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The impact of supply chain disruptions on stockholder wealth in India

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Abstract

Purpose – Supply chain structure, characteristics, and applicable policies differ between developing and developed countries. While most supply chain management research is directed toward supply chains in developed countries, the authors wish to explore the financial impact of disruptions on supply chains in a developing country. The purpose of this paper is to highlight the importance of effective supply chain management practices that could help avoid or mitigate disruptions in Indian companies. The authors study the stock market impact of supply chain disruptions in Indian companies. The authors also aim to understand the difference in financial implications from disruptions between companies in India and the USA.

Design/methodology/approach – Event study methodology is applied on supply chain disruptions data from Indian companies. The data are compiled from public news release in Indian press. A data set of 301 disruptions for a ten-year period from 2003-2012 is analyzed. Stock valuation of a company is used to assess the financial impact.

Findings – The results show that Indian companies on average lose −2.88 percent of shareholder wealth in an 11-day window covering the event day and five days pre- and post-disruption announcement. A significant stock decline was observed as early as three days prior to announcement, indicating possibility of insider trading and information differentials between investors. Irrespective of the location and responsibility of a disruption, companies experience significant negative returns. Company size, book-to-market ratio, and debt-to-equity ratio were found to be insignificant in affecting the stock market reactions to disruptions. The authors also compiled supply chain disruptions data for US companies. When compared to the US companies, Indian companies register a significantly higher stock decline in the event of a disruption.

Research limitations/implications – Supply chain disruptions data from India and the USA are analyzed. Broad applicability of results across countries may require studying other developing countries. The research demonstrates potential effectiveness of investment in supply chain management initiatives. It also motivates research focussed specifically on supply chains in developing countries.

Practical implications – Supply chain decision makers in India could benefit from investment in disruptions management and mitigation practices. The results provide a valuation of effective supply chain management. The findings provide guidance for investors in making decisions when supply chains face disruptions.

Originality/value – The paper studies the financial consequences of supply chain disruptions in a developing country. The study is valuable because of increasing globalization, outsourcing, and the economic role of developing countries.

Keywords India, Risk management, Stock market, Supply chain disruptions management

Paper type Research paper

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Introduction

Success in today's competitive business environment requires efficient, reliable, and responsive management of resources to match supply with demand. It is well documented that supply chain disruptions could affect a company's ability to efficiently deliver the right product at the right time and in the right quantity. Research community has realized the potential for managing and mitigating disruptions. A significant amount of research has been devoted to addressing various aspects of disruptions. The issues addressed include strategic, tactical, and operational. See Ellis *et al.* (2011) for a thorough literature review.

Despite extensive research efforts, the extant quantitative literature on disruptions management is almost entirely focussed on supply chains in developed economies. Supply chains differ between developed and developing economies (Sahay and Mohan, 2003; Sahay *et al.*, 2006b; Zhao *et al.*, 2006, 2007). The suitability of a disruption management practice or strategy may depend on supply chain characteristics, which could vary based on economic and other country specific factors. Therefore, research efforts directed toward managing disruptions in developing economies could be valuable. Besides, in today's global marketplace, supply chains and markets span across countries, and the effects of disruptions could cascade between countries and continents. The Japanese Tsunami of 2011 disrupted supply chains across the world. Efficient operations require understanding and managing all echelons of a supply chain, some of which could be located in other countries. This research is an effort toward unraveling the importance of studying and managing disruptions in developing economies.

We focus on understanding the financial impact of supply chain disruptions in Indian companies. Owing to an open market economy, rapid economic development, democratic government, and differences from the western culture and supply chains, India provides a good opportunity to study the importance of effective supply chain management practices in a developing economy. In this paper we consider an "effective" supply chain practice to help avoid and/or mitigate disruptions. Such practices could create value in supply chains by making them reliable and responsive during disruptions. India represents an economy with a significant global trade and impact on global supply chains. We use stock market reactions following a supply chain disruption as a proxy for financial impact of disruptions. Stock market valuation of a company represents the current and future profitability potentials. According to efficient market hypothesis, financial markets are efficient in adjusting to a value-relevant information. Impact on stock returns should provide a fair valuation of financial impact of supply chain disruptions.

Our research builds on Hendricks and Singhal's (2003) work on understanding the impact of supply chain "glitches" on stock market performance. They underlined the importance of effective supply chain management by revealing the financial impact that follows a glitch in supply chain operations. Their analysis was entirely based on supply chain disruptions in companies that are traded in the US stock markets. We, however, focus on companies in India. The underpinning of our work is that learning and theories applicable to supply chains in developed economies may not be directly applicable to supply chains in less developed economies (Zhao *et al.*, 2006).

Besides the difference in supply chain characteristics between India and western developed countries, cultural and informational aspects may affect disruptions' outcome. National culture affects operational decision making in business organizations (Pagell *et al.*, 2005). Cultural orientation is particularly important when

making supply chain disruptions decisions (Dowty and Wallace, 2010). Dimensions of national culture as defined by Hofstede differ between India and western developed countries (Hofstede *et al.*, 2010).

Stock markets in developing economies such as India are not mature and often demonstrate high volatility (Aggarwal *et al.*, 1999). Moreover, for some investors, information needed to make efficient supply chain and investment decisions may not be easily available. Existence of information differentials between various investors could affect the stock price outcome of disruptions.

Our analysis indicates that supply chain disruptions in India cause a significant negative decline in the stock returns of publicly traded companies. A parametric test shows that in an 11-day event window of (−5,+5) (five days pre- and post-disruption announcement and the day of announcement), companies on average lose −2.88 percent of stockholder equity. Non-parametric tests support the stock decline as the number of companies experiencing negative stock reactions is significantly higher than the rest. Significant stock declines are experienced as much as three days before the announcement. Most stock decline is observed in the pre-announcement period. This indicates that information leakazge may be prevalent and company insiders may have influence on stock markets. Irrespective of the responsibility and location of a disruption, companies face significant negative stock returns. Factors such as company size, book-to-market ratio, and debt-to-equity ratio did not seem to affect the stock returns.

