SUPPLY CHAIN DISRUPTIONS: FIRM, COMPETITOR SUPPLIER AND CUSTOMER IMPACT

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Abstract

This study expands the work on contagion effects caused by supply chain disruptions beyond the impacted firm and competitors to its customers and suppliers. Using hand-collected data, we analyze the news announcements to determine those that resulted in disruptions in supply, demand, production, inventory, distribution, or transportation at one or more stages of a supply chain across different types of disruptions and across six market segments. Using event study methodology and regression analysis, we find statistically significant negative share price responses to announcement of supply chain disruptions for the affected firm and its competitors, but not for consumer and supplier firms. Competitors in more concentrated industries, with higher growth prospects, or with higher debt ratios, are more impacted by disruptions by peer firms. Customers firms in less competitive industries, who exhibit higher risk, or have overall lower sales react more negatively to disruption announcements.

Key Words: **sector financial contagion, supply chain, disruption, event study, market reaction.**

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Introduction

Globally, supply chain management continues to take on an increasingly important role in maintaining a company's competitive advantage. Supply chain disruptions can emerge from demand (e.g., customer's production delays), supply (e.g., labor shortages), regulatory (e.g., increased regulations), infrastructure (e.g., power outages), or catastrophe (e.g., hurricane) reasons (Wagner and Bode, 2008). Burchill (2015) points out unstable supply chains resulting in customer dissatisfaction, lost company revenue, tarnished brand image, and long-term damage to affected companies. Teach (2014) reports that the top business risk for 2013 and 2014 was business interruption through supply chain risk according to a *CFO Magazine* survey of corporate insurance experts in 30 countries. This finding was reinforced in a subsequent survey as Large (2017) reports related concerns (e.g., timely responses to risk issues and meeting expectations regarding time to market among competitors) among the top ten issues facing companies in 2018. Given the importance of the role of supply chain management and the concerns associated with supply chain risk, the topic of supply chain disruptions is more timely than ever. Supply chain disruptions include restrictions in supply, demand, production, inventory, distribution, or transportation at one or more stages of a supply chain. Bhatla, Lane, and Wain (2013) estimate that supply-chain disruptions result in a 7 percent decline in shareholder value in the two-week period leading up the disruption date requiring three months to recover losses. Supply chain disruptions also affect company stock performance (Hendricks and Singhal, 2003, 2005a, 2005b; Schmitt and Raman, 2012; Filbeck, Kumar, and Zhao, 2014;

Filbeck, Kumar, Liu, and Zhao, 2016). Supply chain disruptions impact multiple metrics of performance including cash flow, earnings, return on assets (ROA), and credit ratings.

Contagion effects occur when market reaction effects to one firm's supply chain glitches spread to other closely related entities. Filbeck, et al. (2016) explore whether supply chain disruptions have financial consequences for competitors considering differential impact of market capitalization, industry, growth prospects, competitive framework, and type of disruptions. They find that significant announcement effects exist for supply chain disruptions for competitors but not to the same extent as for the impacted firm. They also find differences based on industry with manufacturing firms impacted most. In the transportation industry, they show that competitors fared worse than the impacted firm. Filbeck, et al. (2016) explore contagion effects in the automotive industry between American and Japanese firms. They find that positioning within the economic cycle can cause differential competitor responses. During bear markets, disruptions in Japanese auto companies result in negative stock outcomes for American companies.

To date, research has primarily focused on the impact that supply chain disruptions have on the affected firm and to other firms within the same industry. In this study, we expand the work on contagion effects caused by supply chain disruptions beyond the impacted firm and competitors to its customers and suppliers. From a managerial standpoint, an expanded understanding of the impact of contagion effects is an important consideration as negative share price responses caused by contagion effects can impact capital structure, cost of capital, and accept/reject decisions for projects. We analyze the news announcements to determine those that resulted in disruptions in supply, demand, production, inventory, distribution, or transportation at one or more stages of a supply chain. We identify four different types of disruptions across six

market segments including capacity, demand and supply, disruptive events, production planning, and quality events. By investigating both industry competition and information spillover effects, we gain a broader sense of the impact supply chain disruptions have across impacted parties.

To estimate how the supply chain disruptions affect the shareholder wealth of the affected company's competitors, customers or suppliers, we employ a standard event study methodology. Specifically, we compute the cumulative abnormal returns (CARs) surrounding the supply chain disruption announcements and use this to measure the magnitude and direction of the stock market reaction to the news announcements. Then we use CARs as dependent variable and examine how factors such as industry characteristics, the impact of the events, firm characteristics of both the event firms and competitors/customers/suppliers influence the magnitude of shareholder wealth. Detailed description of event study methodology is provided in Appendix 1.

The literature review follows in the next section, and then followed by the hypothesis, the sample and methodology, the results, managerial and research implications, and overall conclusions.

Literature Review

Filbeck, Gorman, Greenlee, and Speh (2005) show that the adoption of supply chain management-enhancement tools results in a positive share price reaction. Specific supply chain practices such as inventory turnover (Thomas and Zhang, 2002), just-in-time inventory (Fullerton, McWatters, and Fawson, 2003), and responsive inventory management (Roumiantsev and Netessine, 2007), improve company performance.

The value of supply chain management is often assessed based on the impact on shareholder value to disruptions. Hendricks and Singhal (2003) show a marked decrease in

shareholder value following supply chain glitches. They report a direct relationship between firm size and share price and an inverse relationship between growth prospects and share price response. In a follow-up study, Hendricks and Singhal (2005a) find shareholder wealth decrease by about 40 percent in two-year period (one year before and one year after) surrounding a supply chain glitch. Likewise, declines in shareholder wealth caused by supply chain disruptions have been noted internationally in India (Kumar, Liu, and Scutella, 2015) and Japan (Liu, Sarkar, Kumar, and Jin, 2018). In addition, equity risk increased by almost 14 percent during the year after the disruption. Contingency and flexibility strategies are essential to mitigating such losses (Hou, Zeng, and Zhao, 2012; Skipper, Hall, Haze, and Hanna, 2014; Mandal, 2015; Xin-jun, Lin-qi, and Xing-hua, 2018).

Hendricks and Singhal (2005b) find deterioration of the performance of companies announcing disruptions, measured by operating income, return on assets, return on sales, inventory growth, and sales growth. Hendricks and Singhal (2009) study the effect of demand-supply mismatches on stock prices and find that such events increase the stock price volatility. Schmitt and Raman (2012) explore the effect of operational efficiency improvements on stock outcomes during disruptions. For supply chains with high rate of improvements in operating performance, internal disruptions result in negative stock outcomes. External causes do not result in negative stock outcomes.

Contagion Effects among Competitors

Events affecting a company can also result in contagion share price responses for competitors. The literature documents the impact on competitors related to corporate events such as acquisitions (Stillman, 1983), stock repurchases (Hertzel, 1991), bankruptcy announcements (Lang and Stulz, 1992; Hertzel, Office, and Rogers, 2008), leveraged buyouts (Chevalier, 1995),

large dividend announcements (Laux, Starks, and Yoon, 1998), new product introductions (Chen, Ho, Ik, and Lee, 2002), international cross-listings (Melvin and Valero-Tonone, 2003), mergers and acquisitions (Croson, Gomes, McGinn, and Noth, 2004), new major orders (Galy and Germain, 2007), litigation (Hadlock and Sonti, 2011), bond yields (Chen, Liao, Kuo, and Hsieh, 2013), and earnings announcements (Eshleman and Guo, 2014). In general, competitor firms' stock prices react to news announcements originating from suppliers (Foster 1981; Baginski 1987; Clinch and Sinclair 1987; Han, Wild, and Ramesh 1989; Han and Wild 1990; Pyo and Lustgarten 1990; Freeman and Tse 1992; Firth 1996; Han and Wild 1997; Kim, Lacina, and Park 2008, Raman and Shahrur 2008; Thomas and Zhang 2008; Pandit, Wasley, and Zach 2011; and Cheng and Eshleman 2014).

Stillman (1983) investigates contagion effects associated with acquisitions. He finds no anticompetitive effect exist in his investigation of horizontal mergers subject to antitrust enforcement agency challenges. Hertzel (1991) finds that competitors do not experience abnormal returns to firms announcing stock repurchase tender offers during the announcement window but do experience negative returns over longer time intervals. Melvin and Valero-Tonone (2003) explore the impact of home market prices of the competitor firms associated with firms' discussions to engage in international cross listings. They find competitors firms are negatively impacted by the listing evidenced by negative abnormal returns. This suggests that investors see competitors as less transparent, less informative, and with poorer growth prospects relative to the listing firm.

Using a grocery industry sample, Chevalier (1995) finds that announcements of leveraged buyouts (LBOs) within the industry result in the market value of the grocery chain's competitors. Chen, et al. (2002) find that new products introduced by firms in strategic substitutes competition

result in a stronger share price reaction than those announced by firms in strategic complements competition. The competitors to firms announcing strategic substitutes experience a small, but significant wealth loss.

Laux, et al. (1998) find competitors experience a stock price reaction when a firm within the industry announces significant changes in dividend policy. Differential reactions occur across industries. Dividend contagion effects exist in industries in which competitors are more likely to be affected by industry alignments. Competitive effects tend to offset contagion effects. In addition, a herding effect seems to exist in dividend policy over longer time periods within industries.

Croson et al. (2004) show a positive relationship between positive synergies within industry created by mergers and acquisitions, company size, and the share price response. Conversely, they find that non-merger participants may be driven out of the market for mergers that create negative externalities because of the reduction of profits for the non-merger firms.

