impact of market structure on the recall-profit relationship. Specifically, we explore the influence of a firm's globalization intensity and emerging market penetration on the impact of a recall incident on a firm's profit.

Globalization intensity may moderate the recall-profit relationship. The direction of the moderation effect is not very straightforward. Whereas geographic

⁶ Steven et al., 2012 found that service satisfaction and performance relationship is moderated by market concentration.

diversification can create operational slack (Huchzermeier and Cohen 1996; Allayannis et al., 2001), it can also compound supply chain complexity (Craighead et al., 2007). The extent of the impact of a recall on firm performance may depend on how well the event is anticipated or expected by the market (Jarrel and Peltzman, 1985, Dawar and Pillutla, 2000) and the cost of the recall.

Highly globalized firms are able to spread the risk and, thus, the financial consequence of a supply chain glitch across international boundaries. Given that different countries have different expected quality standards from companies, consumers may react differently across the globe. This would benefit globalized firms during recalls.

On the other hand, an intensively internationalized firm may incur more cost in the reverse logistics because of the number of hands that are involved in the supply chain and the fact that extended supply chains are more complex (Craighead et al., 2007), and consequently, have less visibility and more difficult traceability. Because of the complexity of global supply chains, recovery from supply chain disruptions may take longer and suffer more economic damage (e.g. Rice and Caniato, 2003; Stauffer 2003; Chopra and Sodhi 2004; Tang, 2006; and Deloitte Consulting, 2007). This cost of recalls of highly globalized firms may impact profits more negatively as compared to less internationalized intensive firms.

However, the latter effect is supported in prior works like Hendricks et al., (2009) in their study of stock market reaction to supply chain disruption announcement. One can, therefore, argue that the complexity effect brought about by

globalization outweighs the slack effect. Therefore, our next hypothesis is given as thus:

Hypothesis 2. The extent of globalization negatively moderates the curvilinear recall-profit relationship.

Similar to global intensity, emerging market penetration may positively or negatively moderate the recall-profit relationship. Many emerging market infrastructures are either poor or fledging, as demonstrated by lack of or poor highway systems, inadequate warehousing facilities, and poor or over congested ports. In addition, fledging technological infrastructure and limited use of advance supply chain management systems makes visibility and traceability difficult. Further, Lyles et al., (2008) suggest that emerging economies' supply chains are very deep⁷ or very complex. Extending the normal supply chains spanning suppliers to retailers, contractors in emerging markets also often subcontract to other contractors, often unknowingly to their principals, adding to the complexity of the supply chain. These arrangements would compound the cost of recalls and, consequently, impact profits more negatively. Also, institutional infrastructure, including legislation or regulations and policies and the implementation, and enforcement of rules and regulations hinders compliance to contractual policies. These complex policies and regulations would make the coordination of the reverse logistics difficult and more costly. All these would affect profits negatively when there is a recall.

⁷ Lyles et al., (2008) gave deep supply chains as one reason for product recalls in China referencing the process of "cheng bao".

On the other hand, firms selling in emerging markets also have unique advantages that may reduce the effect of recalls on profits. First, having endured poor customer service standards in the past, consumers in emerging markets may be less sensitive to product quality and product quality glitches than their counterparts in developed countries. Second, just as globalized firms, firms with high emerging market penetration are able to spread the risk of quality failures and thus the financial consequence of a supply chain glitch across emerging markets that may have lower quality expectations and standards.

However, as argued in the case of globalization, the complexity created by emerging market penetration, coupled with the weak infrastructure and institutional entities like legislation, the negative effect of emerging market penetration when there is a product recall may outweigh any positive effect. The next hypothesis is thus:

Hypothesis 3. The extent of emerging market penetration negatively moderates the curvilinear recall-profit

3.3. The moderating role of outsourcing, off-shoring and supply base concentration on the relationship between recalls and financial performance

Firms are different in attributes as well as their sourcing strategies and, consequently, have different capacities in handling shocks. It is, therefore, logical to argue that the severity of the impact of a recall on a firm would vary across firms and be dependent on specific firm characteristics. Specifically, market perceptions about the quality of

products and the impact on cost of a recall may vary by the extent of outsourcing and offshoring intensity and the dispersal of the supply base of a firm.

The outsourcing and offshoring structure of a firm is one of these sourcing attributes that may moderate the intensity of the impact of a recall on firm value. On one hand, the general public expectation, recently backed up by few academic research results (e.g. Gray et al., 2011), is that products made by contract manufacturers and or abroad are of lower quality than products produce in the US. Consequently, a quality failure of an outsourced or off-shored product would not be of a shock to the market as compared to a quality failure of in-house or in-shore products. Therefore, the severity of the market reaction to a recall by a firm with high outsourcing and or offshoring intensity would be less than those by a firm with lower offshoring intensity controlling for the broader effect of outsourcing which subsumes offshoring. On the other hand, an intensively outsourced or offshored firm may incur more cost in the reverse logistics because of the number of hands that are involved in the supply chain and the fact that extended supply chains are more complex affecting visibility and traceability. This cost effect will impact financial performance negatively even if the market does not negatively react through their purchase intentions. This leads to the next two hypotheses.

Hypothesis 4. The extent of outsourcing negatively moderates the curvilinear recall-profit relationship.

Hypothesis 5. The extent of offshoring negatively moderates the curvilinear recall-profit relationship.

The complex and globalized supply chains, resulting from outsourcing and offshoring, often involve a large number of suppliers. Mattel had 37 certified suppliers and hundreds of others in China alone in 2007 (Bapuji and Beamish 2008). The distribution of the suppliers directly affects the visibility of the supply chains, as a large number of small suppliers may make communication and information sharing in the supply chains more difficult.

Diversifying the supply base could lead to supply chains with “upstream complexity” (Choi et al., 2001; Wu and Choi 2005; Bozarth et al. 2009). Supply chain complexity can lead to high costs of coordination (Denis et al., 2002) leading to high costs of the reverse logistics during recalls. From the perspective of TCE on quality, more specifically, supply base complexity may implicitly increase the costs of identifying quality problems by making traceability much more difficult. As Bozarth et al., (2009) argued, the number of suppliers is associated with increased information and physical flows and greater numbers of relationships to be managed. Equally, the reverse logistics may require increased information and physical flows as the number of suppliers increases. In addition, a concentrated supply chain should enable visibility and traceability, leading to early detection of production and supply chain issues.

Another potential moderator is supplier diversification across geographic regions. Even though there is little literature on the effects of global sourcing on recall performance relationship, the broader context of globalization can offer some insights. Geographic diversification, in effect, would inhibit inventory visibility and traceability and, consequently, make any logistics under taking more costly (e.g. Rice

and Caniato, 2003; Stauffer 2003; Chopra and Sodhi 2004; Tang 2006; Deloitte Consulting, 2007). Also, most complexity constructs defined by many academics have included measures of both supply base concentration and geographic diversification of suppliers. The number of suppliers has been identified as a complexity driver (Choi et al., 2001; Wu and Choi, 2005; Goffin et al., 2006; Bozarth et al., 2009) as well as the extent of globalization of the supply base (Cho and Kang, 2001; Nellore et al., 2001; Bozarth et al., 2009). Supply chain visibility and traceability can be much more difficult across many suppliers and across international boundaries as supply chains become diverse and global (e.g. Rice and Caniato, 2003; Stauffer 2003; Chopra and Sodhi 2004; Tang 2006; Tohmatsu, 2007).

Specifically, a more concentrated supplier may ease a firm's effort in coordination the recall process, leading to lower transaction costs involved in such effort. Consequently, supplier concentration may mitigate the negative relationship between product recalls and financial performance.

Hypothesis 6. Supply base concentration positively moderates the curvilinear recall-profit relationship.

Hypothesis 7. National supply base concentration positively moderates the curvilinear recall-profit relationship.

3.4. The moderating role of recall strategy and defect type on the relationship between recalls and financial performance

Recall strategy may affect a firm's finances during a recall. As argued in the introduction, a proactive strategy may have a positive consequence on consumer perceptions about a company's quality standards. A fast response to a quality or

safety flaw in a product may help mitigate the negative impact of the quality or safety failure on the firm's financial performance because of the positive perceptions it creates on consumers (Siomkos and Kurzbard 1994). The implications are that the firm accepts responsibility and is perceived to handle the recalls responsibly. Furthermore, a proactive recall might be directly related to the cost of the reverse logistics. A fast recall slows down the distribution of the product limiting the number of the products to be recalled, preventing incidents that may require litigation, and shortening the length of the reverse chain. All these may lead to a lower cost of managing the recall as compared to a reactive recall.

However, a proactive recall may serve as a signal to the market for a serious defect (Chen et al., 2009). This may cause apprehension in the market about the firm and its products with a negative impact on purchase intentions and, consequently, aggravating the negative effects of product recalls on financial performance. Further, firms overwhelmingly react passively to product recalls (Dawar and Pillutla 2000; Chen et al., 2009). This may lead to more attention given to rare proactive recalls, resulting in more negative reactions (Chen et al., 2009). An example is the coverage the Mattel recalls of 2007 got for lead base paints and detachable magnets. In both cases, the recalls were made prior to any incidents and fast enough to be called a proactive recall strategy. Mattel however, reported an almost 50% loss in sales revenues due to these recalls (Bloomberg, 2007). Proactive recalls may therefore lead to more financial losses as compared to a more passive recall.

Hypothesis 8. Proactive recalls negatively moderates the curvilinear recall-profit relationship.