To contrast between developing and developed economies, we compare the stock market consequences from disruptions between India and the USA. Our results show that, overall in the window (−5,+5), companies in India experience a statistically significant higher negative stock outcome as compared to the US companies. We further analyze the impact of disruptions in a two-day window of (−1,0), which covers the day before and the day of announcement. Unlike India, for the USA most negative consequences of disruptions are limited to this duration. Qualitatively Indian companies experience higher stock declines than the US companies in the window (−1,0). However, the difference is not statistically significant for this window.

The findings of this study have implications for supply chain practitioners, investors, and research community. Supply chain improvements that help avoid or manage disruptions are likely to yield dividends for Indian companies. Managers of Indian companies should plan for disruptions. Globalization and open markets allow investment in stock markets across countries. Therefore, investors across the world could also be interested in our results. Specifically, investors could benefit as our results provide guidance on actions that could help make sound sell or buy decisions in the event of a disruption.

The rest of the paper is organized as follows. We start with a review of the literature. We then present the research questions and theoretical basis for studying supply chains in developing countries. We outline our research methodology. Following presentation of results, we discuss the implications of this research.

Literature review

There is a rich stream of literature related to management of supply chain disruptions. The literature permeates to several academic research areas. See Ellis *et al.* (2011) and Craighead *et al.* (2007) for a comprehensive literature review. Also see Kern *et al.* (2012) for a study relating risk management to risk performance. Our research falls in the domain of estimating the value of effective supply chain management or measuring the financial consequences when supply chains experience disruptions. Within this domain, we focus on an emerging economy, India.

Despite rich literature in supply chain management domain, financial and economic indicators to measure the effectiveness of supply chain strategies are rare. Most research relating supply chain effectiveness to improved financial performance is conceptual and/or based on case studies (Chopra and Meindl, 2012). Using information from company press releases, Filbeck *et al.* (2005) demonstrate that the adoption of supply chain management-enhancement tools results in a positive share price reaction. Specific supply chain practices such as just-in-time inventory (Fullerton *et al.*, 2003), responsive inventory management (Roumiantsev and Netessine, 2007), and inventory turnover (Thomas and Zhang, 2002; Chen *et al.*, 2005) have been shown to improve stock performance of a company.

Another stream of research has taken an indirect approach to show the financial benefits of effective supply chain management. This research stream studies the impact of supply chain disruptions on stockholder value. The argument is that by estimating the stockholder value diminished because of a disruption, one could assess the value of effective supply chain management. Using event study methodology, Hendricks and Singhal (2003) study the effect of supply chain glitches on shareholder wealth. Their results show a marked decrease in shareholder value following announcement of an event. They also reveal insights such as larger firms experience less negative impact, and firms with higher growth prospects experience a more negative stock price impact.

Hendricks and Singhal (2005a) found that in the long term (one year pre- and post-glitches period) the stock reaction to disruptions is nearly −40 percent. Over the long term, the equity risk is higher by 13.5 percent in the year following the disruption. Hendricks and Singhal (2005b) compare the performance of companies that announced disruptions to other companies (who did not announce a disruption in the event period) and make inferences about operating income, return on assets, return on sales, inventory growth, and sales growth. Companies announcing disruptions were found to experience inferior performance on all these measures.

Filbeck *et al.* (2013) explore the impact of market cycle and company domicile on stock performance. Using a data set of automobile companies in the USA they show that stock impact from disruptions is dependent on the market cycles, with bear cycles resulting in a more negative outcome as compared to bull market cycles. Japanese companies (that are traded in the US stock market) demonstrate a more robust performance as compared to American automobile companies. Filbeck *et al.* (2014) explore contagion across competitors in the event of a supply chain disruption. Competitors are found to experience negative stock reactions indicating that negative stock consequences of disruptions are not limited to the companies affected but also cause losses for competitors.

All papers discussed until now in this literature review focus exclusively on companies and supply chains in the USA. Economic and market conditions affect the applicability of supply chain practices. Practices and policies deemed effective in developed countries may not be applicable in supply chains of developing economies. Zhao *et al.* (2006, 2007) call for research efforts to be directed specifically toward supply chains in developing countries. They use China as an example and cite economic, governmental, and cultural differences as motivations for research focussed on China. They also outline the difference in supply chains between China and those in the developed western countries. Similarly, Sahay and Mohan (2003) and Sahay *et al.* (2006a) outline supply chain characteristics in India. Jayaram and Avittathur (2012) outline the challenges that western companies may face in operating under supply chain structures prevalent in India. They also motivate the need for research specifically focussed on these countries.

Research questions and theoretical foundation

Competitive pressure, market saturation, and customer focus has led to numerous supply chain advancements in developed economies of many western countries. Some of these advancements include mass customization, delayed differentiation, cross-docking, collaborative planning and forecasting, RFID and tracking, and supply chain integration. These and other popular practices have proven benefits and are widely used by companies.

In contrast to western developed economies, business landscape is different in developing economies. Business practices that are a norm in western countries are not viable or applicable in developing countries. For example, lean inventory management and JIT practices require supporting logistics and utilities infrastructure that may not be available in developing countries. India ranks 86 out of a total of 142 countries in terms of overall infrastructure (Schwab, 2013). Shipments that take three days in the USA, could take nine days in India. Ships may have to wait five days before docking on Indian ports. In comparison, most European ports have little or no wait times (Jayaram and Avittathur, 2012). Besides, customer need for variety, preference for quality vs cost, and awareness of possible options differ between developed and developing economies. In India, low cost is the most prevalent business practice (Sahay *et al.*, 2006b). This results in supply chains catering to low customization and a highly standardized product. For example, Korean companies such as LG and Samsung offer modified product in Indian market. These products have been designed to reduce the purchase and operating costs (Jayaram and Avittathur, 2012). Supply chain management challenges posed in developing economies could be different from developed economies. Our research is intended to show the value of supply chain improvement in Indian companies.