Hadlock and Sonti (2012) find that when a firm experiences asbestos litigation, its competitor firms experience negative stock price reactions. Smaller firms in more concentrated industries showed the largest share price response. Helwege and Zhang (2013) investigate the contagion effects on the impact of the Lehman bankruptcy. They examine contagion from troubled financial firms and find that periods of recession result in greater contagion effects, particularly for firms with larger market capitalization and higher risk levels. The most pronounced information contagion effects occur for those competitors in the same industry and geographical location and for firms in financial distress instead of already in bankruptcy.

Contagion Effects among Suppliers and Customers

Likewise, the impact of supply chain disruptions can extend beyond the affected company along the supply chain. Chen, Liao, and Huang (2014) discover a contagion effect of corporate failures along supply chains resulted from the financial crisis of 2007-2008. They argue that macroeconomic risks of a firm and its customers are significantly and positively related to the firm's bond yield spreads, while a lack of relation exists between suppliers and their bond yield spreads. They find the effects are strongest when associated with the more important suppliers and customers. Kutsuna, Smith, Smith, and Yamada (2016) find that suppliers and customers of firms initiating an initial public offering (IPO) exhibit higher revenue growth rates; cash balances; and property, plant, and equipment. They attribute this reaction to their IPO spillover hypothesis, arguing that partners in the supply chain are the recipient of positive liquidity shocks associated with the IPO.

Chen, Liao, Kuo, and Hsieh (2013) find that both suppliers' and customers' information asymmetry effects significantly explain a firm's bond yield spreads. Eshleman and Guo (2014) investigate how customer firms' stock prices react to the earnings announcement of supplier firms. They find that customer's stock price reaction increases based on the revenue growth reported by the supplier and past persistence of supplier's earnings. The relationship is directly related to the level of dependence the customer firm has on the supplier.

Recent research has also uncovered relationships for competitors associated with corporation announcements and their supply chain. Hertzel, Officer, and Rodgers (2008) examine competitor share price response associated with bankruptcy. They find that share price responses surrounding bankruptcy filings negatively impact competitors along the supply chain.

Filbeck, et al. (2014) explore whether supply chain disruptions have financial consequences for competitors considering differential impact of market capitalization, industry,

growth prospects, competitive framework, and type of disruptions. Their results indicate that significant announcement effects exist for supply chain disruptions for competitors but not to the same extent as for the impacted firm. The effects are more pronounced for disruptions within the manufacturing industry. However, competitors actually fared worse than the impacted firms within the transportation industry. Share price responses differ based on the competitive landscape within an industry as well as market capitalization of competitors.

Filbeck, et al. (2016) investigate the impact of supply chain disruptions within the automobile industry. They find a share price impact from disruptions that is dependent on market cycles, with bear markets resulting in a more negative outcome than bull markets. Japanese companies demonstrate a more robust performance compared to American automobile companies. During bear markets, disruptions in Japanese auto companies result in negative stock price reactions for American competitors. In contrast, Japanese companies are not found to experience stock declines when American companies experienced disruptions.

Research Gap and Hypotheses Development

In this paper, we extend the work of Filbeck et al. (2014) and evaluate more comprehensively the impact of disruptions on competitors by considering industry concentration, firm characteristics, and the impact on other related parties, namely suppliers and customers.

Our main hypothesis was built on the work of Goldman, Peyer and Setfanescu (2012) who examine how the announcement of an accusation of fraudulent financial misrepresentation impacts competitors of the accused firm. They propose two effects (industry competition effect and information spillover effect) on the stock prices of competitors following the announcement. We extend their work by investigating whether and how these two effects will exert on the stock prices responses of its competitors, customers and suppliers surrounding the supply chain

disruption announcements of a company. We propose that the industry competition effect is only related to the affected company's competitors. It implies that a competitor firm will benefit from the supply chain disruption announcements in the form of reduced competition of the disrupted firm. A customer firm may perceive the disrupted firm to be less dependable and switch to a competitor. This implies a positive abnormal stock return for the competitors following the supply chain disruptions announcement. The information spillover/contagion effect can be seen as negative externalities, i.e., the spillover of the effects of shocks from one or more firms to other firms. It suggests that a competitor/customer/supplier firm suffers from the announcement since it may reveal the existing problems along the supply chain. Most studies of contagion limit their analysis to how shock affect firms in the same industry, or "intra-industry" contagion (i.e., industry competitors or peers). However, in supply chain disruptions events, "inter-industry" contagion is possible as well.

For example, on June 13, 2002[2], there was a labor strike at Johnson Controls Inc. (a diversified technology and multi industrial company worldwide). On the same day, both General Motors Corp. and the Chrysler Group of DaimlerChrysler AG reported parts shortages at their assembly plants. These two seemingly unrelated events were caused by inter-industry[3] contagion effect, as one of the companies Johnson Controls services in is the auto industry, in which it sells lead-acid automotive batteries for passenger cars, light trucks, and utility vehicles, as well as advanced battery technologies to power start-stop, hybrid, and electric vehicles. In this case, a labor strike at Johnson Controls actually leads to a negative effect on its customers: General Motors and Chrysler.

[2] "Labor Strike Results in Parts Shortages at Auto Makers", *The Wall Street Journal*, June 13, 2002.
[3] Johnson Controls' standard industry code (SIC) is 5063 (Electrical Apparatus and Equipment Wiring Supplies, and Construction Materials) while General Motors and Chrysler's SIC code is 3711 (Motor Vehicles & Passenger Car Bodies).

As another example, on August 25, 2006[4], Apple Computer Inc. is issuing a big recall of laptop-computer batteries, following the previous recall by its rival Dell Inc. The series of recalls are caused by the perils of a widely used battery made by a unit of Sony Corp., which also supplied the cells used by Dell. Several contagion effects can be found in this example: The battery manufacturer (a unit of Sony Corp.) is the supplier of both Apple and Dell. The product peril of this manufacturer is causing its customer Dell, and then Apple, product recalls. In this case, there exists both intra-industry and inter-industry contagion effect.

The third example is the largest vehicle recall of safety-belt buckles by Takata Corp in 1997[5]. The recall involves safety-belt buckles, which were used by 11 major manufacturers, but the majority of vehicles were made by Honda and Nissan. This is another example of inter-industry spillover effect that a company's supply chain disruption event can have a negative effect on its customers.

Both industry competition effect and information contagion effect apply to the competitors in the event of supply chain disruptions, therefore, the net effect of the announcements on the competitors is an empirical question as it depends on the nature of the disruptions, which industry, and on which effect dominates. For example, Filbeck, et al. (2016) investigate the impact of supply chain disruptions within the automobile industry. Their results indicate that significantly negative announcement effects exist for supply chain disruptions for competitors but not to the same extent as for the impacted firm. However, their results are only built on automobile industry and it is hard to generalize.

Since the industry competition effect predicts a positive stock market reaction while the information spillover effect predicts a negative reaction to its competitors, another noteworthy

[4] "Apple Follows Dell with Recall of Laptop-Computer Batteries", *The Wall Street Journal*, August 25, 2006.
[5] "Auto safety-belt recall makes slow progress", *The Wall Street Journal*, March 4, 1997.

item is that these two effects may cancel off each other. Based on these arguments, our first hypotheses, stated in alternate form, is:

H1. A negative stock market reaction of supply chain disruptions will exist for competitors of impacted firms.

As for the effect of supply chain disruptions on the affected company's customers, there may only exist contagion effect as there generally has no competition between the company and its customers. We propose a negative but to a less degree market reactions. Using our earlier examples, the negative news of a labor strike of a company may or may not cause a negative market reaction to its customers depending on the level of dependence between the company and its customer, the significance of disruption event, and firm characteristics such as the firm size and growth potential. The supply chain disruptions may be product specific and therefore different customers may not be affected in the same way by a supply chain disruption. For example, RPM International manufactures and sells specialty chemicals for the industrial, specialty, and consumer markets. RPM lists Home Depot, Lowes, Walmart and other stores as their main customers as it sells deck and fence restoration products, metallic and faux finish coatings, exterior wood deck and concrete restoration systems, flooring finishes, and hobby paints and cements to these stores. However, a production delay in one of its products, say, nail enamels and polishes, may not cause any negative market reaction to these stores.

Also, since the event companies and their customers usually belong to different industries, a supply chain disruption in a specific industry does not raise the same level of public attention to its customers in another industry. Therefore, we do not expect the same level of negative market reactions on its customers following a supply chain disruption announcement. Base on the above arguments, we propose the following hypothesis for customers:

H2. When a company announces a supply chain disruption, its customers experience a less negative stock price reaction as compared to the affected company.

We follow similar logic on the effect of supply chain disruptions on the affected company's suppliers, but this case is even more complicated as it is more product specific. Using the previous Takata example, the product recall of safety belt may cause negative market reaction on its customers: Honda and Nissan. However, the reverse may not be holding true. For example, it will be hard to imagine a product recall on Goodyear tires from Honda models will have any negative contagion effect on one of its suppliers Takata, Michelin or Bridgestone, but may exert a negative market reaction on one of its tire suppliers, Goodyear in this case. Based on the above arguments, we propose the following hypothesis for suppliers:

H3. A negative share price reaction occurs on a company's suppliers when a company announces a supply chain disruption.

Previous literature also argues that firm characteristics of affected firm's or industry characteristics may affect the price responses to the supply chain disruptions. For example, Hendricks and Singhal (2003) report a direct relationship between firm size and share price response and an inverse relationship between growth prospects and share price response. Product and industry characteristics can impact the growth prospects of a company. High growth prospect companies often have products that have short product life cycle and delivery times. Thus, disruptions in higher growth industries have a higher potential to cause significant economic damage in the life of the product. The recovery time required to limit losses could also be very short. The impact of such disruptions can extend to all supply chain members, including competitors, customers and suppliers. Goldman, et al. (2012) argue that industry competition, importance of the event, firm characteristics such as opacity of the company (i.e., valuation of

the company is more uncertain), and riskiness of the company will affect the announcement effect on the competitors following a financial misrepresentation announcement.