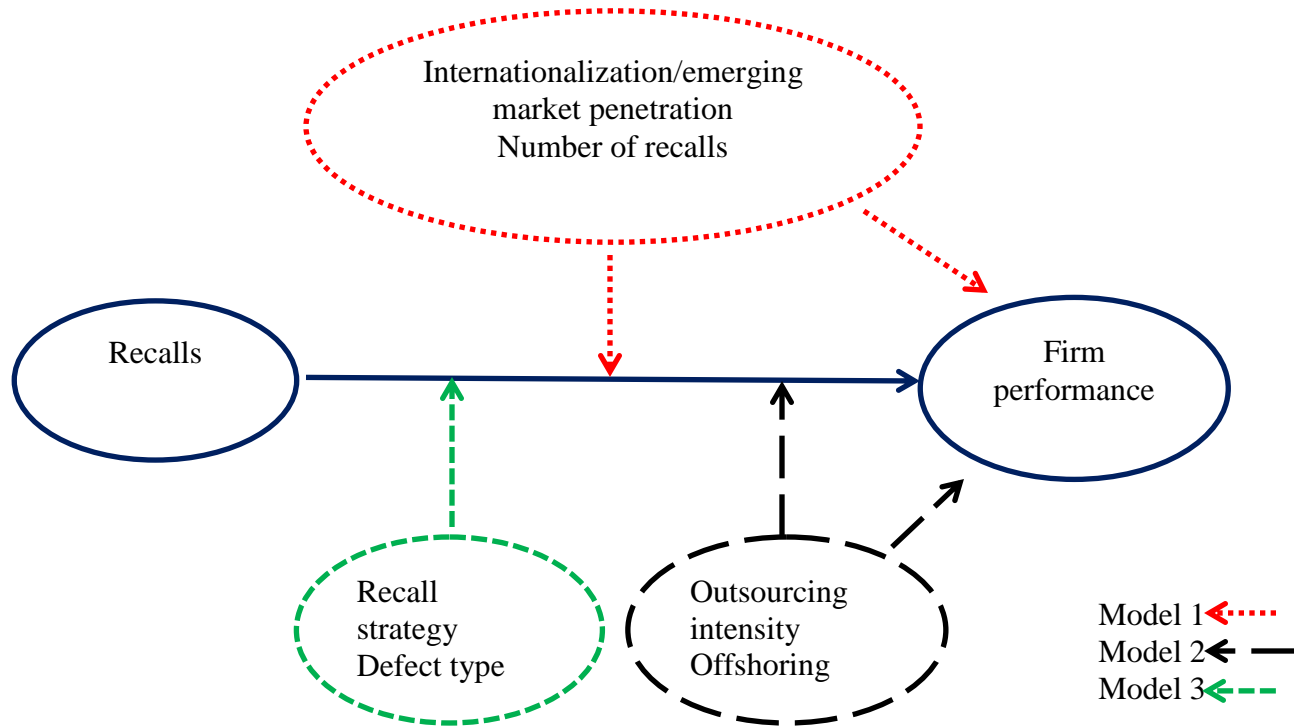
There are reasons to suggest that recalls related to design flaws may hurt the firm's finances more than that of a manufacturing related defect. First, as argued earlier, difficulty in traceability may compound the negative financial effect of a recall. Prior works have suggested that traceability of manufacturing defects may be easier and faster than that of design defects (example Hora et al., 2011). Two explanations are given; common sourcing by a firm wherein more than product uses the same raw material or component and contract manufacturers or suppliers actually supplying other firms. Because of the difficulty in tracing sources of defects when the defects are design related, more cost may be incurred during the recall. Second, most manufacturing is outsourced, while designing processes are kept in-house (Beamish and Bapuji, 2008). Because of this reason, the market may blame the contract manufacturers more for a manufacturing related recall. Indeed, firms always try shift blames and limit damages on their reputation when there is a product crisis like a recall (Rhee and Valdez, 2009). For example Mattel, in announcing the toy recalls due to lead paint hazard, the firm stated that some of its manufacturers "violated Mattel's policies" and used paint from a non-authorized third-party suppliers (Tang, 2008).

Hypothesis 9. Design flaw recalls negatively moderates the curvilinear recall-profit relationship.

4. Model Development

In this section, we develop econometric models to test the above hypotheses. The modeling framework is based on the relationships between product recalls and firm profitability. The underlying hypothesis is that there is a negative overall effect of recalls and firm finances but such a relationship is non-linear. Furthermore, additional moderating effects on this relationship are also examined. Specifically, the moderating roles of a firm's global reach, sourcing structure, and recall strategy are investigated. Recall intensity is expected to have negative quadratic relationship with profits (H1) and intensity in global reach, outsourcing, and offshoring is expected to worsen the negative effect of recalls on financial performance (H2 through H5). Also, supply base concentration is predicted to dampen the negative effect of recalls on performance (H6 and H7) and proactive recalls and design flaws are expected to lead to more financial losses when there is a recall (H8 and H9). Figure 1 illustrates this modeling framework.

Fig. 1: Recall-performance Model



4.1. Empirical Model

As there are three sets of moderators in the essay, the empirical models are also subdivided into three subsections. The reason for the three models is that three different sets of data from different sources are used for the analysis, one for each model. The first subsection outlines the proposed recall performance relationship and the moderating roles of emerging market and global market reach (Hypotheses 1 through 3). The second empirical model tries to capture the effects of sourcing structures (Hypotheses 4 through 7). The third model exemplifies the effects of recall strategy and defect type on the recall profit relationship (Hypotheses 8 and 9).

4.1.1. Recall Profit Relationship (Hypotheses 1, 2 and 3)

As argued earlier, a firm's recall incident may be associated with its profit performance via an inverted U-shaped relationship. This relationship may vary by firm according to their global and emerging market penetration intensity. An econometric model is, therefore, proposed that captures this relationship as well as the moderating effects of global reach and emerging market penetration. Since there are many other factors that may affect firms' profitability, control variables are, therefore included in the analysis to control for effects that otherwise may interfere with the predictions of our main explanatory variables.

The econometric model is given below.

$$\begin{aligned}
 \text{profit} = & \beta_0 + \beta_1 \text{recall} + \beta_2 \text{recall}^2 + \beta_3 \text{recall} * \text{global sales intensity} \\
 & + \beta_4 \text{recall}^2 * \text{global sales intensity} + \beta_5 \text{recall} * \text{internationalization} \\
 & + \beta_6 \text{recall}^2 * \text{internationalization} + \beta_7 \text{recall} * \text{emerging market} \\
 & + \beta_8 \text{recall}^2 * \text{emerging market} + \beta_9 \text{global sales intensity} + \beta_{10} \text{internationalization} \\
 & + \beta_{11} \text{emerging market} + \beta_{12} \text{capital intensity} + \beta_{13} \text{rd intensity} + \beta_{14} \text{sales} \\
 & + \beta_{15} \text{inventory} + \beta_{16} \text{inventory}^2 + \text{time effects} + \text{industry effects} + \text{firm effects} + \varepsilon \dots \dots \dots (1)
 \end{aligned}$$

Where⁸:

- Profit is the dependent variable
- Recall, the main independent variable, is the number of recalls per firm per year. This variable is alternated with a recall intensity variable aimed to capture the magnitude of recalls. Firms may observe no negative impact on

⁸ Detail variable definitions and calculations procedures are given later.

profits or they might be able to improve profits at some non-zero recall number, when the cost of preventing recalls outweighs the failure cost. Alternatively, recalls may have a negative relationship with profits, when the recall cost outweighs the costs of preventing recalls. There may also be a curvilinear association between recalls and profits, with profits increasing when recalls are at a low frequency and decreasing when recalls are more frequent, as described in Hypothesis 1. A square term of the recall variable is, therefore, included in the model to capture this effect.

- Emerging markets, as defined earlier, is a variable that measures the extent to which firms sell in emerging markets. This variable is interacted with the recall variable to capture its moderating impact on the recall-profit relationship
- Global intensity is a variable that measures the extent of global presence of a firm. This variable is interacted with the recall variable to capture its moderating effect on the recall-profit relationship.
- Inventory is a control variable to capture the inventory profit relationship. Inventory may have a positive relationship with profit, as it is a measure of service levels. On the other hand, inventories may have a negative impact on profit, as they incur costs as well as represent tied up capital. Inventory may also have a curvilinear relationship with profits. Profits maybe increasing when inventory levels are lower than optimal and may be decreasing when inventory levels are above optimal. Therefore, a squared term is introduced in the equation to control for this effect.

- Both firm and industry effects are included as control variables in the model. Three-digit North American Industrial Classification System (NAICS) codes are used to classify industry sectors. In North America, industry sectors are classified primarily based on production processes and technologies, both of which may affect product quality, recalls, and profitability. We include these industry-specific variables to control for other omitted industry-specific attributes that influence profitability.
- Capital intensity is a control variable that may be associated with firm performance.
- Rd is a measure of R&D intensity and is a control variable in the model. This variable may reflect a firm's innovative capability and may be associated with a firm's quality performance. The R&D efforts of a firm may reduce the chances of a quality failure, and, hence, lead to lower recalls. On the other hand, higher R&D intensity may also indicate the firm's focus on innovation and new product development, which may increase the likelihood of errors and, thus, positively affects recalls.
- Prior recall is a control variable aimed at capturing the effect of organizational learning. Recall events may "trigger renewed attention to the weak links in the process and foster research toward improving the existing operations by bringing new information and resources" (Thirumalai and Sinha, 2011, p. 381). As such, prior recalls made by firms may lead to efforts that mitigate against future recalls.

- Firm size is used as a control variable. Firm size maybe positively associated with recalls, as larger firms have usually more diversified product base and are, therefore, more complex.
- Employee is a control variable that measures labor per unit of output. We control for this because the chances of human error may increase with increased use of labor.

4.1.2. Recall Profit relationship: the moderating effects of supply base structure (H4-H7)

In the each of the three models of the analysis, the dependent variable is financial performance (specifically profits) but in this model, the explanatory variables are the outsourcing and offshoring intensity, supplier and national concentration. As argued earlier, outsourcing domestically and internationally affects both the quality expectations of products and the costs of reverse logistics during recalls as well as supplier and national concentrations. Therefore, each of these variables is expected to play a moderating role on the recall performance relationship. An econometric model is, therefore, proposed that captures these effects.

The regression equation is given below.

$$\begin{aligned}
 profit = & \alpha_0 + \alpha_1 recall + \beta_2 recall^2 + \alpha_3 recall * outsour + \alpha_4 recall * offshore \\
 & + \alpha_5 recall * supplierconcentration + \alpha_6 recall * nationalconcentration + \beta_7 capital intensity \\
 & + \beta_8 rd intensity + \beta_9 size + \beta_{10} inventory + \beta_{11} inventory^2 + industry effects + \varepsilon \dots \dots \dots (2)
 \end{aligned}$$

Where (detailed variable definitions and calculations are given in the next section):

- Outsource is one of the key independent variables. It measures the extent to which firms source from outside the firm as opposed to making sub-components and products in-house.
- Offshore is the second explanatory variable of interest. It measures the extent to which firms' source internationally.
- Suppliercon is supplier concentration which measures the extent to which a firm concentrates its purchases among a limited number of suppliers or diversifies its purchases among a number of suppliers..
- Natcon is the extent to which a firm concentrates its purchases among suppliers located in across different countries.