Disruptions cause negative financial losses in US supply chains (Hendricks and Singhal, 2003; Filbeck *et al.*, 2013). However, several factors indicate that supply chain vulnerability and stock market financial reactions to disruptions may be different for Indian companies. Some of these factors include the following:

(1) Supply chains in developing economies are structurally different. For example, efficiency inducing practices such as inventory tracking, cross-docking, TQM, JIT, and lean practices are much less prevalent in Indian supply chains when compared to those in developed countries. Push-based supply chains are a norm (Sahay and Mohan, 2003). Push-based supply chain practices are attributed to have an effect on a supply chain's vulnerability to disruptions (Snyder and Shen, 2006).

(2) Indian supply chains are relatively inefficient with production and inventory slack commonplace. In Indian companies, operating efficiency of plants and equipment is lower while supply chain inventory is significantly higher than the US supply chains (Sahay and Mohan, 2003; Jayaram and Avittathur, 2012). At the same time redundancy in resources, such as power backups, are commonplace. Operating slack and resource redundancy or backups could help in managing disruptions (Stecke and Kumar, 2009).

When compared to western countries, India's market logistics is relatively inefficient. Logistics cost as a percentage of GDP is 13 percent for India, while it is under 10 percent for most western countries. For the USA, it is about 8.5 percent. A World Bank survey ranks India's logistics performance at 54 out of 160 countries ranked. The USA is ranked at 9 (Arvis *et al.*, 2014). Logistics infrastructure in India is ranked at 58th position. Logistics infrastructure affects various logistics functions including tracking, tracing, and timeliness of shipments. In all these

dimensions, India ranks past 50. The USA ranks second in tracking and tracing and 14th in timeliness.

(3) Supplier base and retail channels are highly fragmented in India. Small stores dominate India's retail sector. The wholesale and distribution networks are "disastrously inefficient" (Harris, 2012). Instead of regional or national warehouses, Indian companies often establish warehouse operations in different states. Typical Indian warehouses owned by multinational companies are small (between 5,000 and 25,000 square foot). In comparison, most warehouses in the USA or Western Europe are 250,000-1-million square foot in size (Pagadala and Mulaik, 2009). Information such as Point of Sale data are rarely available. These factors may make it difficult for companies to share information and collaborate to improve supply chain performance. Information is critical in planning and mitigating supply chain disruptions (Stecke and Kumar, 2009).

(4) In the USA, supply chain disruptive events such as worker strike, power outages, and delayed shipments are relatively rare. In contrast, such events are not uncommon in Indian companies. India ranks 112 (out of 144 countries ranked) in electrical power infrastructure and supply (Schwab, 2013). By year 2020, underdeveloped port and road infrastructure in India could lead to $140 billion annual losses in waste and delayed shipments (Lakshmi, 2011).

Events that often cause supply chain disruptions differ across counties. For example, high frequency supply chain risks in India are civil unrest and terrorism, while in the USA hurricanes are a primary risk. On a 16-point scale, India and the USA receive a supply chain risk index of 9 and 4, respectively (Arntzen, 2010a). Despite higher risk only 30 percent of Indian companies have active risk management programs. In comparison, over 44 percent of companies in the USA have such programs (Arntzen, 2010b).

(5) Attributes of national culture affect many aspects of business decisions (Hofstede *et al.*, 2010). Western companies are sometimes focussed on short-term returns, while in many Asian companies decisions are motivated by long-term effects. Many Asian companies have lifetime employment, consensual decision making, and collective responsibility (deKoster and Shinohara, 2006). Difference in business strategies related to international expansion, low cost vs differentiation, and compensation schemes could be explained using dimensions of national culture (Pagell *et al.*, 2005). National culture also interacts with disruptions preparedness and response (Kumar *et al.*, 2015). Dowty and Wallace (2010) use cultural biases between countries to characterize interaction among organizations during humanitarian supply chain disasters. Indian national culture is different from most western countries. Like some other business decisions, supply chain disruptions could be handled differently in Indian companies. When compared to the USA, supply chain risk management decisions in India are more inclined toward prevention rather than response (Arntzen, 2010c). Dunning and Pearce (1982) and Porter (1990) argue that home country of a company and physical location of facilities and personnel affect business decisions.

National culture also affects financial markets (Aggarwal and Goodell, 2010). Moreover, financial structure of organizations varies based on national culture (Pagell *et al.*, 2005). The investment and hedging strategies differ between countries with different national culture dimensions (Lievenbrueck and Schmid, 2014). Lievenbrueck and Schmid (2014) show that a country's long-term orientation and

masculinity dimensions impact hedging decisions. India has a higher long-term orientation than most western countries (Hofstede *et al.*, 2010). Therefore, stock markets in India may react differently than the developed western countries.

(6) Stock markets in many developing countries are still evolving. Information availability differentials may exist between different sections of investors. Insider trading is prevalent in markets such as India, China, and Russia (Du and Wei, 2004). To align insider trading rules with the global practices, Securities and Exchange Board of India announced a comprehensive review of existing regulations (Zachariah and Vikaraman, 2013). Stock markets in most developing countries exhibit high volatility, unpredictability, and uncertainty (Iyer and Bhaskar, 2002). This may imply that the stock market reactions to supply chain disruptions may be masked by market's inherent volatility. Bhattacharya *et al.* (2000) report that Mexico's stock market does not seem to react to company news. They indicate insider trading to be responsible for incorporating the impact of news on stock valuation before public announcement date. As a result stock markets do not see a significant impact in post-announcement period.

(7) Economic factors affect supply chain disruptions preparedness. Disruptions planning require diverting capital that could be otherwise used for other supply chain initiatives. For companies in developing economies, investment in disruptions mitigation planning may not have a high priority (Kumar *et al.*, 2015).

To understand the collective impact of above factors we study the effect of supply chain disruptions announcements on stock valuations of a company. The objective is to help establish the importance of supply chain management in India companies. Another motivation is to study the difference in financial impact of disruptions between developing and developed economies. Specifically we seek to answer the following questions:

(1) Do effective supply chain practices pay dividends in developing economies such as India? What is the potential value of supply chain improvements that could help avoid or mitigate disruptions?