Next, we measure how the industry and firm characteristics affect the stock market reaction of the competitors, customers and suppliers. The dependent variable is the cumulative abnormal returns (CARs) of the event firms' competitors, customers and suppliers. We use this variable to measure the announcement effect of the stock price response of the event firms' competitors, customers and suppliers. We include four categories of independent variables (i.e., industry competition, importance of events, firm characteristics of the event firms and the competitors/customers/suppliers) to test whether the firm or industry characteristics may affect the magnitude of the announcement effect. We first discuss the implications for the competitors and then for the customers and suppliers. Detailed definitions of the variables are summarized in Appendix 2. The potential effects of announcements on the cumulative abnormal returns of their competitors, customers, and suppliers are summarized in Table 1. Control variables are included in a regression-based analysis to differentiate differences among sample firms based on sales, debt levels, industry concentration as well as robustness tests to control for the fixed effects of the disruption classification categories.

Category 1: Industry competition

Goldman, et al. (2012) find that greater industry competition is associated with lower (more negative) abnormal returns to the industry competitors of the event firm following the announcement of an accusation of fraudulent financial misrepresentation. Following their study, we use the Herfindahl–Hirschman Index (Herfindahl index) as a proxy for industry competition. The Herfindahl index measures the level of concentration in a given industry, serving as one indicator of market competition. Specifically, for each industry using four-digit SIC codes of

each sample year, we calculate the Herfindahl index as the sum of squares of the market shares of all competitors in the industry. For each company in the industry in each sample year, we define market share as the annual sales of a company divided by the total sales of the composite firms within the industry. By design, the Herfindahl index ranges from 0 to 1 and is an indicator of competitiveness in an industry. A higher Herfindahl index (closer to 1) generally indicates less competition and a higher market power in the industry (monopoly or oligopoly)[6].

If the industry competition effect dominates, competitor companies in a higher Herfindahl index industry (less competitive industry) should experience higher cumulative abnormal returns associated with a supply chain disruption. In other words, a positive correlation between the Herfindahl index and CAR of the competitor firm: a higher Herfindahl index implies lower competition which would imply higher or less negative CAR. This outcome occurs because in industries with limited players (oligopoly), competitors may gain from disruptions at a competitor. For example, in 2011, production-related recalls of Johnson and Johnson's Tylenol resulted in a 24 percent increase in first quarter sales of Aspirin made by its major competitor, Bayer (Kresge, 2011). Toyota, which held the title of world's biggest auto maker since 2008, suffered a sequence of recalls and supplier problems because of the Japanese tsunami in 2011. The events resulted in loss of sales in Toyota and an increasing market share for its competitor General Motors. Conversely, in competitive sectors that have more companies offering similar products to customers, the effect of disruptions at a company may have a limited effect on

[6] Both Herfindahl index and the number of firms in the industry are measures of industry competition and these two measures are negatively correlated: a higher Herfindahl index indicates more concentrated industry, which usually suggests fewer firms in the industry. However, Herfindahl index is a better measure compared with the number of firms as it uses individual company's market share in its calculation. As an example, both industry A and industry B only has two firms. For industry A, the market share of each company is 90% and 10%, respectively. While for industry B, the market share of the companies is 50% and 50%. The Herfindahl index will be 0.82 (=90%x90%+10%x10%) for industry A and 0.50 (=50%x50%+50%x50%) for industry B, which conforms to the fact that industry A is more concentrated (less competition).

competitors. A disruption at one company may not have a significant impact for competitors as the potential implications (positive or negative) of disruptions to competitors may be dispersed and less noticeable. In such industrial sectors, disruptions at one company may not imply consequences for the whole industrial sectors. For example, a bank run of a state commercial bank may not cause a negative market reaction to the whole banking industry as over 400 state commercial banks exist in the same industry. The above arguments lead to our alternative hypothesis 1a:

H1a. If the industry competition effect dominates, competitor companies in a higher Herfindahl index industry (less competitive industry) will experience higher cumulative abnormal returns associated with a supply chain disruption.

However, if information spillover effect dominates, competitor companies in a higher Herfindahl index industry (more concentrated industry) should experience a more negative stock price reaction. Since supply chain disruptions may indicate a problem existing in the whole industry, this spillover effect may have a negative effect on its competitors as well. For example, a safety recall of plastics toys may cause negative market reaction to all toy companies in the industry. The above argument leads to our alternative hypothesis 1b:

H1b. If the information spillover effect dominates, competitor companies in a higher Herfindahl index industry (more competitive industry) should experience a more negative stock price reaction.

Category 2: Importance/Impact of event

Next, we look at how the importance of event affects the CAR of the competitor firms proposed by Goldman, et al. (2012). The importance of event measures the negative magnitude of the event or the impact of the event on public investors. When the (negative) magnitude of the

disruption announcement is large, or the news event causes higher attention from public investors, the resulting impact on the competitor will be likely large as well. Following Goldman, et al. (2012), we use five variables (including one variable in the category 3) as a proxy of the importance/impact of event, specifically as follows:

- CAR_Event: CAR during event window (-1, +1) of the event firms;
- Neg_CAR: a dummy variable which is equal to 1 when the CAR during the event window (-1, +1) for the event firm is negative, and 0 otherwise;
- Number of Hits: Number of hits for the news event. We take log for this variable as it is skewed;
- Hits_Neg_CAR: Interaction term. It is equal to log(Number of Hits) x Neg_CAR.

The first variable, CAR_Event measures the magnitude and direction of the announcement effect on the event firms surrounding the supply chain announcements. We predict a negative relationship between CAR_Event and CAR of the competitor firms based on the industry competition effect, as a supply chain disruption that is more detrimental to the disrupted firm (i.e., lower CAR_Event) will be associated with higher (more positive) competitor abnormal returns. In contrast, the information spillover effect predicts that a supply chain disruption that is more detrimental to the disrupted firm (i.e., lower CAR_Event) will be associated with lower (more negative) competitor abnormal returns.

Similarly, Neg_CAR is a dummy variable which is equal to 1 when the CAR for the event firm is negative. Number of Hits measures the number of hits for the supply disruption news announcement: the larger the number of hits, the bigger the impact of the supply chain disruption and therefore potentially larger stock price responses. Hits_Neg_CAR is an interaction term for Number of Hits and Neg_CAR. Based on these definitions, we have opposite predictions on the signs between Neg_CAR (Number of Hits, Hits_Negative_CAR) and CAR of

competitor companies based on information spillover and industry competition effect. To sum up these predictions, we have the following alternative hypotheses on competitor firms:

H1c: A negative relationship will exist between CAR_Event and CAR of the competitor firms based on the industry competition effect, as a supply chain disruption that is more detrimental to the disrupted firm (i.e., lower CAR_Event) will be associated with higher (more positive) competitor abnormal returns.

H1d: The information spillover effect predicts that a supply chain disruption that is more detrimental to the disrupted firm (i.e., lower CAR_Event) will be associated with lower (more negative) competitor abnormal returns.

Category 3: Firm characteristics of event firms

Hendricks and Singhal (2003) argue that firm characteristics variables, such as firm size, growth potential and debt to equity ratio affect the magnitude of the CARs of the event companies as well. Goldman, et al. (2012) argue that other firm characteristics, such as opacity of the firm value (proxied by market to book ratio) or the riskiness of the company (proxied by standard deviation of monthly returns) following announcement of an accusation of fraudulent financial misrepresentation affects industry competitors of the accused firm. Following their studies, we use three firm characteristics variables of the event firms: Sales_Event, MB_Event, and STDRET_Event, which are defined in the following manner:

- Sales_Event: the log of annual sales of the event firm from Compustat measured at the fiscal year-end prior to the announcement date. We take the log of this variable as it exhibits significant skewness.
- MB_Event: market-to-book ratio of the event firm. We follow Goldman, et al. (2012) and measure market-to-book ratio as the sum of total debt and market value of equity divided by book value of total assets.
- STDRET_Event: the standard deviation of monthly returns of the event firm measured in the year prior to the announcement date.

Sales_Event is another measure of the importance of the event: we believe the larger the company is (i.e., higher sales amount), the more likely it will be noticed by public media, which indicates a bigger impact of the disruption event. Therefore, we predict a positive relationship between Sales_Event and CAR of the competitor firms according to industry competition effect and a negative relationship based on information spillover effect. Market-to-book ratio (MB_Event) is used to proxy the opacity of the firm: the higher the market-to-book ratio (i.e., the firm has more growth opportunity), the more uncertain the firm valuation. When the disrupted firm is opaque (i.e., higher market-to-book ratio), the industry competition effect predicts that the disruption will have no effect on the CAR of the competitor firms. In contrast, the information spillover effect predicts a positive effect: i.e., great opacity will be associated with higher (less negative) competitor abnormal returns. The STDRET_Event is usually measured as a proxy for company's riskiness and serves as a second measure for opacity of the firm (i.e., higher volatility of stock returns indicates more difficult to value the firm's assets), and therefore has the same predictions as the MB_Event. To sum up these predictions of CARs of competitor firms on firm characteristics of event firms, we have the following alternative hypotheses on competitor firms:

H1e: A positive relationship will exist between Sales_Event and CAR of the competitor firms according to industry competition effect and a negative relationship based on information spillover effect.