All other variables are defined as earlier under equation 1.

4.1.3. Recall Profit relationship: the moderating effects of recall strategy and defect type (H8-H9)

In the third model of the analysis, the main explanatory variables are the recall strategy and defect type of individual recalls. Both recall strategy and the source of the defect leading to a recall may influence a firm's profits when there is a recall. Recall strategy as well as the source of defect prompting a recall may play into consumers' perceptions about a firm and costs of reverse logistics during recalls. Therefore, each of these variables is expected to play a moderating role on the recall performance relationship. An econometric model is, therefore, proposed that captures these effects.

The regression equation is given below.

$$\begin{aligned}
profit = & \delta_0 + \delta_1 recall + \delta_2 recall^2 + \delta_3 recall * proactive + \delta_4 recall * design + \\
& \delta_5 capital\ intensity + \delta_6 rd\ intensity + \delta_7 size + \delta_8 inventory + \beta_9 HHI + \\
& industry\ effects + firm\ effects + \varepsilon \dots \dots \dots (3)
\end{aligned}$$

Where

- proactive is a measure of proactive strategy recalls employed by a firm in a year
- design is a measure of recalls due to design flaws in a year

All other variables are as previously defined.

4.2. Data and data sources

Three different sets of data are used to test the hypothesized relationships. Hypotheses 1 through 3 establish the relationships between recalls and performance, along with the moderating influences of emerging and global market reach, and are tested using one data set. All hypotheses relating to the firms’ supply base structure and performance relationships (Hypotheses 4 through 8) are tested using a second set of data, while hypotheses relating to recall specific variables are testes using a third data set (Hypotheses 8 and 9).

4.2.1. Global intensity, emerging market penetration intensity, recall-profit relationship data set (Model 1)

To test the hypotheses in Model 1, we make use of a panel data on public manufacturing firms, including information on their profits, their market characteristics, and the recalls made by each individual firm. By using archival, objective data in this analysis rather than survey responses to a measurement instrument, the information gathered is not dependent on survey respondents’

perceptions and or attitudes. Indeed, such a reliance may lead to biases in the variables or inaccurate information (Goffin et. Al 2006).

This investigation is limited to public firms within the US manufacturing sector. The study is done on recalls that fall within the jurisdiction of the Consumer Product Safety Commission (CPSC)⁹. The sample comprises of public US manufacturing firms for obvious reasons. As stated earlier, first, the research is about product recalls and the sector that may have more control or influence over their product quality and safety decisions is the manufacturing sector. A second obvious reason is the availability of data on public firms. Since public firms are required to make many disclosures, access to a well representative data is easier compared to private firms that are not required to make such disclosures.

Testing the first three hypotheses developed above requires information on product recalls, firm characteristics, geographic diversity intensity, and the profit performances of firms. Data are drawn from two key sources: the Compustat data base accessed through the Wharton Research Data services (WRDS) and the US consumer product safety commission's (CPSC).

To test the first hypothesis, information on recalls made by individual firms and corresponding profit performance measures are required. First, the recall data are collected from US consumer product safety commission's (CPSC) recall announcements between 2005 and 2012, an 8 year period. CPSC records all recall announcements, voluntary or mandated, of all consumer products. This information

⁹These includes recalls on many categories of consumer products across many industries like toys, child products, household products, sports and recreation products, outdoor products, other specialty products.

includes the quantity recalled, the average product prices, the type of recall (voluntary or mandatory), and information on whether the faulty product has resulted in any incidences. The data are used to get the number of recalls each firm makes within our period of observation, along with additional information to be used for subsequent analysis.

Information on profits is gathered from the Compustat data base for the same 8 year-period 2005 through 2011. The data collection started by compiling all recalls from the CPSC recall data between 2005 and 2011. All public firms were then identified independently by four individuals through a manual process. The 6 digit NAICS code was then collected for all the public firms falling within the manufacturing sector 311-339. These NAICS codes were then used to derive information on all firms from the Compustat data base.

Data were collected on all on 6 digit NAICS code ranging from 311111 to 339999 that have made recall announcements falling within the CPSC agency's jurisdiction. For instance, NAICS codes 336111 and 32541, automobile manufacturing and pharmaceutical and medicine manufacturing, whose jurisdiction lies outside the CPSC's authority, were not included in the analyses. In all, after collapsing the industries at the three digit NAICS code levels, only 10 industries fall under the CPSC within the manufacturing sector, at the 3 NAICS digit levels . Detailed description and representation of these 10 industries are given in Table 1. Information of profits and the control variables were then matched with the recall information collected from the CPSC recall data base.

To test these three hypotheses, in addition to the recall and profit performance information, data are required on firms' global and emerging market reach. Annual data for global intensity and emerging market sales were collected from the COMPUSTAT segment database, which reports a firm's annual sales breakdown by product segments and by geographic segments. This data are extracted for all manufacturing firms by 6 digit NAICS code as explained earlier and used for the construction of both the global intensity and emerging market penetration measures. The construction of individual variables is explained below. Using a firm's permanent identifier (GVKEY), defined by COMPUSTAT to track a firm over time even if the company name or ticker changes over time, we then match global intensity and emerging market penetration data with firm financial and recall data developed as explained above. Individual variable computations are explained below.

4.2.2. Moderating effects of outsourcing, offshoring and supply base concentration on recall-profit relationship data set

To test hypotheses 4 through 7 (model 2), we make use of a cross sectional data on public manufacturing firms, including information on their relationships with suppliers as well as their buyers, the strength of these relationships, the recalls made by each individual firm, and firm specific characteristics, including measures of profits.

As stated earlier, this investigation is limited to public firms within the US manufacturing sector. The sample comprises of public US manufacturing firms for obvious reasons. First, the research is about "make or buy" decisions and the sector

that faces that decision most is the manufacturing sector. Other sectors, like retail, almost always depend on secondary firms for their production needs. No doubt, large retailers like Wal-Mart and Target play a critical role in the goods market in the US economy, for instance, and possess and exercise significant power over their chain members. However, since they are not faced with decisions to make or to buy, outsourced internally or offshore, they would not be appropriate sample for this analysis. The second obvious reason is the availability of data on public firms. Since public firms are required to make many disclosures, access to a well representative data base is easier compared to data access from private firms who are not required to make such disclosures.

Data for this analysis were gathered from three different sources. The main hypotheses revolve around outsourcing and offshoring and their interaction impacts on firm recall-performance relationship, as measured by profits. As in the first model, the performance data comes from the Compustat data base and the main explanatory variable, the recall variable, comes from CPSC recall data base.

The third data source is the Supply Chain data from the Bloomberg data base. The explanatory variables, outsourcing intensity, offshoring intensity and supplier and national concentration are collected from the Bloomberg data base. This data set is limited and applicable only to 2010 and 2011, a two year period. Bloomberg offers data on supply chain relationships for about 35,000 firms. The data maps a company to its suppliers, customers as well as its competitors and gives indication of the strength of the dyadic relationship between any two firms. The supply chain data provided by Bloomberg reveals money flows between companies on both a customer

(revenue) and supplier (cost) basis. It gives estimates of the percentage of a supplier's revenue for instance, that comes from a buyer and a percentage of a buyers cost of goods sold that is spent on an individual supplier. Bloomberg uses three different methods to compile this data. The first, termed the "mathematical method," derives the supply chain relationship from public data as well as from information obtained from the companies directly. The second, Bloomberg's own algorithm, quantifies relationships based on defined parameters, where no quantified data exists. With the third approach, Bloomberg purchases proprietary data from other sources. Excerpts of the data description by Bloomberg as well as a screen shot of the supply chain data is given in the appendix.

Because the Bloomberg data is limited to a two year period 2010 and 2011, data were collected on firms from the Compustat and the CPSC data bases for only these two years. Data were collected on all 6 digit NAICS code ranging from 311112 to 339999, except for 336111, as explained earlier. These data were then matched with the Bloomberg data by company name to get a unique data set of about 377 observations for 190 different firms. Recall announcements were then gathered for these 190 firms from the CPSC data base. We are, therefore, able to have firms with zero recalls within our study period and firms with as many as 4 independent recalls. Descriptive data analysis is given in the next section.

4.2.3. Moderating effects of recall strategy and defect type on recall-profit relationship data set (Model 3)

To test hypotheses 8 and 9 (model 3), a cross sectional database on public manufacturing firms was drawn from the CPSC and the Compustat databases. Only firms with recalls within the 2005 to 2012 time period are considered. The focus for this database is on specific recall attributes. As a result, the analysis is limited to those public manufacturing firms who have made at least one recall in the eight year period under review. The recall specific variables, the recall strategy and defect type, are both generated from the CPSC recall announcements. The CPSC recall announcements contain information used to generate the explanatory variables. The CPSC recall announcements include: 1) recall date, 2) the number of units recalled or defected, 3) description of the hazard, 4) the recalling company, 5) number and types of incidents, 6) the average price, 7) country of manufacture, 8) the date the product was first sold in the market and 9) pictures of the product recalled. This information was used and paired with data on the specific firms from Compustat to get a data set for this analysis. Detailed variable description and calculation is given in the next section.

4.3. Measures of variables

Financial performance is operationalized as profits margins across all three models. Short term financial performance, which is the interest of this research is best characterized by profit margins. The profit variable is computed as the difference between sales and cost of goods sold normalized by sales.

$$profit_{ij} = \frac{sales_{ij} - cogs_{ij}}{sales_{ij}}$$

Where ij refers to firm i in year j .

Recall, the major independent variable in all three model sets is a count variable. The number of independent recalls will be used as the independent variable to test the hypothesized relationship between recalls and performance. An alternative measure for the recall variable is the value of the recalls. This is calculated as the quantity of products recalled, or affected by the recall, multiplied by the average price, as given in the CPSC recall announcement. This product is then divided by sales to get a recall intensity measure. In cases where a firm made more than one recall, the magnitudes are calculated individually for each product and then summed over the year before being normalized by sales.

$$Recall = \sum recalls_{ij}$$

$$Recall = \frac{\sum (recall\ quantity * price)_{ij}}{sales_{ij}}$$

Where ij refers to firm i in year j .