We address this question by identifying the potential negative stock consequences of disruptions. Potential stockholder value lost after a disruption could be an indirect measure of the value of effective supply chain management practices that may help avoid or mitigate disruptions (Hendricks and Singhal, 2003).

(2) Does stock impact from supply chain disruptions differ based on the echelon affected?

(3) Does responsibility of supply chain disruptions factor in stock consequences?

(4) Do company specific factors such as size, debt-to-equity ratio, and book-to-market value influence the stock market impact from disruptions?

(5) How does the financial impact of supply chain disruptions in a developing economy such as India compare to a developed economy such as the USA?

Data and methodology

Description of the disruptions data

India is a democratic country and allows freedom of press and media. Therefore we expect the media outlets to report on important events including company related news

that are of public interest. Our disruptions data are derived from *The Economic Times*, which is headquartered in Mumbai, India. The main content of the newspaper is articles and opinions on Indian economy. The Economic Times is world's second most read English language business newspaper (Auletta, 2012).

To compile disruptions data, full text articles were searched in *The Economic Times* for a ten-year period from January 1, 2003 to December 31, 2012. The keywords searched include supplier breakdown, design issues, production delays, inventory shortfall, poor planning, inaccurate forecast, strike, transportation delay, accidents, data breach, fire, earthquake, and ethical complaints. The keywords were selected to cover disruptions in operations, supply, demand, production, inventory, distribution, or transportation at one or more stages of a supply chain. We read the complete text of the articles to identify a supply chain disruption. Representative news announcements include the following: poor forecasting results in excess inventory for Tata Motors, parts shortage from supplier causes production stoppage at Maruti, and Reliance Industries faces operational issues because of power blackout.

Our initial data included a set of 348 disruption points. In compiling the final data, we dropped companies that are not publically traded. We also removed the disruption data if the company did not have stock information surrounding the date of disruption. The resulting data has 301 disruptions representing 135 companies. The size of our data set is large enough to extract the desired insights and is comparable to many recent studies relating supply chain management to stock performance. For example, Hendricks and Singhal (2009) analyze a set of 276 inventory related disruptions announcements, while Hendricks *et al.* (2007) use a data set of 186 supply chain management implementations to study their impact on stock market. The daily stock information for the companies in our data set was obtained from *Wall Street Journal* (www.wsj.com). A summary of descriptive statistics is presented in Table I. Note that the monetary unit is Indian National Rupee (INR). Table II reports the frequency distribution of disruptions by year. There is no noticeable trend in the disruptions frequency.

Event study methodology

We use standard event study methodology to estimate the financial impact of disruptions. The methodology is designed to investigate the impact of an event on metrics. In our application the event is announcement of a supply chain disruption while the abnormal stock returns are used as the metric to assess the impact of the event. Event study methodology is one of the most frequently used tools in the financial research area and has been traditionally effective in estimating stock price reaction to events such as the announcements of earnings, dividends, or mergers (Peterson, 1989). In a general setting an event study is designed to examine the stock returns for a set of

	Employee	R&D (million INR)	Sale/revenue (million INR)	Share outstanding (million)	Total assets (million INR)	Total liability (million INR)	Total equity (million INR)
Mean	18,606.18	580.69	257,553.76	837.46	295,760.55	184,135.40	111,421.97
Median	5,814.00	0.00	45,757.00	205.00	72,451.00	47,006.00	21,753.00
Max	106,004.00	13,892.00	3,959,570.00	8,555.00	3,654,510.00	1,824,470.00	1,820,550.00
Min	392.00	0.00	87.01	−0.05	1.66	0.58	−50,824.00
SD	25,273.93	1,940.64	624,564.51	1,483.51	557,564.49	341,759.34	238,422.21

Table I. Descriptive statistics for Indian companies in disruptions data

Table II.
Disruptions frequency by year

Year	Count of disruptions
2003	22
2004	22
2005	62
2006	62
2007	11
2008	23
2009	25
2010	11
2011	31
2012	32

companies experiencing a similar event (e.g. a supply chain disruption in our case). The event may occur at different point in time for the set of companies. The stock returns are statistically tested for any abnormal or unexpected returns.

The purpose of most event studies in business and management is to assess the stock reactions from a value-relevant event announcement. Supply chain disruptions could affect the operations and thus the profit potential of a company. Efficient market theory suggests that stock markets are efficient and reflect all available information. At any instant, stock price exhibits expectations about future earnings prospects of a firm. Therefore, information about a value-relevant event such as supply chain disruption is expected to cause movement in stock returns.

Around the announcement/publication date of an event, the actual daily stock returns are compared with expected returns. Conceptually, as applied in this paper, event study helps differentiate between the stock returns that would have been expected if the supply chain disruption would not have happened (normal returns) and the returns that were observed (abnormal returns (AR)). Event study methodology is made rigorous and relevant by calculating expected returns using historical data while adjusting for market wide influence and trends. For more details on event studies see Dodd and Warner (1983), Cowan (1992), and Carrado (2011).

We define the announcement/publication day as event day ($t = 0$). Since the stock markets are closed on weekends and holidays, for announcements made during a non-business day, the event day is the next day when the stock markets are open for business. Sometimes information about a disruption may leak to a set of investors before the public announcement date. Company insiders may also have privileged information. In certain cases, the event that caused the disruption may have happened before the announcement date. For example, public announcement about possible supply chain impact from Japanese Tsunami of 2011 were not immediately known. Investors may speculate about possible impacts and stock markets reactions may happen before public announcements. In other instances, uncertainty about the possible impact of an announcement may delay investor response. The impact of disruptions may occur in the days following an announcement. To cover such scenarios, we test the share price response to the announcements beginning five days prior to the announcement date and covering five days post-announcement.

We calculate expected cumulative abnormal returns (CARs) over an 11-day window (days −5 to +5). A shorter two-day window of (−1,0) is also studied. The 11-day window covers the financial impacts that may happen before the announcement day

because of information leakage, and following the announcement because of delayed reactions by investors. The shorter window of (−1,0) is intended to capture the immediate impact of a disruption.