H1f: The information spillover effect predicts a positive effect: i.e., great opacity will be associated with higher (less negative) competitor abnormal returns.

Category 4: Firm characteristics of competitor firms

We use four firm characteristics of competitor firms in this category: MB_Competitor, STDRET_Competitor, Sales_Competitor and Debt_Competitor. All three variables are previously defined for the affected firm and the final variable is defined in the following manner:

- Debt_Competitor is measured as long-term debt divided by the book value of total assets for the fiscal year end prior to the announcement date.

While, the industry competition effect in general would predict no effect of these variables on the CAR of the competitor firms, other factors may influence this result empirically. For instance, a more highly leveraged competitor facing financial distress may benefit from the windfall caused by the disruption of a competitor's operations. The information spillover effect predicts market-to-book ratio of the competitor firm will have a negative effect on the CAR of the competitor firms. This prediction is because for more opaque competitors (i.e., higher market to book ratio), the market will place more weight on the new (and negative) information from the disruption announcement. This difference leads to a negative relationship between the MB_Competitor and CAR of the competitor firms.

Hendricks and Singhal (2003) argue that the stock market's reaction to supply chain disruptions will be more negative for smaller firms than larger firms (Hypothesis 2). This is because companies of smaller size are more sensitive to the supply chain disruptions as they have limited ability influence and change the behavior of other supply chain partners to help recover from glitches (Kuper, 2002). We follow similar arguments and propose a positive relationship between the firm size of the competitor firms (proxied by Sales_Competitor) and CARs of the competitor firms.

The predicted sign on STDRET_Competitor is less clear. STDRET is a second measure of opacity of the competitor firm, and therefore should have the same sign as MB_Competitor (negative sign, i.e., the competitor firm with higher volatility should have more negative CARs

from the disruption announcement). In contrast, STDRET is a proxy for company's riskiness. A competitor firm that is more volatile is more likely to be less negatively affected by the supply chain announcement because the market has grown to expect more uncertainty in general for the security due to its overall higher risk (i.e., positive sign). Therefore, empirical findings will determine which rationale dominates.

The information spillover effect predicts a positive relationship of the competitor firm's sales and the CAR of the competitor firms because a larger competitor has stronger resiliency in warding off the negative effect of the announcement. For the same reason, a supply chain disruption announcement may have a more negative effect on a competitor with higher debt ratio or higher volatility. The above arguments lead to the following alternative hypothesis:

H1g: The industry competition effect predicts no effect of competitor firm characteristics on the CAR of the competitor firms. The information spillover effect predicts higher market-to-book ratio and smaller firm size of the competitor firm will have a more negative effect on the CAR of the competitor firms.

Sales_Event, Sales_Competitor and Debt_Competitor are included as control in each regression.

Implications for Customers and Suppliers

The prediction of all these variables on the CARs of the disrupted companies' customers or suppliers is similar. The industry competition effect may be less applicable for the customers and suppliers, but the information spillover effect may. However, the extent of the effect will be much smaller in magnitude. Since supply chain disruptions may be indicative an industry-wide problem (such as labor shortage, industrial shortage), it may have a smaller effect on the affected company's customers or suppliers, which is usually in a different industry.

Sample

We define our sample period as 1990 to 2010. We searched the full text of articles appearing in the *Wall Street Journal* (WSJ) and the *Dow Jones News Service* (DJNS)[7] in the ABI/Inform database to collect a sample of supply chain disruption announcements. The keywords searched cover a variety of disruptions in supplies, production, operations, and transportation. A sample of these keywords include supplier breakdown, design issues, production delays, inventory shortfall, poor planning, inaccurate forecast, strike, delay, accidents, data breach, fire, and earthquake. Following Wagner and Bode (2008), we divide supply chain disruptions into five categories[8]: (1) demand; (2) supply; (3) regulatory, legal and bureaucratic; (4) infrastructure; and (5) catastrophe. We analyzed the resulting news announcements to determine those that resulted in disruptions at one or more stages of a supply chain. Examples of key words in each type are as follows:

- Demand: inaccurate forecasts, product introduction delays, shortage, equipment shortage, poor planning, poor organization, production delays, production stoppage.
- Supply: capacity constraints, labor shortage, capacity shortage, product recalls, inferior quality, supplier bankruptcy, supplier labor strike.
- Regulatory, legal, and Bureaucratic: company sued, increased regulation, investigation following recalls.
- Infrastructure: industrial accidents, transportation accidents, information (electricity) blackout, power outage, labor strike, union strike.
- Catastrophe: SARS outbreak, flooding, hurricane, fire, bird flu, terrorist attacks.

[7] We followed Hendricks and Singhal (2003, 2005, and 2009) and searched the news articles only in the *Wall Street Journal* (WSJ) and the *Dow Jones News Service* (DJNS) as event study results typically evaluates short-term stock price responses to news announcements. Less well-accepted public media will incur less pronounced announcement effect. In our sensitivity test, we searched all news media using more recent 2016 data as a comparison.
[8] There exist other supply chain disruption classifications in the literature. For example, Svensson (2000) divided them into two categories (quantitative and qualitative) while Jüttner (2005) proposed three categories (supply, demand, and environmental).

We collected 1,401 announcements on different disruptions during our sample period. From the original sample, 238 of these announcements affect more than one company. For example, the information blackout in May 2005 affected Aflac, Bear Stearns, Credit Suisse Group, Commerce Bancorp, and Wells Fargo. We consider each individual company in the same event as separate event companies in this scenario. Companies that do not have stock return data surrounding the event dates from Center for Research in Securities Prices (CRSP) or data from financial statements (e.g., annual sales, book value of equity) from Compustat database are deleted. Since only three announcements are categorized in Regulatory, legal and Bureaucratic type, we removed these three announcements and therefore this disruption type. The final sample consists of 1,054 viable announcements with four disruption types.

Next, we divide our whole event sample into six market segments according to each company's two-digit standard industry code (SIC): Manufacturing, Transportation, communications, electric, gas and sanitary services, Wholesale and retail trade, Finance, insurance and real estate, Services, and Other (which includes Agriculture, Forestry, Fishing, Mining, Construction, and Public Administration).

We report the summary description of the event sample in Table 2. About 76 percent of the disruptions (806 out of 1,054) belong to manufacturing segment, followed by transportations segment (84) and wholesale and retail trade (84). About 64 percent (673 out of 1,054) of the disruptions are on supply side, followed by disruptions associated with demand side (189) and catastrophe (103). Some of the disruptions occur within a single certain market segment such as manufacturing segment. For example, about 85 percent (573 out of 673) of the supply side disruptions, 64 percent (121 out of 189) of the demand side disruptions, and 62 percent (64 out

of 103) of the catastrophe occur in manufacturing segment. One conclusion from this table is that our event study results may be driven by certain market segments and certain type of disruptions.

Next, we form our portfolio of competitor, customer, and supplier sample, respectively. FASB No. 14 required firms to report certain financial information for any industry segment that comprised more than 10 percent of its consolidated annual sales, assets, or profits[9]. The industry segments are divided into business, geographic and operational segments. In addition, the identity of any customer representing more than 10 percent of the total sales of a firm had to be disclosed. Both industry segment information and customer information can be retrieved from the Compustat industry segment files.

Much data in the raw industry segment file is not usable. For example, many firms report the geographic locations (e.g., "Asia" and "Europe and rest of the world") or market segment (e.g., "Commercial" and "Automotive") of the company rather than the individual customer in which they have over 10 percent sales in that year. Even for the data which has listed individual customers, sometimes the data cannot be used such as "20 customers," "U S ARMY," "U S GOVT," "U S NAVY," "SAN ANTONIO," or "Not reported." Even after screening for these issues, the customer information is still not in an immediately usable format.

Each company can list an abbreviation of the customer's name, and the name can vary across years for the same company. For example, General Motors can be listed as "GEN MTR," "GEN MTR INTL," "GEN MTR NRTH AMER," "General Motors Co," and "GENERAL MOTORS CORP" from different companies and different years.

[9] According to FAS 14 (1976) and FAS 30 (1979), the reporting regime requires the disclosure of the existence of an important customer, but not necessarily its identity. Starting in 1998, FASB No. 131 governs industry segment disclosures.

To link the customer names with full company data, we manually search each customer name for the disrupted event firm and match with CRSP historical header file. We chose to match manually rather than the fuzzy program match because of the higher probability of matching errors. A manual match also enables us to identify and correct the possible typos in the customer names (e.g., ABBOTT LABORATORIES as "ABOTT" and J C Penny as "PPENNEY (J C) CO"). In cases in which visual inspection determines an almost certain match, we link the customer name with the CRSP name, permanent identification number (PERMNO) and Compustat CUSIP and GVKEY. For those customers which have changed CRSP names, permanent identification number or CUSIP, we match the customer names with the financial company data using the date closest with the disruption announcement date. Following Hertzel et al. (2008), all matches of the customers are restricted to the five years prior to and including the year of the disruption announcements. If the matching process produces multiple matches over the five-year period, we choose the year closest to the announcement year. While some discretion is involved in matching customer names with firm financial data, we are conservative when conducting the manual matches. Since the majority of disruption announcements are in the manufacturing segment, we find many customers are foreign, primarily from Asian countries (e.g., "SAMSUNG ELECTRONICS CO -ADR" and "Shanghai General Motors Company Limited"). Also, we find many customers are privately held companies for which the financial data is not retrievable.

We use the resulting database to identify customers of the disrupted firms in our sample and then invert the database to identify suppliers. We include in our supplier sample all firms listing as a customer in any of the five fiscal years prior to the disruption announcements.