4.3.1. Globalization, emerging market penetration intensity measures

The globalization measure is sub-divided into two parts aimed at capturing the spread of a firm's sales across international boundaries/geographic regions in addition to the proportion of foreign to domestic sales (Han et al., 2007). Internationalization or the

extent to which a firm's product penetrates the global market is measured as 1 minus the sum of the squared share of sales in each geographic region, following the Herfindahl-Hirschman Index (HHI). This measure has been extensively used as a globalization or internationalization metric in the literature.

$$\text{Internationalization intensity} = 1 - \sum_{k=1}^P X_k^2$$

Where X is the share of sales in each geographic region and P is the total number of regions. A value of 1, which is possible when the second term nears zero, indicates that a firm is present in infinite number of countries and as the value approaches zero, the number of regions the firm operates in approaches one. Global sales intensity, which measures the extent of a firm's reliance on the global market, is measured as the ratio of foreign sales to total sales.

$$\text{global sales intensity} = \frac{\sum \text{foreign sales}}{\sum \text{sales}}$$

Emerging market penetration is calculated as the ratio of the sum of sales generated from different emerging markets to a particular firm's total sales in a year (Han et al., 2012).

$$\text{emerging market}_{ij} = \frac{\text{sum of sales in emerging markets}_{ij}}{\text{Total sales}_{ij}}$$

To construct the global and emerging market variables, data is extracted from the COMPUSTAT segment data base which reports annual sales breakdown by region, product, and even states. The data were then cleaned by going through the geographic regions manually and checking for consistencies. For instance, many

firms list US, USA, United States, United States of America etc. If the entropies are calculated without correcting these, each name would be recognized as a separate region. The same procedure is followed for all of the regions. These data were then used first to calculate the globalization entropy. Subsequently, a firm's emerging market sales was identified using a list of emerging economies derived from the literature. . The following list of countries was used to identify the emerging markets: Argentina, Brazil, Chile, China, Colombia, Czech Republic, Egypt, Hungary, India, Indonesia, Israel, Korea, Malaysia, Mexico, Morocco, Pakistan, Peru, Philippines, Poland, Russia, South Africa, Taiwan, Thailand, and Turkey (Han et al., 2012). These data were then matched with the performance-recall data.

4.3.2. Sourcing structure; outsourcing, offshoring and supply base concentration measures

Outsourcing intensity was measured as the percentage of a firm's cost of goods sold (COGS) that are expended on its suppliers as given in the Bloomberg data. The larger this percentage, the more intense is a firm's outsourcing activity.

$$\text{Outsourcing in intensity (Outsour)} = \frac{\sum \text{expenditure to secondary firms}}{\text{Cost of goods sold}}$$

Offshoring intensity similarly, was measured as the percentage of a firm's COGS expended on foreign firms. Foreign firms were defined as firms registered or headquartered in foreign countries.

$$\text{Offshoring in intensity (Offshore)} = \frac{\sum \text{expenditure to foreign firms}}{\text{Cost of goods sold}}$$

Supplier concentration was measured as the sum of squared cost of goods sold expended on each supplier, following the Herfindahl-Hirschman Index (HHI).

$$suppliercon = \sum_{i=1}^N S_i^2$$

Where S is the share of COGS expended on firm i and N is the total number of suppliers. A value of 1 indicates that a firm has only one supplier and a value approaching zero indicates that the number of suppliers approaches infinity.

National concentration is calculated as the sum of squared cost of goods sold by suppliers in the firm's domicile country.

$$Nationcon = \sum_{j=1}^M X_j^2$$

Where X is the total share of COGS expended on suppliers in country j (the firm's domicile country) and M is the total number of suppliers. Similarly, a value of 1 implies that all of a firm's suppliers are domiciled in 1 country.

4.3.3. Recall strategy, defect type measures

The CPSC recall announcements contain information that is used to operationalize the recall strategy as well as the defect type. Specific information is given on 1) recall date, 2) number and types of incidents, 3) the date the product was first sold in the market, and 4) description of the defect or hazard that resulted in the recall. This information was used to compute the two key explanatory variables in the third model.

The first of the two key explanatory variables specific to individual recalls under investigation is the recall strategy. As discussed earlier, only two strategies are of interest in this study. Two alternative measures are used to operationalize this

variable. First, the CPSC recalls clearly state the number of reported incidents, if any, by the recall time, including injuries or deaths associated with the recalled product. The reasoning is that if there is no report of any incident prior to the recall, then the firm moved proactively to manage the defects. On the other hand, if a recall is made after reports of incidents, this suggests a more passive strategy by the firm (Chen et al., 2009). The number or sum of incidents in a year is, therefore, used. This captures both the strategy and the extent to which the firm waits to make the recall.

A second measure is a variable measuring the “time to recall” (Hora et al., 2011). The rationale is that a firm, employing a proactive strategy, may move quickly to recall a defective product. Secondly, as the time to recall a product that is defective lengthens, the chances of incidents, including injuries or deaths increases. The two different measures, therefore, effectively capture the effects of the recall management strategy a firm adapts in handling a recall. This variable, time to recall, is estimated as the difference between the date the product entered the market as reported by the CPSC and the announcement date of product recall (Hora et al., 2011). Since there may be more than 1 recall in a year, the sum of these differences between recall time and the time the product was first sold are used. Alternatively, the averages are used as well.

The second explanatory variable here is the type of product defect associated with the recalled product. As explained earlier, the CPSC, under the heading “description of the hazard,” explains the defects associated with the recall. Categorizing the product defect therefore, was done by carefully analyzing the content under this heading. Design defects are defects that may be present even

before manufacturing is begun. They include defects like size, position and type of components, such as small detachable parts like the magnets in toys, button eyes and beads, or the use of strings leading to strangulation or entrapment. Manufacturing defects result from the manufacturing process. They include use of toxic materials such as high lead content paint in toys, faulty assembly or improper welding, or the use of substandard component parts (Beamish and Bapuji, 2008). This information was used to code each recall, as either a design or a manufacturing related defect type. The coding was done independently by four graduate students and a professor with extensive knowledge in quality issues. Three of the coders were not directly related to the study. There was a small percentage (less than 6 %) of the time when the coders were unable to classify a recall into any of the two categories. These were dropped from the final analysis. The consistency of the coding gives sufficient confidence that helps deem it as reliable (Beamish and Bapuji, 2008). Each defect was then coded as a categorical variable, with design flaw coded as 1 and manufacturing defect coded as 0. However, our studies are at firm-year level and not at an event level. Therefore, a ratio is created to capture the percentage of design or manufacturing flaws in a year per firm. For example, if a firm made 5 recalls in a year, and 3 of those recalls are coded as design, the variable design is then $3/5$, which is 0.6. From our hypothesis, the interaction between this variable and the recall variable should have a negative sign. That is the more design flaws a firm has, the stronger the negative impact of recalls on profits.

4.3.4. Control variables

Like the dependent and the key explanatory variable, recalls, the same set of control variables are used in all three different models. These are inventory, R&D intensity, capital expenditure intensity, and sales which is a proxy for size. R & D and capital intensity are both measured by a firm's research and development expenditure and capital expenditure respectively normalized by sales.

Inventory is calculated as thus, following (Chen et al., 2005; Han et al., 2012).

$$Inventory\ days_{ij} = \frac{365 \times Total\ Inventory_{ij}}{COGS_{ij}}$$

Assuming 365-day year

Firm size is measured by firm sales and time. Both industry and firm dummy variables are included in all models to capture both industry and firm effects.

4.4. Descriptive statistics

The descriptive statistics are also given in three subsections representing the three different models respectively.

4.4.1. Descriptive statistics: Global extensity and intensity, emerging market penetration intensity

Firm emerging market, global presence characteristics, along with the distribution of firms by industry are given in Table 1. Table 2 provides overall descriptive statistics. From Table 1, it can be seen that firms from the computer and electronics manufacturing sector (334) account for about 40% of the firm-years of observations, while firms from the furniture manufacturing industries (337) are least represented, with slightly more than 1% of the observations. In terms of emerging market penetration, firms with operations in computer and electronics manufacturing (334)

have penetrated emerging markets the most (24% of total sales), followed by food manufacturing (20%). On the other hand, firms in the furniture (2%), followed by other durables firms (3%), have the least emerging market penetration.

Table 1: Distribution of firms by industry

Naics ⁺	No. of firm-years	No. of unique firms	Avg. firm emerging market penetration	Avg. firm global intensity	Avg. firm global extensity	recall	profit
311	150	24	0.2	0.32	0.36	0.13	3644
322	147	28	0.08	0.44	0.29	0.03	1638
325	1640	331	0.1	0.36	0.37	0.03	2336
332	131	22	0.09	0.43	0.25	0.11	701
333	583	99	0.06	0.5	0.26	0.14	1151
334	3447	628	0.24	0.54	0.27	0.02	755
335	311	59	0.12	0.34	0.32	0.08	361
336	529	85	0.08	0.4	0.28	0.15	3721
337	94	15	0.02	0.29	0.36	0.29	478
339	729	142	0.03	0.32	0.33	0.31	554
Average (*Totals)	7761*	1433*	0.16	0.45	0.3	0.06	1353

⁺ Industry definitions are given in Appendix B

With respect to geographic locations or globalization, most industries are fairly concentrated in terms of their sales activity. The most concentrated are firms in the food, chemical, and furniture industries, all selling to an equivalent of three countries with approximately equal shares. In contrast, the least concentrated is the fabricated metals (332) sector, selling to an equivalent of four countries with approximately equal shares. Similarly, almost all industries are active in foreign markets for their sales. For industries in the electronics sector, over 50% of their sales on average come from foreign markets. At the opposite end, only 29% of sales come from foreign markets on average for firms in furniture industry (337). The highest recalls are in the furniture industry and other durables with an average of 0.29 recalls

and 0.31 per firm over the seven year period, followed by transportation equipment industry (336).

The mean emerging market penetration intensity for all firms is 15% of sales (Table 2). All firms have a mean of 0.26 recalls per firm year and the maximum number of recalls for an individual firm during the analysis period is 13.

Table 2: Descriptive statistics

variable	mean	sd	min	max
global intensity	0.45	0.37	0	1
global extensity	0.30	0.23	0.03	1
emerging market penetration	0.16	0.48	0	0.94
recall	0.26	0.46	0	13
Gross profit	1352.54	4874.08	-426.092	62482

4.4.2. Descriptive statistics: Sourcing structure; outsourcing, offshoring and supply base concentration

Firm sourcing characteristics and the distribution of firms by industry are given in Table 3 and overall descriptive statistics are provided in Table 4.