For robustness and to ensure that the results are not dependent on the choice of an estimation model, we use market returns model and mean returns model. In market returns model, the estimation parameters accommodate the general trend of the market. Mean returns model accounts for the changes in the historical stock price of the affected company. Both models have been effectively used in event study literature. See Brown and Warner (1985) for details of the models. The parameters needed to estimate the AR were calculated using past 255 trading days (about one year) stock price. The estimation period is (–300, –46). We follow Dodd and Warner (1983) and use standard event study methodology.

The market model is specified as:

$$R_{jt} = \alpha_j + \beta_j R_{mt} + u_{jt}, j = 1, ..., N;\ t = -300, ..., -46,$$

where N is the number of disruption points in the sample, R_{jt} the return on stock j for day t, R_{mt} is the return on market proxy m for day t, u_{jt} the random error for stock j for day t and is normally distributed with $E[u_{jt}] = 0$, α_j the estimated intercept term for stock j, and β_j the estimated risk coefficient for stock j. The market model is estimated using the equally-weighted market returns from SENSEX index of the Bombay Stock Exchange. Hendricks and Singhal (2003) use an estimation window of 200 days. Our longer estimation window of 255 days (−300 to −46) is expected to yield better parameter estimates.

We calculate the AR for each day in the test period. In all, 11 days returns were calculated. The period begins five days before the announcement day and ends five days after the announcement day. The market model AR for stock j for day t is defined as:

$$AR_{jt} = R_{jt} - (\alpha_j + \beta_j R_{mt}), j = 1, ..., N;\ t = T_1, T_1 + 1, ..., \text{and } T_2,$$

The mean model AR for stock j for day t is defined as:

$AR_{jt} = R_{jt} - \overline{R_j}$, where $\overline{R_j}$ is stock j's mean return for the estimation period.

For both models, $E[AR_j] = 0$, *i.e.,* no AR is expected in an efficient market in equilibrium. If $E[AR_j] \neq 0$, i.e., ARs are observed, we infer that disruptions cause a change in shareholder wealth. Well-informed investors use the information about an event and accordingly adjust their future earnings expectations from the company's shares.

The CARs for stock j over the event window is $CAR_j = \sum_{k=T_1}^{i} AR_{jk}$. The time-series of CARs tells us whether ARs would have occurred had investors bought the test portfolio in day T_1 and held until day i, $i = T_1, T_1 + 1, \ldots$, and T_2. We follow Patell (1976) to test the statistical significance of ARs, which are based on standardized normal distribution. The standardized abnormal returns (SAR) for stock j in day t, is calculated as $SAR_{j,t} = AR_{j,t}/S_{j,t}$. The AR is divided by the standard error from the market model estimation for stock j. The average standardized abnormal return (ASAR) for day t is $ASAR_t = \frac{1}{N}\sum_{j=1}^{N} SAR_{j,t}$. Finally for each day, the Z-statistic is calculated as $Z_t = \sqrt{N} \times ASAR_t$. The limiting distribution of Z_t is the unit normal, under the null hypothesis that the mean normalized, SAR equals zero. Over the testing period, which begins with T_1 and ends with T_2, the cumulative normalized, ASAR is $CASAR_{T_1,T_2} = \left(\frac{1}{N}\right)\sum_{t=T_1}^{T_2}\sum_{j=1}^{N} SAR_{j,t}/\sqrt{T_2 - T_1 + 1}$. Then, the Z-statistic is

$Z_{T_1,T_2} = \sqrt{N} \times CASAR_{T_1,T_2}$, and has a unit normal limiting distribution under the null hypothesis that the cumulative normalized, average standardized prediction error over the period from T_1 through T_2 equals zero.

We also perform a non-parametric sign test to make inference about the sign (positive or negative) of ARs in the estimation period. Null hypothesis for the test is that there is a 50 percent probability of ARs being positive or negative. A normal approximation to the binomial distribution is used. The test controls for the normal symmetry of positive and negative returns in the estimation periods. See Cowan (1992) for details.

Empirical results

Financial impact of supply chain disruptions in Indian companies

In this section we present the empirical findings of event study on supply chain disruptions in Indian companies. Table III presents the AR around the disruptions announcement date. The table shows that supply chain disruptions cause significant decline in stock returns. Most significant negative AR are observed on or before the announcement day of the disruptions. The mean AR are significant starting from day−3. Day−3 registers a significant drop of −0.50 percent in stockholder's wealth. Significant and additional drops of −0.39, −0.66, and −0.58 percent were observed on days −2, −1, and 0, respectively. Note that the returns are not as statistically significant for post-announcement days. Indian companies experience negative wealth effects from disruptions, however, information leakage may be operational as most negative returns are observed on or pre-disruption announcement dates.

A non-parametric sign statistics is also presented in Table III. A significantly higher number of disruptions result in a negative return (when compared to positive returns). As with the mean statistics, most significant negative sign returns are observed on or before announcement day.

Table IV reports CAR. Panel A covers windows around the announcement day. Companies on average lose −2.88 percent of stockholder wealth in a (−5,+5) day window around the date of a disruption announcement. Other windows around the announcement date also show a significant negative mean AR. The sign statistics support the results.

	Mean statistics		Sign statistics	
Day	Mean abnormal returns (%)	Patell *Z*-statistics	Positive: negative returns	Generalized sign *Z*-test
−5	0.13	0.277	140:143	1.031
−4	−0.27	−1.193	118:163	−1.486****
−3	−0.50	−4.073***	107:171	−2.649**
−2	−0.39	−1.580****	111:171	−2.374**
−1	−0.66	−3.517***	111:170	−2.323*
0	−0.58	−2.156*	113:170	−2.187*
1	0.06	1.322****	136:146	0.611
2	0.09	0.42	117:164	−1.605****
3	−0.30	−1.133	116:166	−1.777*
4	−0.27	−1.345****	130:151	−0.05
5	−0.24	−0.312	135:147	0.491

Table III. Market model event study results: abnormal stock returns for disruptions in Indian companies

Notes: Number of disruptions = 301. *,**,***,****Significant at 0.05, 0.01, 0.001 and 0.10 levels, respectively