For the full sample of our disruption announcements, we identify a total of 86 customers (for 62 announcements) and 214 suppliers (for 116 announcements). Taken together, we identify customers and/or suppliers for 17 percent (197 announcements) of the total disruption announcements. This percentage is roughly consistent with Hertzel et al. (2008) who used the same database to identify customers and suppliers for bankruptcy filings. Since the customers include only "important" customers, customers must be publicly traded (therefore the financial information can be retrievable), and the regulation only requires customer disclosure but not the actual customer identity[10], we need to interpret the results on the customers and suppliers with caution. We explain the matching process in detail with an example in Appendix 3.

Next, we follow Lang and Stulz (1992) and identify industry competitors of the event firms. We identify competitors as any firms, besides the event firms, customers, and suppliers, which have the same four-digit SIC codes as the event firms.

Table 3 reports the descriptive statistics for the event (i.e., disruption announcement firms), competitor, customers and supplier samples. We define market capitalization[11] as the previous year-end share price multiplied by the number of outstanding shares. All the other variables have the same definitions as in Table 1. For competitor, customer and supplier sample, since one disruption announcement may match with multiple competitors, customers, and suppliers, we first calculate the average for each variable for each event, and report the averages of these variables across events in the table. From Table 3, for an average disruption announcement, we identify 47 competitor firms with the range of 2 to 498 competitors per event. Approximately 75 percent of the companies with customer or supplier identifications have only

[10] Out of the companies who reported their individual customer data in our sample, about 57percent of the companies list "Not Reported" in their customer names, and about 43 percent report at least one of their customer names as "x customers" or "x distributors."
[11] Market capitalization (or market value of common equity) and annual sales are typical proxies for firm sizes.

one or two customers or suppliers with a range of 1 to 5 customers and 1 to 8 suppliers per event. This finding is consistent with that of Fee and Thomas (2004) and Hertzel et al. (2008). However, this does raise an issue of data limitation as our customer and supplier sample is significantly smaller compared with our event and competitor sample.

We observe that the event sample has the largest market capitalization ($59.5 billion), while competitor sample has the smallest market capitalization ($2.7 billion). Because of the previously mentioned matching criteria, the customer sample has a relatively larger market capitalization ($56.4 billion) compared with supplier sample ($14.7 billion). The pattern for the sales is similar: the event sample has the largest average annual sales ($76.2 billion) and the competitor sample has the lowest sales ($2.4 billion). Since competitor firms and event firms come from the same four-digit SIC codes, we observe the same Herfindahl index (0.24 on average) for event and competitor sample. The supplier sample has the highest average Herfindahl index of 0.42.

Empirical Tests and Results

In this section, we examine the announcement effects of the supply chain disruptions for the competitor, customer and supplier samples. We define the announcement day as the event date (t=0). To test for possible leakage of approaching news or delayed investor response, we test the share price response to the announcements beginning five days prior to the announcement date by calculating cumulative abnormal returns (CARs) over our event window (days -5 to +5). Expected returns are estimated from the market model during the interval (-5, 5), and estimates of the parameters are calculated for the period (–326, –71). Abnormal returns are calculated as

Market Adjusted Returns (MAR) with the CRSP value-weighted index as the market index. We follow Dodd and Warner (1983) and employ standard event-study methodology.

Event Study Results – Univariate Tests

Table 4 reports the results of the event study for all samples. For the event sample, we observe a statistically-significant (at the 1 percent level), negative CAR of -1.49 percent over the event window of (–5, +5). From different event windows results, we can see that most of the negative CARs are realized prior to the announcement date (-5, 0). The three-day CAR (-1, +1) is -1.08 percent which is also statistically-significant. The results are consistent with the previous findings of Hendricks and Singhal (2003). However, the magnitude of CARs following a disruption is different from Hendricks and Singhal. The difference in CARs could be attributed to differences in the search terms used in the two studies and data compilation differences. Our search terms cover a broader range of disruptions than those used by Hendricks and Singhal. They primarily covered demand and supply "glitches," while our data includes operational issues as well. Such issues have the *potential* to affect supply and demand and may reveal poor planning and management. For example, we include events such as weather disasters that disrupt normal operations and have the potential to affect supply or demand. In contrast, Hendricks and Singhal focus on announcements that report excess inventory, shortages, or production stoppage. Such announcements could be considered as the consequence of poor decisions and cause supply chain disruption. Nevertheless, the abnormal returns we find are comparable to various marketing, financial, accounting, information technology, and operations related event studies in literature (See Table IV in Hendricks and Singhal, 2003).

Results of Table 4 show that significant announcement effects exist on the competitors as well, but to a much smaller degree: an average competitor experienced a -0.39 percent

(statistically significant at the 1 percent level) CARs in the (-5, +5) event window, compared with a -1.49 percent CARs from the event sample. It seems to suggest that information spillover effect (negative impact on competitors) dominates for competitors. However, since the net effect on the competitors depends on which effect (industry competition or information spillover) dominates, our results may only be valid for this sample period or may be driven by the large sample size of the competitor companies. Therefore, we need to interpret the results with caution and do not generalize to the other sample periods, events, or industries[12].

We do not find any statically significant CARs for either the customer or supplier firms in any of the event windows. This finding is consistent with our hypothesis that supply chain disruptions will have a much less effect on the customers or suppliers, as most of the customers and suppliers are from a different industry as the affected firm. Also, because of the previously mentioned customer or supplier identification method (i.e., companies only report customers with greater than 10 percent sales, they do not have to reveal the names, and customers and supplier must be publicly traded companies to retrieve financial data), our sample tends to feature relatively larger customers and suppliers. As we hypothesize in the previous section, these companies may not be easily affected by the supply chain disruptions.

Table 5 shows the event study results for different disruption types. For brevity, we only report the CAR of event window (-1, +1) for different samples. For event sample, we observe that demand and supply events yield the most negative CARs (-3.03 percent) during the event window of (-1, +1), and this result is statistically significant at the 10 percent level. Production planning events yield a negative CAR of -1.65 percent (statistically significant at the 1 percent level), followed by quality (-0.87 percent, statistically significant at the 1 percent level). For

[12] In our Sensitivity test section, we update the results with 2016 data, and use random selected competitor sample to control for issues of large sample size. We do find insignificant positive results on the competitor firms.

competitor sample, we observe statistically-significant (at least at the 10 percent level) negative CARs in capacity, disruptive events and production planning disruptions for the (-1, +1) event window, of which disruptive events have the most negative impact on competitors (a statistically-significant -0.96 percent return. This suggests that competitors are affected by the disruptions differentially based on industry and type of disruption. Consistent with previous findings, we do not observe any statistically significant CARs for the customer and supplier sample. Although these findings seem to be consistent with our hypothesis 2 and 3, we need to interpret the results with caution because of the data limitation issues when we identify customers and suppliers.

5.2 Regression Results

Next, we use regression analysis to identify factors that influence the direction and magnitude of the change of the stock market's reaction on competitors, customers, and suppliers to supply chain disruptions. Our dependent variable is the CARs of competitors/customers/ suppliers over the event window (-1, +1)[13]. Our independent variables include four categories of variables listed in Table 1. We report the regression results of competitors, customers, and suppliers samples in Table 6, 7 and 8, respectively.

In Table 6, we find negative regression coefficient on the Herfindahl Index, which suggests the information spillover effect dominates the industry competition effect in our sample: competitors in industries that are more competitive (i.e., a lower Herfindahl index) experience higher (less negative) abnormal returns around the disruption announcements.

[13] We use CAR of event window (-5, +5) as dependent variable as a robustness check in the "Robustness Tests" section.

The regression coefficients on the importance of the events (i.e., CAR_Event, Neg_CAR, Number of Hits, Neg_CAR_Hits, Sales_Event) are also statistically significant. The more important events (i.e., lower CAR of the event firm (CAR_Event), events that are associated with negative CAR of the event firm (Neg_CAR), events that are associated with negative CAR of event firm and with large number of hits in the news (Neg_CAR_Hits), and events with larger event firm involved (Sales_Event)), are associated with lower (more negative) competitor CARs. Therefore, the positive sign on CAR_Event, and the negative signs on Neg_CAR, Neg_CAR_Hits, Sales_Event in the regressions all suggest the information spillover effect typically dominates the competition effect.

Other than Sales_Event (which is also an indicator of the importance of the event) of the event firms' characteristics, the coefficients on the other two variables which measure the opaqueness of the event firm (MB_Event, STDRET_Event) are not statistically significant.

Of the four firm characteristics of the competitor firms, both MB_Competitor and Debt_Competitor have statistically significantly negative coefficients. This suggests that competitors with higher growth prospect (i.e., higher MB ratio) and higher debt ratio experienced a much more negative market reaction after disruption announcements. However, the coefficients on STDRET_Competitor is positive, which suggests that a competitor firm with a higher volatility receives less negative reaction in the supply chain announcement as the market has grown to expect more uncertainty for the security due to its overall higher risk. Overall, the regression results generally suggest that the information spillover effect dominates the industry competition effect for competitor firms surrounding a supply chain disruption announcement.

The regression results of the customer sample are reported in Table 7. Only a couple of variables yield statistically significant results. It shows that customers in less competitive

industries (i.e., a higher Herfindahl Index), more risky firms (i.e., higher standard deviation of returns) and smaller customers (i.e., smaller Sales_Customer) typically experience more negative CARs after the disruption announcements. The regression results of supplier sample (reported in Table 8) suggest that suppliers seem to be unaffected by the disruption announcements as none of these variables are statistically significant.