Table 3: Distribution of firms by industry

NAICS ⁺	No. of unique firms	Avg. firm outsourcing	Avg. national concentration	Avg. supplier concentration	Avg. firm recall	Profit
311	24	0.272	0.342	0.004	0.292	7104
322	12	0.2	0.331	0.006	0.083	5315
325	74	0.235	0.332	0.038	0.324	9385
332	12	0.23	0.393	0.017	0.25	1526
333	36	0.406	0.304	0.013	0.306	3333
334	97	0.63	0.349	0.076	0.092	4961
335	8	0.108	0.271	0.001	0.25	2358
336	45	0.55	0.356	0.031	0.133	3109
337	2	0.009	0.259	0	0.5	849
339	18	0.285	0.325	0.01	0.278	2745

⁺Industry definitions are given in Appendix B

From Table 3, it can be seen that firms from the computer and electronics manufacturing sector account for about 25% of the firm-years of observations, while firms from the leather and nonmetallic manufacturing industries are least represented with less than 1% of the observations each. In terms of outsourcing, firms with operations in computer and electronics manufacturing outsource the most (63% of COGS), followed by firms in the transportation equipment sector (55%). On the other hand, firms in the leather industry sector (<1%), followed by nonmetallic industry firms (1%) have the least outsourcing intensity. With respect to geographic locations (national), most industries are fairly concentrated in terms of their sourcing behavior. The most concentrated are firms in the petroleum industry, sourcing from an equivalent of three countries, each with approximately equal shares. The least concentrated sectors are plastics and rubber, each with an equivalent of 10 ten countries, each with approximately equal. On the contrary, almost all industries are quite spread out in terms of suppliers. The most concentration of suppliers, however, is for firms in the computer and electronics sector. The highest recalls are for firms in the furniture industry sector, with an average of 0.5 recalls per firm over the two year period, followed by firms in the chemical industry sector.

The mean outsourcing intensity for all firms is 17% of cost of goods sold (Table 4), with a mean of 0.188 recalls per firm year and a maximum recalls of four for any an individual firm in a single year.

Table 4 Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Outsource	328	0.179	0.232	0	0.855
Offshore	328	0.087	0.156	0	0.553
National concentration	328	0.339	0.139	0.117	0.722
Supplier concentration	328	0.038	0.081	0	0.423
Recall	328	0.188	0.535	0	4
Profit	328	5360	9225	16.97	56596
R&D intensity	328	0.063	0.066	0.001	0.33
Capital intensity	328	0.041	0.037	0.007	0.308
Size (Sales)	328	12437	16698	52	108249

4.4.3. Descriptive statistics: Recall strategy and defect type

A total of 411 firm-year observations are included in this part of the study of 106 unique firms. It includes only firms who made recalls and only years that the specific firm made a recall. The distribution by industry is given in Table 5 and the descriptive statistics are given in Table 6. The most represented industry sector is the machinery sector, with 25 firms followed by the computer and electronics sectors. The most recalls, however, are in the other durables industry sector, which includes toy manufacturers. In terms of the value of recalls, recalls in transportation equipment industry sector have the highest value, followed by firms in the computer and electronics and electrical equipment sectors, respectively. On average, recalls lagged behind the time the item was first sold the longest in the electrical equipment industry sector (335). However, recalls in the fabricated metal industry sector have the most counts of incidents.

Table 5 Distribution of firms by industry: Recall specific model

NAICS ⁺	Firm-years	Unique firms	Recall	Recall Value*	Time to recall_Avg	Time to recall_sum	Design	Incidents
311	2	1	1.000	4.271	87.000	87.000	1.000	1.000
322	2	2	1.000	8.430	467.500	467.500	0.000	1.000
325	22	6	2.000	141.000	485.136	805.318	0.364	2.227
332	8	4	1.500	150.000	652.375	652.375	0.500	82.125
333	95	25	1.884	1270.000	1518.284	2746.568	0.387	59.547
334	47	20	1.638	2500.000	1008.298	1784.681	0.511	18.830
335	38	11	1.895	2460.000	2231.000	3172.263	0.270	17.789
336	88	10	3.409	3060.000	594.449	1857.966	0.207	7.750
337	27	8	2.259	608.000	1423.481	3127.741	0.385	9.778
339	82	19	3.902	1300.000	749.561	2808.037	0.537	18.232
Total	411	106	2.597	1770.000	1085.064	2352.027	0.383	25.333

*In 100,000 dollars; ⁺Industry definitions are given in Appendix B

From Table 6, an average firm made almost three recalls in a year, with the maximum number of recalls during the study period for an individual firm is thirteen. About a third of all recalls are due design flaws and, on average, each recall is associated with 23 incidents.

Table 6 Descriptive statistics: Recall specific model

variable	mean	sd	min	max
recall	2.597	2.384	1.000	13.000
Recall value*	1770.000	3230.000	0.000	18200.000
time to recall_avg	1085.064	2798.369	26.000	39828.000
time to recall_sum	2352.027	3420.750	26.000	39828.000
design	0.383	0.404	0.000	1.000
american	0.390	0.453	0.000	1.000
incidents	25.333	129.588	0.000	2200.000

*In 100,000 dollars

5. Models and results

This study the first model addressing Hypotheses 1 through 3, adapted nested fixed coefficients and random effects models as an estimation technique since firm effects

are nested in industry effects. This technique controls for both industry- and firm-level effects. The assumption is that the association between the dependent variable, firm financial performance, and the major explanatory variable, recalls, includes random coefficients and random intercepts at the industry level (Han et al., 2012).

All variables are standardized with mean 0 and standard deviation 1 except for the recall variable, to control for skewness and to reduce artificial collinearity, since second order variables are used in the estimation process.

5.1. Global extensity and intensity, emerging market penetration intensity (Hypotheses 1, 2 and 3)

Table 7 provides the correlations between the variable pairs. There is a positive correlation between recalls and profits and as expected a strong positive correlation between sales and profits. There is a surprising negative correlation between emerging market penetration and profits however, but the correlation between profits and the foreign sales ratio or global intensity is positive. However, internationalization, a measure of how spread or concentrated a firm is in terms of national markets has a negative correlation with profits.

Table 7: Model one correlation between variables

	emerging market (1)	capital intensity (2)	inventory (3)	R&D intensity (4)	profit (5)	recall (6)	sales (7)	Recall value (8)	Global intensity (9)	Global extensit y (10)
1	1.000									
2	0.021	1.000								
3	-0.029	-0.010	1.000							
4	-0.011	0.797	-0.016	1.000						
5	-0.047	-0.006	0.006	-0.010	1.000					
6	-0.040	-0.003	-0.024	-0.005	0.158	1.000				
7	-0.041	-0.005	-0.036	-0.009	0.846	0.152	1.000			
8	-0.018	-0.001	-0.013	-0.002	0.077	0.295	0.111	1.000		
9	0.350	-0.009	-0.035	-0.029	0.155	-0.001	0.158	0.017	1.000	
10	-0.057	0.006	-0.004	0.022	-0.142	-0.038	-0.135	-0.018	-0.368	1.000

To reduce heteroscedasticity, all variables except the recall variable, are standardized.

The estimations using fixed and random effects provide very similar results, so only the fixed coefficients random effects results are presented here¹⁰. Regression results for the fixed coefficients for all explanatory variables are presented in Table 8.

Random coefficients of recalls and its squared term and global intensity at the industry level are presented in Table 9.

Four different sub models are estimated as presented in Table 8. The first three sub-models are estimated without the interaction terms. In sub-model 1, the recall value is excluded in the estimation. The recall value variable is included in the second and in the third the recall and the recalls squared variables are left out.

¹⁰ Fixed coefficients fixed effects results are available upon request

Table 8: Regression results for nested fixed coefficients random effects Model (Hyp 1, 2 and 3)

Variable	Sub-Model1 (Standard error)	Sub-Model2 (Standard error)	Sub-Model3 (Standard error)	Sub-Model4 (Standard error)
Capital intensity	-0.000(0.010)	-0.000(0.010)	0.000(0.011)	0(0.01)
Inventory	0.115***(0.011)	0.114***(0.011)	0.112***(0.011)	0.114***(0.011)
Inventory ²	-0.004***(0.000)	-0.004***(0.000)	-0.004***(0.000)	-0.004***(0.000)
Sales	0.832***(0.007)	0.834***(0.007)	0.841***(0.007)	0.832***(0.007)
R&D intensity	0.000(0.011)	0.000(0.011)	-0.000(0.011)	0.000(0.02)
Emerging market intensity	-0.019**(0.007)	-0.019**(0.007)	-0.020**(0.007)	-0.018**(0.007)
Global sales intensity	0.025***(0.008)	0.026***(0.008)	0.024**(0.008)	0.024**(0.008)
Internationalization	-0.020**(0.007)	-0.020**(0.007)	-0.021**(0.007)	-0.022**(0.007)
Recall Value	-	-0.038***(0.008)	-0.020**(0.008)	-0.038***(0.008)
Recall	0.172***(0.030)	0.215***(0.031)	-	0.388***(0.099)
Recall ²	-0.016***(0.004)	-0.019***(0.004)	-	-0.091*(0.048)
Recall*Emerging				0.124(0.272)
Recall ² *Emerging				-0.077(0.140)
Recall*Global sales				0.128*(0.07)
Recall ² Global sales				-0.022(0.016)
Recall*Internationalization				0.226***(0.07)
Recall ² Internationalization				-0.068**(0.021)
Intercept	0.003(0.007)	-0.000(0.006)	0.009(0.007)	-0.001(0.006)
Model Wald Chi-squared	-			1978
Model probability (>Chi-squared)	-			0
Likelihood ratio test vs. linear regression (Chisquared)	-			508.93
Probability (>LR Chi-squared)	-			0

*, **, and *** denote 10%, 5% and 1% significance levels for two-tailed tests, respectively

The model¹¹ has a highly significant Chi-squared score of 1978 (P<0.001). The likelihood ratio tests for the presence of random effects is also highly significant (508.93), indicating the existence of these random effects at industry and firm levels.