Windows	Mean statistics: Mean abnormal returns (%)	Mean statistics: Patell *Z*-statistics	Sign statistics: Positive: negative returns	Sign statistics: Generalized sign *Z*-test
Panel A: CAR around the disruption announcement date				
(−1,+1)	−1.17	−2.509**	118:167	−1.696*
(−2,+2)	−1.47	−2.465**	122:163	−1.221
(−3,+3)	−2.25	−4.038***	106:179	−3.121***
(−4,+4)	−2.78	−4.407***	119:166	−1.577****
(−5,+5)	−2.88	−3.993***	112:174	−2.459**
Panel B: CAR pre-disruption announcement date				
(−5,0)	−2.24	−4.982***	103:182	−3.477***
(−4,0)	−2.37	−5.589***	106:179	−3.121***
(−3,0)	−2.11	−5.652***	99:186	−3.952***
(−2,0)	−1.62	−4.185***	112:172	−2.357**
(−1,0)	−1.24	−4.008***	114:170	−2.119*
Panel C: CAR post-disruption announcement date				
(0,+1)	−0.51	−0.594	120:164	−1.406****
(0,+2)	−0.43	−0.244	125:159	−0.811
(0,+3)	−0.72	−0.778	129:155	−0.335
(0,+4)	−0.99	−1.296****	119:165	−1.525****
(0,+5)	−1.23	−1.310****	123:162	−1.102

Notes: Number of disruptions = 301. *,**,***,****Significant at 0.05, 0.01, 0.001 and 0.10 levels, respectively

Table IV. Market model event study results: cumulative abnormal returns for disruptions in Indian companies

Table IV panels B and C report CARs for days leading up to the disruption announcement and days following the announcement date. Note that significant negative AR are observed only in the pre-disruption windows. Post-disruption windows show no significant returns. The window of (−5,+5) in Panel A displayed a negative mean CAR of −2.88 percent, while the window (−5,0) shows a negative CAR of −2.24 percent. In contrast, no significant returns are observed in post-announcement windows. This result indicates that the markets respond to disruptions, with almost all of the negative returns occurring in the pre-disruptions announcement period. Stock returns also registered significant negative returns on the announcement day.

The event study results presented above uses market model for estimating AR. To ensure that our results are not driven by the choice of model we now present event study result using mean model. The results presented in Table V show a stock decline similar to market model in Table IV. Most stock decline in response to supply chain disruptions occur in the days leading up the announcement. Little AR are observed in the days following the announcement day. Our results are robust in the choice of event study model.

Stock consequences of unpredictable disruptions

Results presented above showed that stock impact of disruptions happen mostly in pre-announcement periods. Insiders and information differentials could be responsible for the drop in stock returns in pre-disruption announcement periods. However, all disruptions cannot be predicted. For example, in events such as accidents or weather disaster, company insiders may not have prior information and the stock decline is not expected before public event announcement date. To understand the stock consequences

Windows	Mean statistics: Mean abnormal returns (%)	Mean statistics: Patell *Z*-statistics	Sign statistics: Positive: negative returns	Sign statistics: Generalized sign *Z*-test
Panel A: CARs around the disruption announcement date				
(−1,+1)	−1.09	−2.147*	127:158	−0.83
(−2,+2)	−1.37	−2.316*	125:160	−1.067
(−3,+3)	−2.02	−3.538***	124:161	−1.186
(−4,+4)	−2.41	−3.555***	124:161	−1.186
(−5,+5)	−2.74	−3.578***	121:165	−1.595****
Panel B: CARs pre-disruption announcement date				
(−5,0)	−1.94	−4.047***	118:167	−1.898*
(−4,0)	−2.05	−4.640***	123:162	−1.305****
(−3,0)	−1.74	−4.509***	116:169	−2.135*
(−2,0)	−1.45	−3.570***	127:157	−0.775
(−1,0)	−1.19	−3.708***	123:161	−1.251
Panel C: CARs post-disruption announcement date				
(0,+1)	−0.47	−0.425	130:154	−0.419
(0,+2)	−0.50	−0.647	135:149	0.176
(0,+3)	−0.84	−1.239	128:156	−0.656
(0,+4)	−0.93	−1.085	131:153	−0.3
(0,+5)	−1.37	−1.668*	132:153	−0.236

Notes: Number of disruptions = 301. *,**,***,****Significant at 0.05, 0.01, 0.001 and 0.10 levels, respectively

Table V.
Mean adjusted model event study results: cumulative abnormal returns for disruptions in Indian companies

of these events we identified 42 such announcements. Examples of such announcements include, flash floods cause delayed delivery of Honda car parts; Japan earthquake: auto output to suffer; and western grid collapse jolts manufacturers. Note that we consider an event date as the disruptions announcement date. For our analysis, we do not consider a natural or accident event as unpredictable if the public announcement date does not coincide with the actual date of event itself. In some cases a company may not know (and thus may not announce) the effects of a natural or accident event well past its actual occurrence date. In such cases the public announcement could be made at a later date.

The event study results for unpredictable disruptions announcements are presented in Table VI. Market model was used to obtain the results. The table reports daily stock returns for an 11-day period starting from five days prior to five days post-announcement date. As expected, no significant abnormal stock returns were observed in the pre-announcement days. The table supports the assertion that company insiders may be responsible for pre-announcement stock decline reported in Tables III, IV, and V. We, however, caution against over emphasis on Table VI as the number of data points is relatively small to make strong conclusive findings.

Analyzing by location of a disruption

A supply chain often consists of multiple echelons. A disruption at an echelon may affect other echelons because of their interconnectedness. We classify the disruptions data into categories based on the primary location of the disruption. We categorize the disruptions location as the announcing company, its customers (downstream), and suppliers (upstream). Table VII reports the findings. Findings suggest that irrespective of a disruption's location, the stock market experiences a significant negative return.

