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Published in:
International Journal of Production Research

DOI:
[10.1080/00207543.2015.1015751](https://doi.org/10.1080/00207543.2015.1015751)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2016

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Zsidisin, G. A., Petkova, B. N., & Dam, L. (2016). Examining the influence of supply chain glitches on shareholder wealth: does the reason matter? *International Journal of Production Research*, 54(1), 69-82. <https://doi.org/10.1080/00207543.2015.1015751>

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Examining the influence of supply chain glitches on shareholder wealth: does the reason matter?

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(Received 30 July 2014; accepted 25 January 2015)

This paper investigates how different reasons for supply chain glitches influence shareholder wealth. Prior research indicated that supply chain glitches can decrease shareholder wealth by a staggering 10.28%. We argue that the reason for the supply chain glitch is an important moderator for understanding how supply chain glitches affect shareholder wealth. In this paper we re-assess the effect of supply chain glitches on shareholder wealth for a new time period (i.e. 2001–2012) whilst including the moderators from the original study (growth prospects, firm size, debt-equity ratio and timing) and adding the reason for the supply chain glitch as an important new moderator. Our results show that on average supply chain glitches decrease shareholder wealth by 1.94%. Further, our results indicate that supply chain glitches that arise due to regulatory, catastrophic and infrastructural reasons trigger more significant negative reactions in financial markets as compared with glitches that occur from the supply side. We discuss the implications of our findings both for theory building and for business practice, and end with limitations and suggestions for future research.

Keywords: supply chain management; performance measures

1. Introduction

Supply chain management (SCM) is the management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole (Christopher 2011). As proposed by Hendricks and Singhal (2003), the value derived from effective SCM can be measured by assessing the financial damage when supply chains are not managed effectively. In that case, so-called supply chain glitches occur. The study of supply chain glitches can be viewed as a subset of the broader topics of supply chain risk (Juttner, Peck, and Christopher 2003; Wagner and Bode 2008; Zsidisin and Ritchie 2009) and supply chain vulnerability (Christopher and Peck 2004; Peck 2005), which has experienced a significant increase in attention in both academic scholarship and business practice during the past 15 years.

The concept of risk, and specifically that of supply chain risk, has evolved in the literature, and has been defined as a ‘variation in the distribution of possible supply chain outcomes, their likelihood, and their subjective value’ (Juttner, Peck, and Christopher 2003, 200). As identified by Wagner and Bode (2008), within the view of most supply chain professionals, there is a much greater focus on those outcomes which result in some form of realised loss or harm to the organisation. In order for organisations to experience the detrimental effects supply chain risk, an important precursor or condition is that their organisation is open to supply chain vulnerability, which has been simply defined as ‘an exposure to serious disturbance’ (Christopher and Peck 2004, 3).

One of the most prevalent and studied forms of supply chain disturbances consists of supply chain disruptions, which consist of unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain (Craighead et al. 2007; Hendricks and Singhal 2003; Kleindorfer and Saad 2005; Svensson 2000). As discussed by Wagner and Bode (2006), supply chain disruptions have been described using similar terms such as ‘glitches’, ‘disturbances’ and ‘crises’ (303), depending on their level of severity. With regard to our study, we are investigating the shareholder effects of supply chain glitches, which are defined as a disruption in the matching of supply and demand (Hendricks and Singhal 2005).

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Supply chain glitches have severe financial consequences for firms. First, Hendricks and Singhal (2003) found that supply chain glitches that result in production or shipment delays (i.e. when supply is smaller than demand) decrease shareholder wealth by a staggering 10.28%. Second, providing further insights into why financial markets react so negatively to these supply chain glitches, Hendricks and Singhal (2005) found that these glitches lead to a decrease in sales growth of 6.72%, an increase in costs of 10.66% and an increase in inventory of 13.88%. Third, Hendricks and Singhal (2009) report that shareholder wealth decreases by almost 7% as a response to excess inventory in the supply chain (i.e. when supply is larger than demand).

In this study, we focus on shareholder wealth effects due to supply chain glitches which lead to production or shipment delays. Compared to the study of Hendricks and Singhal (2003), we include an essential additional moderator: the reason for the supply chain glitch. Hendricks and Singhal (2003, 515, footnote 12) indicated that the reason for supply chain glitches is very important for understanding their effect on shareholder wealth, but they did not conceptually and empirically explore if and how supply chain glitches influence this effect. Building on the framework of Wagner and Bode (2008), we investigate the effect of four reasons for supply chain glitches: supply-side reasons, regulatory reasons, catastrophic reasons and infrastructural reasons. We argue that some glitch reasons may have more severe consequences, are more difficult to manage and may be perceived as more severe than other reasons. In particular, we argue that the effect of a supply chain glitch announcement on shareholder value is more negative for 'regulatory', 'catastrophic' and 'infrastructural' reasons than for 'supply side' reasons.