In all sub-models, the coefficient for the recall variable is positive and the coefficient for the recall squared variable is negative and both are highly significant

¹¹ The 4th sub-model which is the full model and includes all interaction terms is used for the analyses,

($P < 0.001$). These results support a curvilinear relationship between recalls and financial performance. This is consistent with Hypothesis 1 and suggests that profits may decline when recalls are either too high or too low. In Sub-model 1 in which the recall value is excluded, the recall and recall squared variable have positive and negative significant results respectively. This result is unchanged after adding the recall value which controls for the magnitude of the recalls. The results are therefore insensitive to recall magnitude or value.

For the globalization variable, which is divided into global sales intensity and internalization intensity, the results are partially supported. The coefficient for the recall-global sales intensity interaction is positive and significant but the coefficient for the recall squared-global sales intensity is insignificant. This suggests that the relationship between recalls and profits is weaker with high global sales intensity. This is the opposite of expectations as suggested in Hypothesis 2. However, the coefficient for the interaction between recall and internationalization intensity (which measures the spread of a firm across international boundaries) is positive and significant and the recall squared-internationalization interaction coefficient is negative and significant. This suggests that the number of countries a firm depends on for its sales may influence the relationship between recalls and immediate financial performance. Since the recall squared-internationalization is negative and significant, this finding supports Hypothesis 2. In all, therefore, Hypothesis 2 is partially supported. The coefficients for the third set of interaction terms, the recall-emerging market penetration term as well as the recall squared-emerging market coefficient are insignificant. There is no support for Hypothesis 3 consequently.

The coefficients for a number of control variables show expected signs. Inventory appears to have an inverted U-shaped relationship with performance in line with past literature. Sales are positively related to profits as expected. Most notably, the average recall value is negatively associated with financial performance. This means that the magnitude of a recall impacts profitability negatively. The coefficient for global sales intensity, that is, the ratio of foreign sales to total sales is positive and significant but the coefficient for internationalization which measures the concentration or dispersion of a firm's sales across international boundaries is negative and significant. These suggest that global sales intensity is actually positively related to financial performance which has been found in prior studies. But internationalization or globalization in some literature, which measures the number of countries a company has sales in, is negatively associated with profits. This result is also consistent with past literature (example Lampell and Giachetti, 2013). Contrary to expectation however, the coefficient for emerging market penetration is negative¹².

As given in Table 9, the relationship or association between recalls and profits varies across industries in the form of random slopes and random intercepts. Table 9 gives the coefficients of the hypothesized variables for select industries; 6 out of the 10 industries. Three of the six industries have positive and negative random coefficients for recall and recall-squared variables. These include computer and electronics sector (334), electrical equipment sector (335) and transportation equipment sector (336). In the machinery (333) and furniture (337) sectors, however, the first order coefficients are negative and both second order coefficients are

¹² Han et al., 2012 found a positive relationship between emerging market penetration and financial performance.

insignificant. Recalls in these industries would therefore, be associated with further negative financial performance. The influence of emerging market penetration, global intensity and global extensity also vary across industries. Emerging market penetration, for instance, worsens the negative association between recalls and profits in the machinery sector (333), but the opposite happens in the computer and electronics sector.

Table 9: Industry-Level Random Coefficients

NAICS industry ⁺	Recall	Recall ²	Recall*Emerging market	Recall*global intensity	Recall*global extensity
325	-0.090** (0.038)	0.080* (0.047)	0.065 (0.108)	-0.108*** (0.027)	-0.101*** (0.025)
333	-0.037** (0.012)	0.017 (0.014)	-0.057* (0.030)	0.014* (0.008)	0.004 (0.007)
334	0.192*** (0.032)	-0.620*** (0.064)	0.191*** (0.016)	-0.095*** (0.029)	0.382*** (0.027)
335	0.019** (0.008)	-0.028** (0.009)	-0.008 (0.011)	0.002 (0.006)	-0.003 (0.003)
336	-0.744*** (2.517)	-0.047** (0.022)	0.006 (0.016)	0.084*** (0.013)	0.006 (0.016)
337	-0.061* (0.036)	0.471 (0.510)	-0.002 (0.011)	-0.115 (0.161)	-0.006 (0.032)

*, **, and *** denote 10%, 5% and 1% significance levels for two-tailed tests, respectively

+ Full industry definitions are given in Appendix B.

5.2. Sourcing structure; outsourcing, offshoring and supply base concentration (Hypotheses 4, 5, 6 and 7)

Regression results of the moderating effects of sourcing structures on the association between financial performance and recalls are given in Table 10. The model has a highly significant Chi-squared score of 608 (P<0.001). The likelihood ratio tests for

the presence of random effects is also highly significant (14.38), indicating the existence of these random effects at industry and firm levels.

The coefficient for the recall variable is positive and the coefficient for the recall-squared variable is negative and both are highly significant ($P < 0.001$ and $P < 0.1$ respectively), reinforcing the suggestions from Model 1 that there is a curvilinear relationship between recalls and financial performance. Also, the peak of the relationship, assuming all other variables at their mean levels is two recalls which exactly matches that of Model 1. The recall outsourcing interaction coefficient is positive and significant at a reasonable significance level and the coefficient for the recall squared outsourcing interaction variable is negative and significant. Hypothesis 4 which states the outsourcing intensity moderates the curvilinear relationship between recalls and profits is therefore supported. The recall-offshoring variable, unlike expectations, has a significant positive coefficient but the recall squared-profit interaction coefficient is insignificant. This is obviously an unexpected result suggesting that for firms sourcing more from abroad, the negative aspect of the association between recalls and profits is weaker. That is, such firms are able to delay to a higher recall when the negative effect kicks in. The recall-supplier concentration variable also has an insignificant coefficient. Hypothesis 6 is, therefore, not supported. The recall-national concentration variable, and all other recall squared interaction variables are insignificant.

A number of control variables have expected coefficients. Sales, R&D intensity both have positive coefficients and inventory has a positive coefficient and a negative coefficient on its squared term.

Table 10: Regression results for model 2 (Hyp 3, 4, 5, 6 and 7)

Profit	Coef.	Std. Err.
Intercept	-0.048*	0.027
Recall	0.290**	0.095
Recall ²	-0.071*	0.037
Recall*outsourcing	1.073*	0.603
Recall*Offshoring	0.135**	0.053
Recall*Supplier concentration	-1.529	1.206
Recall*National concentration	0.429	1.709
Recall ² *Outsourcing	-0.626*	0.371
Recall ² *Offshoring	0.409	0.365
Recall ² *Supplier concentration	1.409	1.152
Recall ² *National Concentration	-1.322	1.66
Outsourcing	-0.102	0.098
Offshoring	0.145**	0.065
Supplier concentration	-0.084	0.089
National concentration	-0.019	0.057
R&D intensity	0.164***	0.033
Capital intensity	0.025	0.023
Sales	0.750***	0.034
Inventory	0.142***	0.037
Inventory ²	-0.015*	0.009
Model Wald Chi-squared	608	
Model probability (>Chi-squared)	0	
Likelihood ratio test vs. linear regression (Chisquared)	14.75	
Probability (>LR Chi-squared)	0	

*, **, and *** denote 10%, 5% and 1% significance levels for two-tailed tests, respectively

5.3. Recall strategy and defect type model

Regression results of Model 3, the recall strategy and defect type model is given in Table 11. Though weakly significant, the results on the recall-profit relationship is consistent with the other models. The interaction between average number of incidents and recalls has insignificant coefficients. However, the coefficient for

average time to recall and recalls interaction term is negative and significant. The hypothesis that recall strategy may impact the recall profit relationship is therefore partially supported. The recall-design interaction has a negative significant coefficient. This supports the hypothesis, therefore, that design flaws that lead to recalls will exacerbate the negatively aspect of recalls on profits more than manufacturing problems. The coefficient for the squared recall interaction terms is only significant for average time to recall. This is explained later.

Table 11: Regression results for model 3 (Hyp 8 and 9)

Profit	Coef.	Std. Err.
Intercept	0.112	0.093
Recall	0.096*	0.054
Recall ²	-0.021*	0.012
Recall*Design	-0.053*	0.032
Recall*Time	-0.471*	0.254
Recall ² *Design	0.005	0.012
Recall ² *Time	0.090*	0.052
Design	0.065	0.078
Time	0.388*	0.208
R&D intensity	-0.058**	0.024
Sales	0.880***	0.024
Capital intensity	0.028	0.027
Inventory	0.125***	0.028
Inventory ²	-0.026**	0.011
Model Wald Chi-squared	645	
Model probability (>Chi-squared)	0	
Likelihood ratio test vs. linear regression (Chisquared)	108	
Probability (>LR Chi-squared)	0	

*, **, and *** denote 10%, 5% and 1% significance levels for two-tailed tests, respectively

6. Discussions

6.1. Global extensity and intensity, emerging market penetration intensity

It is common knowledge that product recalls are on the rise and some academics have even suggested that recalls are here to stay (example Berman, 1999). For insight into the recall challenge, it is important to evaluate the immediate or short term impact of recalls on firms' financial performance. This research explores the possibility of firms still being profitable, at some number of recalls, or, alternatively, the possibility that the impact of a recall is associated with minimal negative impact on financial performance.

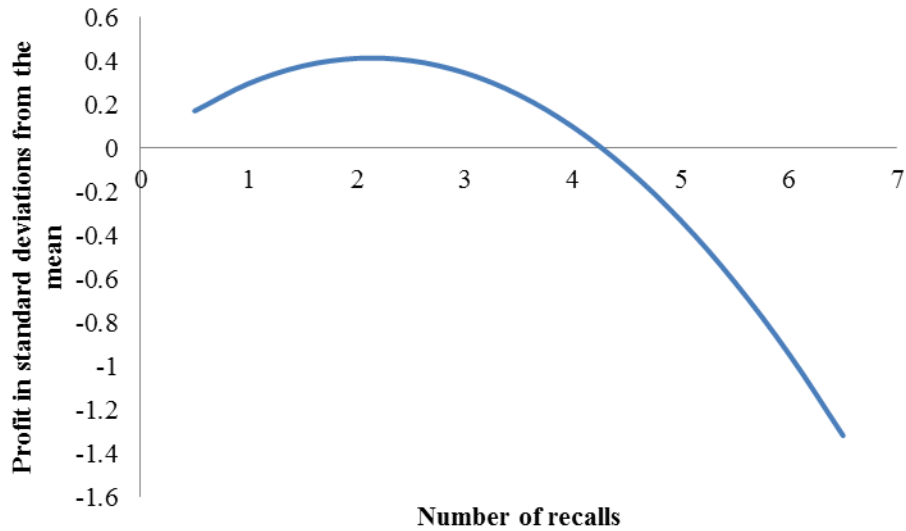
First, a major contribution of this research is the suggestion that recalls, irrespective of the magnitude or the total value of items affected by a defect that prompts recalls, may actually be associated with higher financial performance. The implications are that the number of recalls made and the value or magnitude of the recall may actually be measuring two different things. The recall value obviously may be measuring the direct costs of the recall, that is, the reverse logistics costs of the recall. On the other hand, the recall itself may be a signal to the market. First, recalls could be a proxy for a firm's explorative innovative activities such as venturing into new products. These activities may be associated with higher profits. Second, the implication is that avoiding some limited number of recalls involves high costs. This is shown by the initial positive slope of the recall-profit function. Successive recalls, however, may signal a poor quality to the market, which may impact financial

performance negatively and lead to the suggested inverse U-shaped relationship between recalls and profits as illustrated in Fig. 2.