Day	Mean statistics Mean abnormal returns (%)	Patell *Z*-statistics
−5	0.14	0.809
−4	−0.72	−0.991
−3	−0.12	−1.141
−2	−0.46	−0.881
−1	0.42	0.020
0	−0.45	−0.809
1	0.47	0.382
2	0.36	−0.092
3	−0.19	0.235
4	0.04	0.105
5	−0.06	0.387

Notes: Number of disruptions = 42. None of the returns are significant. Returns reported were obtained using market model

Table VI. Daily abnormal stock returns for unpredictable disruptions in Indian companies

Responsibility	Count	Mean statistics Mean abnormal returns (%)	Patell *Z*-statistics	Sign statistics Positive: negative returns	Generalized sign *Z*-test
Company-internal	127	−2.23	−2.061*	60:67	0.104
Customer-downstream	45	−4.47	−2.601**	14:31	−2.122*
Supplier-upstream	54	−4.41	−3.016**	19:35	−1.556****
Other	9	−3.93	−0.512	3:6	−0.919

Notes: Returns reported were obtained using market model. *,**,***,****Significant at 0.05, 0.01, 0.001 and 0.10 levels, respectively

Table VII. Cumulative abnormal returns in event window (−5,+5) for disruptions in Indian companies categorized by location of disruption

In the window of (−5,+5), a company's internal disruptions cause a significant stock decline of −2.23 percent. Disruptions originating from downstream and upstream supply chain result in significant stock declines of −4.47 and −4.41 percent, respectively. Disruptions at any echelon of supply chain are consequential for financial performance of a company. It is interesting to see that qualitatively, disruptions at suppliers and customers lead to higher negative stock impact than the disruptions that happen at the company itself. However, a *t*-test reveals that CARs for the three categories are statistically indifferent.

Analyzing by responsibility of a disruption

Disruptions could be caused by poor planning and operations in a supply chain. They could also be attributed to external factors, which are outside the control of supply chain members. Based on the responsibility of disruptions, we classify disruptions data into two categories. First category, internal, cover disruptions that are attributed to operations and planning of one or more of the supply chain members. The second category, external, include disruptions caused by factors beyond the control of supply chain members. These include nature-related events such as earthquake, flash floods, and Tsunami. The second category also covers disruptions caused by non-nature events such as change in laws and international trade regulations.

Table VIII reports stock impact for categories based on disruptions responsibility. Irrespective of the responsibility, stocks register significant negative returns. Indian companies lose −3.20 percent of stockholder equity when the one or more of supply chain members are responsible for disruptions. External causes that are beyond direct control of supply chain members result in stock impact of −2.18 percent. Although qualitatively internal responsibility disruptions show a higher negative return than the external responsibility events, a *t*-test for difference in means in not significant. Investors punish companies equally, regardless of the cause of disruption.

Effect of company specific factors

We use regression analysis to test the dependence of event study results on factors such as company size, book-to-market ratio, and debt-to-equity ratio. The size of a company may indicate the ability of a company to absorb the potential effects of a disruption. Similarly, book-to-market ratio which may represent the market valuation of a company could indicate the value of a stock from investors' perspective. Debt-to-equity ratio measures the financial leverage of a company and may affect stock volatility in the event of a disruption. Hendricks and Singhal (2003) demonstrated that disruptions consequences for the US supply chains are affected by these factors. We use the following regression model:

$$CAR_{j(-5,+5)} = Intercept + \alpha\, SIZE_j + \beta\, BM_j + \gamma DE_j$$

where, the dependent variable is *CAR* for the window (−5,+5). $SIZE_j$, BM_j, and DE_j represent the size, book-to-market ratio, and debt-to-equity ratio, respectively, for company represented by *j*.

Table IX reports the regression results. In India, company specific factors that we considered do not have a significant impact on stock impact from disruptions. Stock market reactions from disruptions are not affected by company size, book-to-market

Table VIII. Cumulative abnormal returns in event window (−5,+5) for disruptions in Indian companies categorized by the responsibility of disruption

		Mean statistics		Sign statistics	
Responsibility	Count	Mean abnormal returns (%)	Patell *Z*-statistics	Positive: negative returns	Generalized sign *Z*-test
Internal: supply chain	236	−3.20	−4.183***	93:133	−1.629****
External: environmental	142	−2.18	−2.793**	55:87	−1.745*

Notes: Returns reported were obtained using market model. *,**,***,****Significant at 0.05, 0.01, 0.001 and 0.10 levels, respectively

Table IX. Regression results summary

Variable	Parameter estimate	*t*-Value
Intercept	−0.0199	−0.30
Size	−0.0001	−0.20
Book-to-market ratio	0.0002	0.21
Debt-equity ratio	−0.0010	−1.26

Notes: $R^2 = 0.006$. None of the variables are significant

ratio or debt-to-equity ratio. Financial structure, lack of disruptions planning, economic structure, and inherent market volatility could be the responsible factors.

Comparison with the USA

To understand the stock reactions in Indian companies in perspective to those in western countries, we conduct event study on disruptions in the US companies. We collect disruptions data from publications in the *Wall Street Journal*. The search period and keywords used for the US disruptions data are the same as for Indian companies. University of Chicago's Center for Research in Security Prices (CRSP) tape was used to obtain the daily stock prices for disrupted companies. In all, we collected 449 US supply chain disruptions data. Of these we dropped data corresponding to companies that are not publically traded. Another set was dropped because CRSP did not have stock information for relevant period. We ended up with 310 valid and usable disruptions. The parameter estimation and event study procedure outlined in Event study section is used. All efforts were made to ensure that the disruptions data and event study parameters for India and the USA to be similar.

Event study results for the disruptions in the US companies are presented in Table X. In a window of (−5,+5) surrounding the disruption, US companies lose a significant −1.13 percent in stockholder wealth. The impact is also significant in the days closer to the announcement. The negative stock impact is −0.79 in the two-day window. Both returns are significant. The sign test statistics, also shown in Table X corroborates the findings as the number of instances of negative returns is significantly higher than positive returns. For the USA, most significant negative returns were concentrated in the days −1 and 0. We did not find significant impacts on stock impact in days after the announcement or days prior to −1. The results imply that the US investors are quick in reacting to disruptions, with the impact mostly limited to the window (−1,0).