Robustness Tests

We use Ordinary Least Squares (OLS) regressions so far to test the effect of the industry and firm characteristics on the cumulative abnormal returns of the competitors/customers/suppliers. We check for normality of the variables in the regression models using Kolmogorov-Smirnov statistics, Cramer-von Mises statistics, and Anderson-Darling statistics, and many variables fail the normality tests. To test the robustness of the regression results in Tables 6, 7, and 8, we employ two additional tests. First, we control the fixed effect of disruption types and use a more robust regression model: Generalized Linear Model (GLM), which is a flexible generalization of ordinary linear regression that allows for response variables that have error distribution models other than a normal distribution. Second, we use CAR of competitors (customers, suppliers) of event window (-5, +5) as dependent variable and run GLM regressions again after controlling for the fixed effect of disruption types. Our results are reported in Table 9. For brevity, we only report the regression results for model (4) in previous tables. Overall, Table 9 shows qualitatively similar results as previous regression models and suggests that our conclusion is not affected by different event window or different disruption types.

To test whether our conclusions change over the time or over different news resources, we expand our searches. In this case, we do not limit our searching source types to only the *Wall*

Street Journal (WSJ) and the *Dow Jones News Service* (DJNS) and search supply chain disruptions news announcements in the entire ABI/Inform database for the year 2016. This method has proved to increase our manual search efforts tremendously. For example, a key word search "product recall" returns almost 20,000 news announcements for 2016 alone. Because of the time limit, we did an incomplete search of disruptions events for the year 2016. This limited dataset serves as a sensitivity test of whether the previous results on event and competitor firms are driven by large sample size. There are 224 events reported from the incomplete search, which are more comparable to our sample size of customers (66) and suppliers (54). To come up with a comparable sample size of the competitors, for each event firm, we randomly select three competitors from the same industry (using 4-digit SIC codes). We end up with 524 competitors after filtering as some industries have less than three competitors and some companies do not have complete information from CRSP and Compustat.

We report only the event study results of 2016 in Table 10. Though the results need to be interpreted with caution because of the data limitation, we do find that our conclusions from event studies on event firms, customers and suppliers do not change. One thing that is worth noting is the insignificant positive CARs over event windows (-5, +5) and (-1, +1) for our random competitor sample, which suggests muted effects of industry competition and information spillover.

DISCUSSION AND CONCLUSIONS

Supply chain disruptions are increasingly a primary risk management concern for organizations. Whether disruptions are a result of demand, supply, regulatory, infrastructure, or catastrophe reason, the implications can be quite damaging from cash flow and earnings

depletion to increased credit risk to shareholder loss, ultimately recreating reputational damage. But damage is not restricted to just the affected firm. Competitors can suffer from contagion effects. In this paper, we expand the existing literature to consider possible damage caused to customers and suppliers.

Disruptions in supply chains have the potential to impact all members along the supply chain, including competitors, customers and suppliers. While previous research has primarily focused on the impact of supply chain events on the affected firm and its competitors, this paper expands previous studies considering the impact on customers and suppliers. In this paper, we explore two effects (information spillover and industry competition) on the stock prices of supply chain disruption announcements by a company of its competitors, customers and suppliers. We find the announcement of a supply chain disruption results in statistically significant negative abnormal returns for both the affected company and for its competitors. However, the announcement does not have a share price impact on either the firms' customers or suppliers. These results offer support of our hypothesis that supply chain disruptions will have much less effect on the customers or suppliers, as most of the customers and suppliers are from a different industry. However, our sample is limited to customers that represent at least 10 percent of sales and are publicly traded. Since only larger customers and suppliers are a part of our sample, they are less susceptible to the impact of disruptions caused by the firms to which they purchase or supply, respectively. We find that the information spillover effect dominates the industry competition effect.

The market reacts differentially to an affected firm and its competitors based on disruption type. For the firm impacted by the supply chain disruption, the market reacts most negatively to demand and supply events followed by production planning events, and then

quality events. Competitor firms of the impacted firm are most negatively impacted when the impact firm experiences a disruption events followed by capacity events and production planning disruptions.

Competitors in industries that are more concentrated, with higher growth prospects and higher leverage ratios are more negatively impacted by disruption announcements. Shareholders of customers in less competitive industries, who exhibit higher risk, and have overall lower sales react more negatively to disruptions. No evidence exists that suppliers are impacted by disruption announcements based on the nature of industry in which they reside. A possible rationale for the muted response to disruptions for customers and lack of reaction for suppliers is less market awareness as to the population of these two groups. A smaller sample size may also explain the lack of statistical results.

Theoretical Implications

Our paper contributes to the existing literature in supply chain disruptions by expanding the theoretical framework of contagion effects beyond competitors to consider suppliers and customers. We offer two competing theoretical frameworks for observed market reactions using a hand collected data set, creating a categorizing system for disruptions, and controlling for other explanatory effects. By investigating both industry competition and information spillover effects, we gain a broader sense of the impact supply chain disruptions have across impacted parties. News announcements are sorted disruptions in supply, demand, production, inventory, distribution, or transportation at one or more stages of a supply chain. These four types of disruptions are analyzed across six market segments including capacity, demand and supply, disruptive events, production planning, and quality events.

Implications for Managers

From a managerial standpoint, an expanded understanding of the impact of contagion effects is an important consideration as negative share price responses caused by contagion effects can impact capital structure, cost of capital, and accept/reject decisions for projects. Our findings have implications for managers in industries in which competitors and customers are impacted.

Managers must be prepared to address directly shareholder concerns that disruptions occurring in another firm within their industry is not necessarily an indication of weaknesses for their stakeholders. Competitors in more concentrated industries, with higher growth prospects, or with higher debt ratios are more impacted by disruptions by peer firms. Customers firms in less competitive industries, who exhibit higher risk, or have overall lower sales react more negatively to disruption announcements. For example, A shareholders of firms in industries in which less growth and leverage exist have less reason to be concerned about potential contagion affects caused by a supply chain disruption occurring. Likewise, customers in more competitive industries that are less risky, and with fewer sales do not hold the same concerns about contagion effects.

Limitations of the Study

Results of this study should be interpreted with some caution as some limitations exist on applicability. While we create different categories of disruptions, the nature of the announcements and other firm-specific characteristics can impact different firms in different ways. Also, smaller subsample sizes making drawing broad generalizations challenging. No mechanism exists to isolate the effects of the industry competition effect and the information spillover effect. In fact, since these two effects move in opposition to each other, one possible explanation for a lack of statistically significant results may be a result of them balancing each

other. This result is particularly true if the sample size is small, as it is for the models predicting effects for suppliers and customers. Moreover, as pointed out in the discussion of results, customer and supplier data tends to be highly skewed with respect to the customers-per-event and suppliers-per-event. Future research can help differentiate responses based on awareness of the composition of these population groups.

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Appendix 1: Standard event study methodology

An event study methodology is widely used in various research areas, such as accounting and finance, management, economics, marketing, information technology, law, political science, operations and supply chain management, to analyze the market reaction to firm specific and market-wide events using stock returns around the time when event occurred. In the current study, the "event" is defined as supply chain disruptions. The purpose of this methodology is to determine whether the announcement of an event produces a "significant" stock price reaction around the time of the announcement. To conduct such tests, daily stock returns are measured around the announcement date and compared with the expected return. To understand the effect on shareholder returns, this methodology is applied to estimate abnormal returns (ARs) around the date of a supply chain disruption announcement. The daily abnormal return is calculated by deducting daily expected (normal) return from the daily actual return. The most common model for expected returns is the "market model" (MacKinlay 1997). Following this model, the analysis implies to use an estimation window (e.g., 100 trading days) prior to the event to derive the typical relationship between the firm's stock and a market index (e.g., S&P 500) through a regression analysis. Based on the regression coefficients, the expected returns are then projected and used to calculate the abnormal returns.

The rationale behind event study methodology is "given rationality in the marketplace, the effects of an event will be reflected immediately in security prices. Thus a measure of the event's economic impact can be constructed using security prices observed over a relatively short time period" (MacKinlay 1997). Event window is defined as the day of the event and several days prior and after the event. The event date (or announcement date) is defined as date 0. Typical event windows are (-1, 1) and (-5, 5), which represents 1 day or 5 days before or after the event date,

respectively. It is important to note that results over short event window are more reliable than results over long event windows (e.g., 30 to 90 trading days after the event) as the latter have many limitations. To test whether individual abnormal returns differ from zero with some statistical validity, usually cumulative abnormal returns (CARs, i.e., summation of daily abnormal returns over the event window) are calculated and tested for statistical significance (e.g., t-stat or z-stat). Therefore, in this study, the magnitude and statistical significance of the CARs is used to measure the announcement effect of the event, i.e., the change in security prices that results directly from a piece of supply chain disruptions news announcements.

Appendix 2: Variable definitions

Dependent variable

CAR	Cumulative abnormal returns. The daily abnormal return is calculated by deducting daily expected (normal) return from the daily actual return. The most common model for expected returns is the "market model" (MacKinlay 1997) which we employ in this study. Following this model, the analysis implies to use an estimation window (e.g., 100 trading days) prior to the event to derive the typical relationship between the firm's stock and a market index (e.g., S&P 500) through a regression analysis. Based on the regression coefficients, the expected returns are then projected and used to calculate the abnormal returns. In this study, we use CARs over event window (-5, +5) or (-1, +1) to measure the magnitude of the announcement effect following supply chain disruption announcements using an event study methodology.

Independent variables

Category 1: Industry competition

Herfindahl	Herfindahl–Hirschman Index (Herfindahl index), a proxy for industry competition. The Herfindahl index measures the level of concentration in a given industry, serving as one indicator of market competition. Specifically, for each industry using four-digit SIC codes of each sample year, we calculate the Herfindahl index as the sum of squares of the market shares of all competitors in the industry. For each company in the industry in each sample year, we define market share as the annual sales of a company divided by the total sales of the composite firms within the industry. By design, the Herfindahl index ranges from 0 to 1 and is an indicator of competitiveness in an industry. A higher Herfindahl index (closer to 1) generally indicates less competition and a higher market power in the industry (monopoly or oligopoly).