From Fig. 2, at the mean values of all other variables, profits peak at 2 recalls per year. That is, controlling for the magnitude of the recalls, the optimal number of recalls is 2 recalls in a year. This peak however varies across firms depending on the intensity of their foreign sales as well as their extent of internationalization. This is illustrated below.

Holding all other variables at their mean levels, global sales intensity tends to reinforce the initial positive relationship between recalls and profits extending the peak position of the profit. Even though this finding is contrary to the hypothesized relationship, it is not really that surprising. Global sales intensity can create operational slack (Huchzermeier and Cohen 1996; Allayannis et al., 2001) as argued in the hypothesis development. It turns out that the operational slack effect outweighs the complexity effect in moderating the recall performance relationship. This would benefit firms with high global sales firms during recalls as shown in Equation 4 and Fig. 3.

Fig. 2: Recall profit relationship at mean values of other variables



$$profit = 0.3886recalls - 0.091recalls^2 + 0.128recalls * global\ sales.....(4)$$

$$\frac{\partial profits}{\partial recalls} = 0.388 - 0.182recalls + 0.128global\ sales = 0 \text{ (to get the max)}$$

At the mean levels of global intensity, for instance, (that is the foreign sales ratio = 0), the peak profit coincides with 2 recalls.

At high global sales intensity (global intensity = 1; one standard deviation above the mean), the peak profit is reached at 3 recalls.

$$0.388 - 0.182recalls + 0.128 = 0 \text{ (to get the max)}$$

$$\therefore recalls \cong 3$$

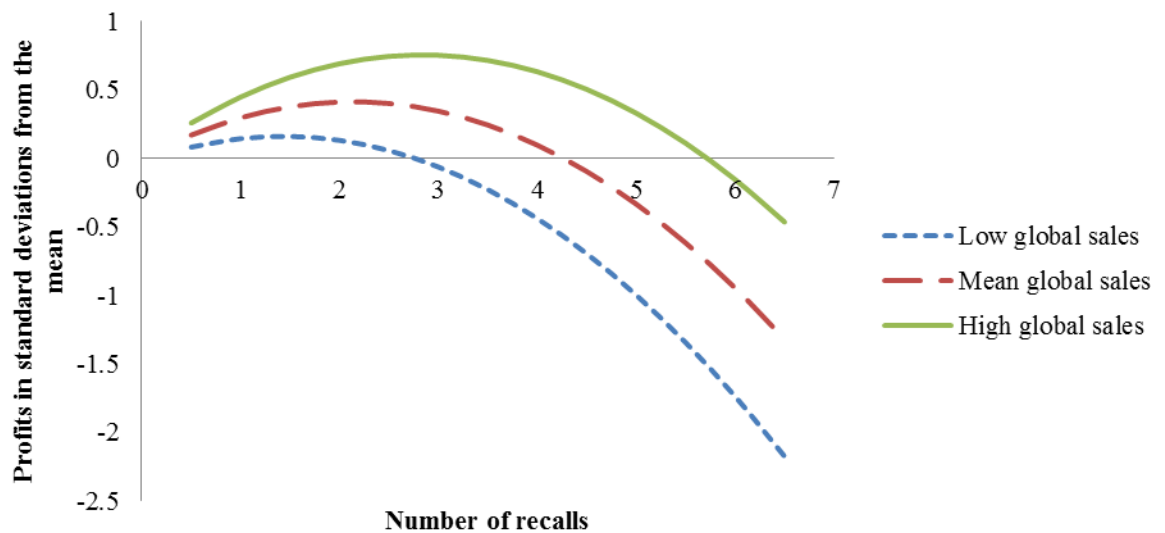
At low global sales intensity (global intensity = -1; one standard deviation below the mean) the profit curve peaks the earliest at 1 recall.

$$0.388 - 0.182recalls - 0.128 = 0 \text{ (to get the max)}$$

$$\therefore recalls = 1.4 \cong 1$$

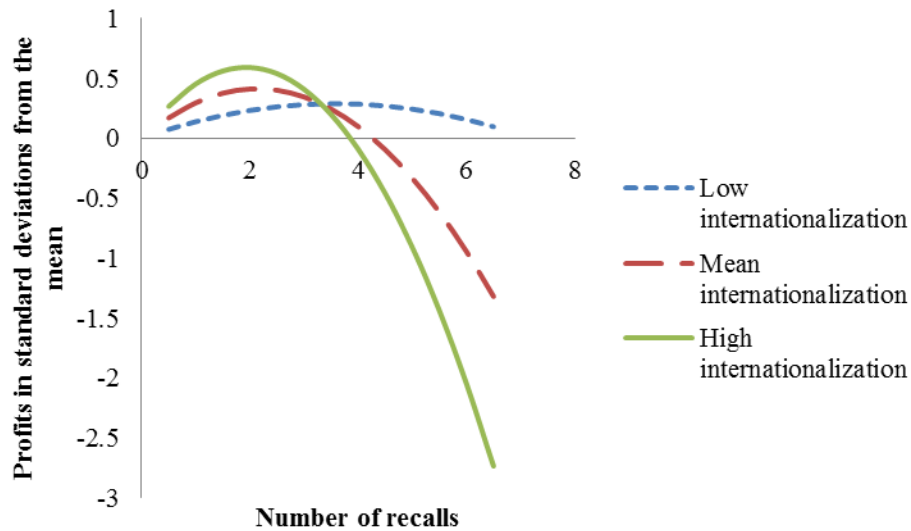
These results imply that firms with a high global intensity would suffer less during a recall as compared to a firm with less global sales ratio. This moderating effect of global intensity is illustrated in Fig.3.

Fig. 3: Recall profit relationship at -1, 0 and 1 standard deviation from the mean global intensity



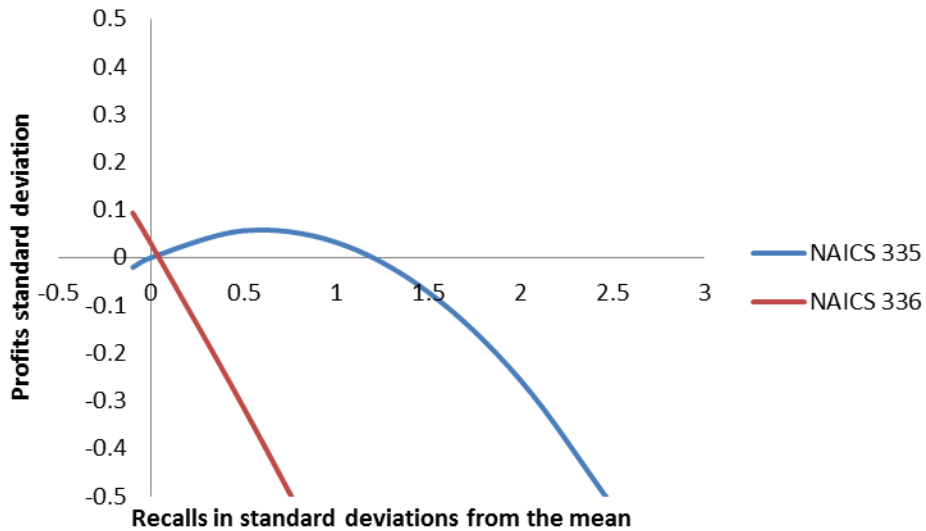
This recall-profit relationship also varies across various levels of internationalization intensity as illustrated in Fig 4. As hypothesized, because of the complexities introduced by high internationalization, recalls and recovery may cost more. From Fig 4., at low internationalization levels, the recall-profit relationship is weaker and peaks at about 4 recalls. However, at high levels of internationalization, the relationship is stronger and profit peaks at just below 2 recalls per year.

Fig 4: Recall profit relationship at -1, 0 and 1 standard deviations from the mean of internationalization intensity



These associations or relationships also vary across industries. Fig. 5 illustrates the recall-profit relationship in two different industries. Whereas the electrical equipment segment (335) shows some initial resilience by staying profitable above the mean with up to 1 standard deviation above the mean recalls, while the transportation equipment segment (336) displays a continuous negative association with recalls. A possible reason for this differential may be the hazard or risks associated with the use of products from each industry.

Fig. 5: Recall profit relationship in two different industries at the mean levels of all other variables



6.2. Supply base structure; outsourcing, offshoring and supply base concentration

The second set of moderators of interest on the recall-financial performance relationship is supply base structure. The popular media recently has insinuated that one reason for the spate of recalls is outsourcing and offshore outsourcing. In this essay, however, interest is not in causation of recalls, but rather in the possibility of worsening or alleviating any negative consequences of a recall.