Despite significance, the abnormal stock returns we obtained for disruptions in the US companies are different from a similar study conducted by Hendricks and Singhal (2003). We believe the differences could be attributed to the selection of search terms and subjective judgment while compiling the data. Our search terms are broader than those used by Hendricks and Singhal (2003). Their search terms were mostly focussed on demand and supply "glitches." Besides demand and supply issues, we consider operational issues with the potential to affect supply and demand as disruptions. For example, a weather disaster that disrupts normal operations and has a potential to affect supply or demand is considered a disruption. In contrast, Hendricks and Singhal (2003) focussed on announcements that reported excess inventory, shortages, or production stoppage, which could be considered as the consequence of a supply chain disruption. The AR we found are comparable to various marketing, financial, information technology, and operations related event studies in literature (see Table IV in Hendricks and Singhal, 2003).

Table X. Market model event study results: cumulative abnormal returns for disruptions in the US companies

Windows	Number of valid disruptions	Mean statistics: Mean abnormal return (%)	Mean statistics: Patell *Z*-statistics	Sign statistics: Positive: negative returns	Sign statistics: Generalized sign *Z*-test
(−5,+5)	310	−1.13	−2.922**	130:180	−2.280*
(−1,0)	310	−0.79	−3.167***	131:179	−2.167*

Note: *,**,***,****the significance at 0.10, 0.05, 0.01, 0.001 levels, respectively

We now quantitatively compare the stock impact in the USA and India. A *t*-test for difference in CARs over a window of (−5,+5) for disruptions in Indian companies and the US companies is significant at 5 percent. *t*-Tests summary is shown in Table XI. Detailed tables are not shown for brevity. However, CARs over (−1,0) are not statistically different between the two countries. These results indicate that, overall, in days surrounding a comparable supply chain disruption announcement, Indian companies experience a larger stock decline when compared to companies in the USA. The impact in immediate vicinity of announcement date is qualitatively higher for India (when compared to the USA), however, the difference is statistically insignificant.

Discussion and implications of findings

In developed economies of western countries, competitive pressure has driven supply chains to be efficient, reliable, and responsive. In contrast, supply chains in developing economies have not evolved to the level of western countries. Inefficiency, redundancy, and slack in operations are commonplace. Supply chain disruptions planning and mitigation requires economic resources. Therefore, one could also expect that supply chain mitigation and risk management in developing countries is not at par with the western countries. For example, in India, over one-third of companies have no supply chain strategies (Sahay *et al.*, 2006a). Disruptions may have costly consequences for supply chains. Our results on stock market consequences from supply chain disruptions confirm this. Companies lose −2.88 percent in stockholder wealth in days surrounding disruptions. Overall losses are significantly higher than that experienced by companies in the USA. Supply chains in India have been slow in adopting practices prevalent in the western countries. Our results could provide impetus for improving supply chain and disruptions management practices in India.

Indian stock market is efficient in incorporating the financial impact of disruptions. However, the negative impact is experienced well in advance of the announcement dates. Information leakage to insider traders and lack of disruptions mitigation abilities could explain this phenomenon. Many companies may not have formal risk management initiatives. Therefore investors, especially those that have privileged insider information, react to disruptions thereby lowering the stockholder wealth. Investors could benefit from our results as they have a better assessment of stock consequences from disruptions in India.

India provides rich opportunities for companies and investors. While markets are stagnant in western countries, developing countries provides alternate options. Open economies and globalization of businesses underline the importance of our research. Our results show that companies face negative stock returns irrespective of responsible

Table XI.
Test for difference in mean CARs between India and the USA

Window		India	USA	Difference in mean CARs (India-US)	Test for difference in mean CARs
	Number of disruptions	301	310		
(−5,+5)	Mean CAR	−2.88%	−1.13%	−1.75%	*t*-Test indicates disruptions in Indian companies cause larger decline in CARs. Significant at 5%
(−1,0)	Mean CAR	−1.24%	−0.79%	−0.45%	No significant difference in CARs

supply chain echelon. Companies experience negative returns when disruptions happen at a supplier or customer. With global markets, suppliers, and customers could be located across countries. This may imply that disruptions in Indian companies could potentially affect stock outcome of trading partners in other countries. Japanese Tsunami affected companies across the globe. Although we do not study impact of disruptions across countries, extensions of our work could help provide guidance for international business partners.

Conclusion

Supply chain management in developing economies has not been at par with those in western countries. Economic, cultural, developmental, and customer preference are some of the causes of the differences between supply chains of developing and developed economies. Stock markets of developing countries have been known to have higher variability than those in developed countries. Despite the differences, little research has been focussed on supply chains of developing countries. Globalization and open economies motivate research directed toward supply chains in developing economies.

We study the financial impact of supply chain disruptions in Indian companies. A ten-year period from 2003-2013 was considered. We find that disruptions on average cause a significant drop of −2.88 percent in stockholder wealth in the days around a disruption. In a two-day window that includes the day before and day of announcement, stock drop was found to be −1.24 percent. Stock declines were observed irrespective of the location and responsibility of a disruption. Indian companies could potentially gain by improving supply chain efficiency and performance by investing in disruptions mitigation strategies. Our results are of importance for supply chain decision makers, researchers, and investors.

A comparison of disruptions consequences between India and the US supply chains indicates a significantly higher negative impact on Indian companies. Our research and analysis is primarily focussed on quantitative analysis of stock market impact from disruptions. However, we do not provide conclusive evidence to identify the underlying causes of the difference in stock impact between India and the USA. We motivated the research using differences in supply chain structure, stock market, and national culture. Perhaps extension of our work could focus on establishing a link between these differences and supply chain disruptions.

Despite importance, the countries considered and different types of disruptions limit our results. We analyze disruptions in companies in India and the USA, however, a generalization of results to find difference between developing and developed countries require studying a bigger set of countries. Also, the type and severity of disruptions could provide further insights into the effects of disruptions. Future research in these areas could lead to improved understanding of supply chain disruptions.

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