Category 2: Importance/Impact of events

CAR_Event	Cumulative abnormal returns (CARs) over event window (-1, +1) of the event firms. This is a measure of the impact of supply chain disruption announcements. More negative CAR_Event indicates more negative stock market responses to the news, and therefore more detrimental value to the event firms.
Neg_CAR	A dummy variable which is equal to 1 when the CAR during the event window (-1, +1) for the event firm is negative, and 0 otherwise. A measure of supply chain disruption impact.
Number of Hits	Number of hits for the news event. We take log for this variable as it is skewed. A measure of supply chain disruption impact.
Hits_Neg_CAR	Interaction term. It is equal to log(Number of Hits) x Neg_CAR. A measure of supply chain disruption impact.

Category 3: Firm characteristics of event firms

Sales_Event	Sales of the event firms, i.e., annual sales of the event firm from Compustat measured at the fiscal year-end prior to the announcement date. We take the log of this variable as it exhibits significant skewness. A measure of supply chain disruption impact as annual sales is a proxy for firm size. The larger the annual sales of the event firms usually indicates a bigger impact of the disruption announcements.
MB_Event	Market-to-book ratio of the event firm. We follow Goldman, Peyer and Setfanescu (2012) and measure market-to-book ratio as the sum of total debt and market value of equity divided by book value of total assets. A proxy for the opacity of the firm: the higher the market-to-book ratio (i.e., the firm has more growth opportunity), the more uncertain the firm valuation.
STDRET_Event	The standard deviation of monthly returns of the event firm measured in the year prior to the announcement date. A proxy for company's riskiness and serves as a second measure for opacity of the firm (i.e., higher volatility of stock returns indicate more difficult to value the firm's assets)

Category 4: Firm characteristics of competitor/supplier/customer firms

MB	Market-to-book ratio of the competitor/supplier/customer firm. We follow Goldman, Peyer and Setfanescu (2012) and measure market-to-book ratio as the sum of total debt and market value of equity divided by book value of total assets. A proxy for the opacity of the firm: the higher the market-to-book ratio (i.e., the firm has more growth opportunity), the more uncertain the firm valuation.
STDRET	The standard deviation of monthly returns of the competitor/supplier/customer firm measured in the year prior to the announcement date. A proxy for company's riskiness and serves as a second measure for opacity of the firm (i.e., higher volatility of stock returns indicate more difficult to value the firm's assets)
Sales	Sales of the competitor/supplier/customer firms, i.e., annual sales of the competitor/supplier/customer firm from Compustat measured at the fiscal year-end prior to the announcement date. We take the log of this variable as it exhibits significant skewness. A proxy for the firm size of the competitor/supplier/customer company.
Debt	Measured as long-term debt divided by the book value of total assets for the fiscal year end prior to the announcement date for the competitor/supplier/customer firm. A measure of financial leverage ratio.

Appendix 3: Example of matching event company, customers and suppliers

As an example: “Auto-Parts Makers See Shares Tumble”, Dow Jones Newswire and The Wall Street Journal, 05 June 2002. The article indicated that because of inaccurate forecasts, auto parts makers could be saddled with excess inventory and idle factories. Several auto parts makers' stock prices fell sharply: for example, Johnson Controls Inc. shares dropped more than 4% on that day.
In this example, June 5th, 2002, the announcement date of this news is defined as the event day (t=0). Johnson Controls Inc. is the affected company (event company). In order to research on how this announcement on Johnson Controls has on its competitor, customers and suppliers, we did the following steps:

First, we searched Center for Research in Securities Prices (CRSP) for its identification so that stock return data can be retrieved to calculate the abnormal returns surrounding the announcement dates. CRSP has several identifications including permanent identification number (PERMNO) 45356, ticker symbol JCI, and CUSIP number G5150210.

Second, to find Johnson Controls’ customers, we retrieve the customer data from Compustat segment files. Compustat data uses a slightly different set of identifying variables for companies: e.g., CUSIP, GVKEY (006268 for Johnson Controls), or ticker symbol. Therefore, to find the customer data for Johnson Controls, we need to match the CUSIP or ticker symbol of the company as PERMNO is unique to CRSP data and is not available for Compustat data. The customer data shows that Johnson Controls reports 7 customers, which are Toyota, Volkswagen, 3 customers, Ford, Nissan, Daimler Chrysler and General Motors. Of these customers, “3 customers” are considered as invalid data. Then we manually search the CRSP data with these customer names and remove Volkswagen as we can only retrieve their stock return data and financial data for publicly traded companies and Volkswagen is not publicly traded in US stock exchanges. We then record the identifications for the rest 5 customers for Johnson Controls.

One thing that is worth noting is that a big proportion of companies do not report their customer names, or if they do, they choose not to reveal their customer names. For example, General Motors only

report their geographic market segments in the data (e.g., North America, Asia). Amgen Inc. lists their customers fields as “Not reported” or “x customers”, which made the customer data not usable. This brings up the issue of data limitation for our customers in the sample.

Third, we then then invert the database to identify suppliers. We include in our supplier sample all firms listing as a customer in any of the five fiscal years prior to the disruption announcements. In this example, Johnson Controls will be one of the suppliers of Toyota, Ford, Nissan, Daimler Chrysler and General Motors. Because we only search the customers for event firms which reported supply chain disruptions in our sample period rather than the entire list of customer names in the customer database, there is big data limitation on supplier data as well.

Table 1: Summary of theory implications

Variable	Competitors		Customers		Suppliers	
	Industry comp.	Info. Spillover	Industry comp.	Info. Spillover	Industry comp.	Info. Spillover
Category 1: Industry competition						
Herfindahl	+	-	0	- or 0	0	- or 0
Category 2: Importance of event						
CAR_Event	-	+	0	+ or 0	0	+ or 0
Neg_CAR	+	-	0	- or 0	0	- or 0
Number of Hits	+	-	0	- or 0	0	- or 0
Hits_Neg_CAR	+	-	0	- or 0	0	- or 0
Category 3: Firm characteristics of event firms						
Sales_Event	+	-	0	- or 0	0	- or 0
MB_Event	0	+	0	+ or 0	0	+ or 0
STDRET_Event	0	+	0	+	0	+
Category 4: Firm characteristics of competitor/customer/supplier firms						
MB	0	-	0	-	0	-
STDRET	0	+ or -	0	+ or -	0	+ or -
Sales	0	+	0	+	0	+
Debt	0	-	0	-	0	-

+ - indicates anticipated positive share price effect
0 – indicates anticipated neutral share price effect
- – indicates anticipated negative share price effect

Table 2: Sample description of different disruption types

	Market Segment						
Type of disruptions	Manufacturing	Trans., comm., electric, gas & sanitary services	Wholesale & retail trade	Finance, insurance, & real estate	Services	Other*	Total
Catastrophe	64	13	11	6	2	7	103
Demand	121	15	23	8	6	16	189
Infrastructure	48	24	6	5	3	3	89
Supply	573	32	44	7	13	4	673
Total	806	84	84	26	24	30	1054

*: "Other" market segment includes Agriculture, Forestry & Fishing, Mining, Construction, and Public Administration.

Table 3: Sample descriptive statistics for the event, competitor, customer and supplier sample

Variable	Number of firms	Mean	Standard Deviation	Percentile min	25	50	75	max
Event sample	1,054							
Market capitalization ($ billions)		59.5	72.9	0.0	9.5	31.0	78.3	504.2
Herfindahl Index		0.24	0.19	0.02	0.14	0.16	0.30	0.95
Sales ($ billions)		76.2	85.8	0.0	8.4	39.2	152.4	458.4
Market to book ratio		2.12	1.99	0.80	1.10	1.40	2.30	24.00
Debt ratio		0.21	0.15	0.00	0.11	0.20	0.28	1.02
Competitor sample	22,829							
Number of competitors per event		47	71	2	12	20	39	498
Market capitalization ($ billions)		2.7	4.9	0.0	0.6	1.3	2.6	44.7
Herfindahl Index		0.24	0.19	0.02	0.14	0.16	0.30	0.95
Sales ($ billions)		2.4	3.5	0.0	0.6	1.4	2.6	24.8
Market to book ratio		2.06	1.19	0.64	1.36	1.74	2.25	13.58
Debt ratio		0.16	0.09	0.00	0.10	0.14	0.19	0.60
Customer sample	86							
Number of customers per event		1.37	0.87	1	1	1	1	5
Market capitalization ($ billions)		56.4	87.2	0.0	5.1	16.0	80.1	504.2
Herfindahl Index		0.39	0.23	0.05	0.21	0.32	0.59	0.98
Sales ($ billions)		74.7	109.9	0.0	11.9	36.9	66.2	406.1
Market to book ratio		1.98	1.13	0.76	1.27	1.67	2.33	6.50
Debt ratio		0.17	0.12	0.00	0.07	0.14	0.23	0.67
Supplier sample	210							
Number of suppliers per event		1.82	1.28	1	1	1	2	8

Market capitalization ($ billions)	14.7	31.8	0.0	1.2	2.5	11.7	170.3
Herfindahl Index	0.42	0.19	0.07	0.23	0.46	0.59	0.81
Sales ($ billions)	8.3	6.6	0.1	2.5	6.6	11.6	28.3
Market to book ratio	1.56	0.69	0.90	1.15	1.27	1.58	4.26
Debt ratio	0.25	0.14	0.00	0.14	0.30	0.33	0.52