Unexpectedly, both outsourcing and offshoring appears to assuage any negative association between recalls and profits and low levels of recalls. There are explanations for this unexpected result. The general public expectation, recently backed up by few academic researches results (e.g. Gray et al., 2011), is that products made by contract manufacturers abroad are of lower quality than products produced in the US. Consequently, a defect of an outsourced or off-shored product would not be of a shock to the market as compared to a quality failure of in-house or on-shored

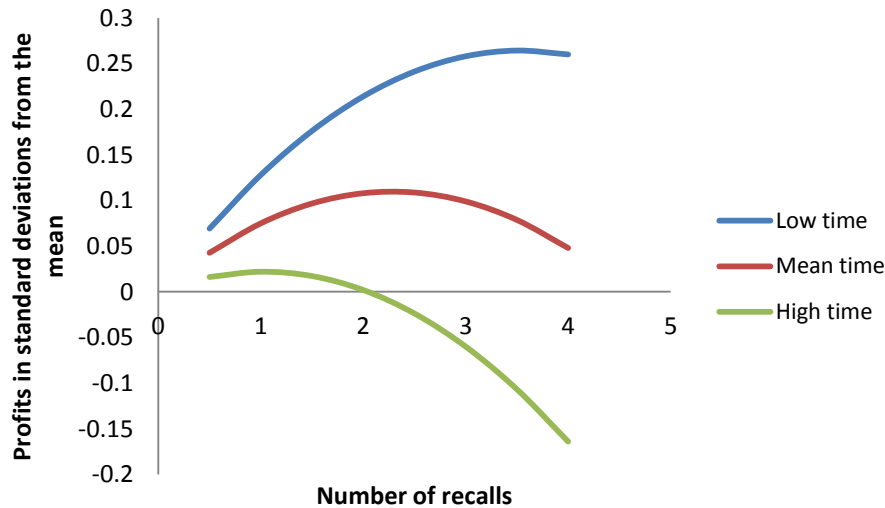
products. Therefore, the severity of the market reaction to a recall by a firm with high offshoring intensity would be less than those by a firm with lower offshoring intensity. Indeed, the regression results suggest that the expectation effect outweighs the costs of reverse logistics effect when there is a recall at low levels of recalls. However, at high levels of recalls, high outsourcing actually hurts the firm when there is a recall. This exactly matches expectations because of the longer supply chain in an outsourcing environment. Longer supply chain may mean higher reverse logistics costs during a recall through coordination difficulties, transportation costs for instance.

6.3. Recall strategy and defect type

The only recall specific variables found to significantly influence the recall-profit relationship are defect type and time to recall. That is, design defects that lead to recalls worsen the negative impact of recalls on performance. This differing association between recalls and profits across defect types is illustrated in Fig 6.

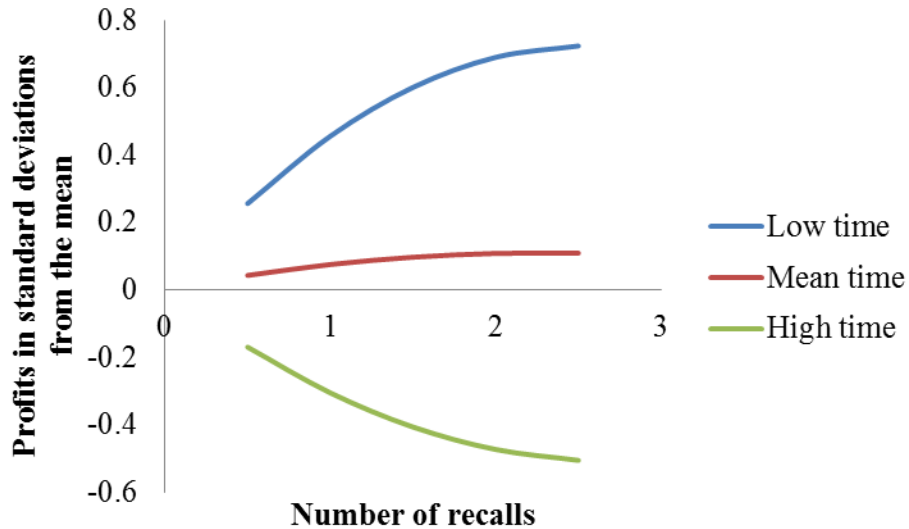
Clearly from Fig 6, it can be seen that design errors are associated negatively with profits. However, firms are able to remain profitable with recalls when such recalls are due to manufacturing errors.

Fig. 6: Recall profit relationship at -1, 0 and 1 standard deviation from the mean percentage of design problems



This research found two relationships between time to recall and financial performance; directly on profits and indirectly by influencing the recall profit relationship. The surprising finding that there is a positive relationship between time to recall and profits (the direct relationship) perhaps partly answers the question academics have been asking for a while now; “why it takes so long to recall a defective product that poses a potential safety hazard?” (Roth et al., 2008; Trottman and Mitchell, 2010, Hora et al., 2011). However, time to recall tends to greatly moderate the curvilinear recall profit relationship. The study shows that firms that are proactive and make recalls sooner are able to maintain their profits at low recall rates and firms with mean time to recall have almost no effect of recalls on profits. However, firms with high time to recall are associated with a negative profit performance when there is a recall as illustrated in Figure 7.

Fig 7: Recall profit relationship at -1, 0 and 1 standard deviation from the mean percentage of average time to recall



7. Implications and limitations

7.1. Managerial Implications

There are quite a few managerial implications of this study. First, the finding that few recalls may not necessarily be associated with negative financial performance is quite significant. The research suggests that if the magnitude of a recall is kept in check, a firm can remain profitable or even increase profits at as much as two recalls per year. This suggests optimization of defects as opposed to their elimination.

The study also points to the importance of diversifying the market base. High foreign sales are not only associated with high profits but also ameliorates any negative association between recalls and profits. Even though the direct effect is expected, the moderating influence on the recall-profit relationship is surprising given that foreign sales intensity may make the supply chain a lot more complex.

Offshoring or offshore outsourcing remains a popular strategy among manufacturing firms. Indeed, this study adds credence to this managerial practice by suggesting that not only does offshoring lead to higher profits, but surprisingly, reduces the negative association between recalls and profits. Outsourcing domestically on the other hand, is not found to have any association with profits directly neither does it influence the recall profit relationship.

The finding that design related recalls hurt firms more is another important managerial implication of the research. Managers should therefore pay more attention to design problems and efforts should be directed to avoid such recalls.

7.2. Research implications

The major finding of the research, the non-linear association between recalls and profits is a novel and mind tickling result that may need corroborative findings in different industry settings. Further work is encouraged at either individual firm, industry or other industrial settings.

Another potential future research direction is the relationship between emerging markets and financial performance. Though not the main interest in this study, the finding here is that the relationship is negative contrary to some recent suggestions (example Han et al., 2012). This mixed findings present opportunities for further research that can add to our understanding of emerging market penetration and financial performance.

This study also only looked at supply base concentration ignoring the length of the supply chain. There is the potential that the length of the supply chain also adds to its complexity and therefore may compound any negative association between

recalls and performance. Addition in this area could be an important contribution to the research stream.

7.3. Limitations

There are a few limitations to the study. First, data limitations restrict parts of the study to only a two-year time period. A study using a panel dataset may better allow for the investigation of causal factors. Second, our study is limited to publicly traded firms. A study that can include private firms is desired to add further insights to the subject area since a reasonable number of recalls are made by private firms. Third, the Bloomberg database used in parts of the study as source for key explanatory variables has data mainly on large firms. Adding small firms to the analysis may improve the generalization of the findings.

Conclusion

This dissertation is among the first and few comprehensive look at product recalls from a supply chain perspective. Despite the anecdotal evidence supported by few scholarly works that recalls affects firm financial performance many, industries including the consumer goods industry have seen increases in recalls in recent times. The spate of recalls within the last two decades has led to suggestions that recalls might just be here to stay (Berman, 1999). This study contributes to our understanding of product recalls by first investigating recall drivers from global supply chain perspective and then reexamining the association between recalls and profit margins.

In the first essay, the dissertation provides a theory-based explanation for and empirical evidence of lower quality in an outsourcing environment and consequently higher product recall events. Interesting moderation effects are also found that contributes to or are consistent with the agency theory perspective. For instance, theory suggests physical as well as cultural distances exist among countries and that these distances inhibit information flows. This study empirically suggests that these distances exacerbate the agency problem and thus offshore outsourcing is even more related to quality problems than inshore outsourcing. The study also implicitly found that high transactions costs in the form of coordination difficulties and transactions risk moderate the agency problem.

In the second essay, a mind tickling theoretical and empirical proposition is given on the recall profit relationship consistent with traditional quality management

literature. Moreover, interesting moderation effects are found from global supply chain and recall management perspective.

Together, the two essays in this dissertation provide additional explanations for product recalls first in the form of supply chain strategies and second in the form of moderators of the effects of recalls on firm profits, all from supply chain lens. This study therefore adds an important strategic supply chain perspective to the theory of the firm. I hope it provides managers with a perspective to weigh the total costs of operations when exploring or deciding on the make or buy decision. I also hope it serves as a reference point for future research on broad quality implications of different supply chain strategies or structures.

Appendices

Appendix A; Excerpts from Bloomberg on the supply chain data

Mathematically Derived Data.

Bloomberg presently has hundreds of thousands of supply-chain relationships, and this number is growing daily. For each of these relationships, we determine how the product or service that is being sold is accounted for by the customer, and we put it into one (or more) of four “cost buckets”: COGS, CAPEX, R&D, and SG&A. Thus when INTC tells us in its 10-K that it receives 21% of its revenues from HPQ, we identify the fact that INTC is selling semiconductors to HPQ, and that HPQ accounts for these semiconductors as a COGS item on its income statement. We then multiply 21% times INTC’s revenues and divide that by HPQ’s COGS, and derive that INTC represents 9.5% of HPQ’s COGS. This number, while proprietarily derived and currently unique to Bloomberg, is nevertheless factual, insofar as the number that INTC gives us (21%) is correct.

Algorithmically Derived Data.

Bloomberg has an algorithm that takes into account numerous types of data -- including but not limited to quantified and unquantified relationships, accounting types, financials, geographies, end markets, operating segments, products, channels, and a variety of industry data. We are then able to assign quantified values to relationships where no quantification is publicly known. Take, for example, AAPL and T. Many people know that T is a customer of AAPL, but neither AAPL nor T disclose the size of the relationship. Bloomberg’s algorithm determines that AAPL

receives 5.11% of its revenues from T, and further that AAPL accounts for 9.49% of T's COGS (at the time of this writing). Further, we plan to provide statistical confidence intervals to provide users the range for which we have high confidence in which this single-point estimate resides.

Appendix B. Industry definitions Table

NAICS code	Industry
315	Apparel
322	Printing
325	Chemical
332	Fabricated metal
333	Machinery
334	Computer and electronics
335	Electrical
336	Transportation equipment
337	Furniture
339	Other durables

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