Table 4: Event study results for different samples surrounding the announcement date

	Event window				
	(-5, -2)	(-1, 0)	(1, 5)	(-5, +5)	(-1, +1)
Event sample (N = 1,054)					
CARs (%)	-0.49	-1.01	0.01	-1.49	-1.08
t-stat	(-2.70***)	(-5.32***)	(0.03)	(-3.94***)	(-4.58***)
Competitor sample (N = 22,829)					
CARs (%)	-0.09	-0.36	0.06	-0.39	-0.24
t-stat	(-1.66*)	(-8.35***)	(0.96)	(-4.31***)	(-4.77***)
Customer sample (N = 86)					
CARs (%)	0.78	0.00	-0.79	-0.02	-0.16
t-stat	(1.22)	(-0.01)	(-1.30)	(-0.02)	(-0.42)
Supplier sample (N = 210)					
CARs (%)	0.00	-0.03	0.08	0.04	0.40
t-stat	(0.00)	(-0.11)	(0.14)	(0.07)	(1.07)

***, **, * indicate statistical significance at 0.01, 0.05 and 0.10 level, respectively.

Table 5: Cumulative abnormal return (CAR) of event window (-1, +1)

	Event Sample	Competitor Sample	Customer Sample	Supplier Sample
Catastrophe				
N	103	5,182	5	10
CARs (%)	-0.21	-0.98	2.75	1.82
t-stat	(-0.48)	(-9.65***)	(1.47)	(1.02)
Demand				
N	189	4,243	22	35
CARs (%)	-1.88	0.18	-0.35	0.46
t-stat	(-2.76***)	(1.52)	(-0.53)	(0.29)
Infrastructure				
N	89	1,583	2	7
CARs (%)	-1.38	-0.27	-1.78	3.33
t-stat	(-2.36**)	(-2.58***)	(-3.26***)	(1.44)
Supply				
N	673	11,821	57	159
CARs (%)	-0.97	-0.06	-0.31	0.24
t-stat	(-3.22***)	(-0.88)	(-0.63)	(0.72)

***, **, * indicate statistical significance at 0.01, 0.05 and 0.10 level, respectively.

Table 6: Regression results for the competitor sample

Dependent variable	CAR Competitor (-1, +1)				
	(1)	(2)	(3)	(4)	(5)
Category 1: Industry competition					
Herfindahl_Event	-0.691	-0.891	-0.929	-0.752	-0.799
	(-1.50)	(-1.94*)	(-2.02**)	(-1.63)	(-1.72*)
Category 2: Importance of event					
CAR_Event	0.045		0.031	0.045	0.043
	(8.39***)		(5.31***)	(8.38***)	(7.93***)
Neg_CAR		-0.936			
		(-8.88***)			
Number of Hits			0.063		
			(3.91***)		
Hits_Neg_CAR			-0.059		
			(-6.81***)		
Category 3: Firm characteristics of event firms					
Sales_Event	-0.087	-0.064	-0.094	-0.079	-0.072
	(-3.35***)	(-2.52**)	(-3.58***)	(-2.95***)	(-2.49**)
MB_Event				0.036	
				(1.60)	
STDRET_Event					0.338
					(0.52)
Category 4: Firm characteristics of competitor firms					
MB_Competitor				-0.055	
				(-3.27***)	
STDRET_Competitor					1.355
					(3.45***)
Sales_Competitor	0.016	0.017	0.013	0.001	0.043
	(0.76)	(0.79)	(0.61)	(0.07)	(1.87*)
Debt_Competitor	-0.340	-0.520	-0.488	-0.447	-0.544
	(-2.12**)	(-2.14**)	(-1.99**)	(-1.82*)	(-2.22**)

***, **, * indicate statistical significance at 0.01, 0.05 and 0.10 level, respectively.

Table 7: Regression results for the customer sample

Dependent variable	CAR Customer (-1, +1)				
	(1)	(2)	(3)	(4)	(5)
Category 1: Industry competition					
Herfindahl_Customer	-3.201	-3.189	-3.081	-3.481	-3.494
	(-1.69*)	(-1.66)	(-1.63)	(-1.80*)	(-1.83*)
Category 2: Importance of event					
CAR_Event	-0.010			-0.012	-0.008
	(-0.38)			(-0.42)	(-0.32)
Neg_CAR		0.076			
		(0.10)			
Number of Hits			-0.099		
			(-0.84)		
Category 3: Firm characteristics of event firms					
Sales_Event	0.171	0.130	0.122	0.175	0.313
	(0.70)	(0.60)	(0.57)	(0.71)	(1.20)
MB_Event				-0.195	
				(-0.78)	
STDRET_Event					5.800
					(1.37)
Category 4: Firm characteristics of Customer firms					
MB_Customer				-0.312	
				(-0.74)	
STDRET_Customer					-15.866
					(-2.15**)
Sales_Customer	0.425	0.449	0.410	0.436	0.217
	(1.78*)	(1.94*)	(1.77*)	(1.79*)	(0.85)
Debt_Customer	-1.924	-2.248	-2.921	-3.655	0.618
	(-0.60)	(-0.72)	(-0.92)	(-0.98)	(0.17)

***, **, * indicate statistical significance at 0.01, 0.05 and 0.10 level, respectively.

Table 8: Regression results for the supplier sample

Dependent variable	CAR Supplier (-1, +1)				
	(1)	(2)	(3)	(4)	(5)
Category 1: Industry competition					
Herfindahl_Supplier	0.407	0.403	0.451	0.841	0.928
	(0.27)	(0.27)	(0.30)	(0.55)	(0.60)
Category 2: Importance of event					
CAR_Event	-0.037			-0.012	-0.014
	(-0.38)			(-0.12)	(-0.14)
Neg_CAR		-0.042			
		(-0.05)			
Number of Hits			-0.205		
			(-1.62)		
Category 3: Firm characteristics of event firms					
Sales_Event	-0.130	-0.110	-0.216	-0.058	-0.180
	(-0.28)	(-0.24)	(-0.46)	(-0.12)	(-0.38)
MB_Event				0.628	
				(1.26)	
STDRET_Event					-2.440
					(-0.32)
Category 4: Firm characteristics of Supplier firms					
MB_Supplier				0.013	
				(0.03)	
STDRET_Supplier					10.988
					(1.57)
Sales_Supplier	-0.485	-0.481	-0.421	-0.446	-0.263
	(-1.39)	(-1.38)	(-1.19)	(-1.24)	(0.70)
Debt_Supplier	0.033	0.019	0.290	1.007	-1.985
	(0.01)	(0.01)	(0.13)	(0.42)	(-0.76)

***, **, * indicate statistical significance at 0.01, 0.05 and 0.10 level, respectively.

Table 9: Robustness tests

	Competitor		Customer		Supplier	
	Control for fixed effect of disruption type	CAR (-5, +5) as dependent variable	Control for fixed effect of disruption type	CAR (-5, +5) as dependent variable	Control for fixed effect of disruption type	CAR (-5, +5) as dependent variable
Category 1: Industry competition						
Herfindahl_Event	-1.218	-2.071	-2.768	-0.128	0.732	0.912
	(-2.60**)	(-2.42**)	(-1.37)	(-0.03)	(0.47)	(0.33)
Category 2: Importance of event						
CAR_Event	0.045	0.046	-0.018	0.037	-0.017	-0.038
	(8.37***)	(8.29***)	(-0.61)	(0.81)	(-0.17)	(-0.33)
Category 3: Firm characteristics of event firms						
Sales_Event	-0.063	0.062	0.183	-0.840	0.108	-0.310
	(-2.29**)	(1.24)	(0.70)	(-1.38)	(0.21)	(-0.34)
MB_Event	0.022	0.326	-0.177	0.264	0.613	1.274
	(0.94)	(7.70***)	(-0.70)	(0.45)	(1.21)	(1.45)
Category 4: Firm characteristics of rival (customer, supplier) firms						
MB	-0.057	-0.025	-0.174	-1.611	0.066	-1.269
	(-3.35***)	(-0.80)	(-0.39)	(-1.57)	(0.14)	(-1.50)
Sales	-0.013	0.049	0.344	0.510	-0.495	0.467
	(-0.59)	(1.20)	(1.34)	(0.87)	(-1.34)	(0.72)
Debt	-0.301	-0.779	-2.435	-11.832	0.664	-1.436
	(-1.22)	(-1.74*)	(-0.61)	(-1.31)	(0.28)	(-0.34)

***, **, * indicate statistical significance at 0.01, 0.05 and 0.10 level, respectively.

Table 10: Event study results for different samples: 2016 data

	Event window				
	(-5, -2)	(-1, 0)	(1, 5)	(-5, +5)	(-1, +1)
Event sample (N = 224)					
CARs (%)	-0.51	-0.30	-0.42	-1.26	-0.55
z-stat	(-1.31)	(-2.05**)	(-1.21)	(-2.68***)	(-2.39***)
Random competitor sample (N = 524)					
CARs (%)	-0.07	0.16	0.07	0.19	0.18
z-stat	(-0.36)	(0.93)	(1.33)	(1.10)	(0.96)
Customer sample (N = 66)					
CARs (%)	0.14	0.06	-0.83	-0.70	0.04
z-stat	(0.60)	(0.23)	(-1.89**)	(-1.03)	(0.12)
Supplier sample (N = 54)					
CARs (%)	-0.08	-0.38	-0.19	-0.59	0.10
z-stat	(-0.85)	(-0.99)	(-0.22)	(-1.03)	(0.36)

***, **, * indicate statistical significance at 0.01, 0.05 and 0.10 level, respectively.