The remainder of this paper is set up as follows. First, in Section 2, we describe the literature regarding supply chain glitches and shareholder wealth. Second, in Section 3, we present our sample, describe the event study methodology for calculating shareholder wealth effects due to supply chain glitches and explain how we assess the effects of moderators. Third, we present our results in Section 4. Finally, in Section 5, we discuss these results, acknowledge the limitations of our study, provide theoretical and practical implications and directions for further research.

2. Literature review and hypotheses

2.1 Supply chain glitches and shareholder wealth

Hendricks and Singhal (2003) provide an excellent overview of how effective SCM affects shareholder wealth. In this reasoning, effective SCM is argued to positively affect various shareholder value drivers within the firm. Effective SCM positively influences the key operational metrics (KOM) of firms; these KOM relate supply chain performance to areas such as forecasting and planning accuracy, supplier performance, delivery performance, lead time, inventory, capacity and quality. When these KOM are managed effectively, firms are able to meet customer demand by achieving supply chain reliability, responsiveness, relationships and resilience (Christopher 2011; Hendricks and Singhal 2003). As the ability of a firm to meet customer demand increases, its direct financial metrics such as cash flows, earnings and return on assets (ROA) as well as its intangible assets such as reputation and credibility also increase (Hendricks and Singhal 2003). Increased financial metrics and intangible assets are evaluated positively by financial markets and thus shareholder value increases.

In our study, similar to the study of Hendricks and Singhal (2003), we investigate supply chain glitches in which firms are unable to meet consumer demand due to production or shipment delays. In such cases, firms are not able to satisfy current demand and they cast doubts on their ability to satisfy future demand. As laid out by Hendricks and Singhal (2003), this may lead to a loss in sales and market share in the short term. Furthermore, reputation loss and reduced loyalty can further reduce sales and market share and force down prices. Finally, supply chain glitches increase various costs such as contract penalties, shipping, inventory write-off and storage. In sum, supply chain glitches negatively affect the value of the firm, which should be evaluated negatively by financial markets.

Although we argue that the shareholder wealth reaction due to supply chain glitches will be negative, it is impossible to accurately predict how negative it will exactly be. One approach to make a prediction is to take the effects found by Hendricks and Singhal (2003) as a reasonable prediction. Yet, there are some limitations to their study in terms of currency and reason for the supply chain glitch, which are discussed below.

First, we aim to focus on a more recent time period. The reason for this is that announcements tend to disappear over time and as such we only want to focus on the period after the initial study (i.e. 2002–2013).¹ We expect that due to three reasons, shareholder wealth may be affected differently by supply chain glitches in more recent years. *For one*, due to fiercer competition (because of globalisation and an economic downturn), the pressure to increase efficiency and responsiveness of business processes by means of outsourcing and offshoring has increased. When firms outsource and offshore, they have less control over business processes which increases their vulnerability to supply chain glitches (Manuj and Mentzer 2008; Simchi-Levi, Kaminsky, and Simchi-Levi 2009). As competition has increased, anticipating

and appropriately counteracting supply chain glitches has become more important for firms (Wagner and Bode 2006). It is possible that due to their increased importance, supply chain glitches may be evaluated more severely by financial markets compared to prior decades. *Moreover*, the rise of the internet has increased the use of e-commerce and e-business in the past decade. E-fulfilment activities require supply chains that are developed for parcel delivery, reverse logistics, geographically dispersed distribution and short lead times (Simchi-Levi, Kaminsky, and Simchi-Levi 2009). These requirements put greater pressure on SCM and increase the vulnerability to supply chain glitches. For this reason, it is possible that supply chain glitches in the past decade have been evaluated more severely by financial markets. *Finally*, many firms have further professionalised their supply chain processes in the past decade (Ganesan et al. 2009). In previous decades, firms tended to be insufficiently prepared to maintain a stable performance after a supply chain glitch (Blackhurst et al. 2005; Hale and Moberg 2005). Yet, in more recent years, the awareness and availability of means to counteract supply chain glitches have increased (Jüttner 2005; Wagner and Bode 2006, 2008). By creating more responsive and flexible supply chains, firms may be able to compensate for supply chain glitches more easily (Blackhurst et al. 2005; Braunscheidel and Suresh 2009). Therefore, it can also be argued that firms have become better equipped to handle supply chain disruptions in the past decade, and that financial markets should thus have reacted less severely to recent supply chain disruptions compared to the period investigated by Hendricks and Singhal (2003).

Second, in the overview of prior event studies provided by Hendricks and Singhal (2003, 512, Table 4), only strategic events (such as financial leverage announcements) result in relatively large shareholder wealth reactions of 3.0–7.63%. Other, more operational and tactical events (such as effective total quality management (TQM) implementation or effective environmental performance) only trigger relatively small reactions (of around 1%). When we examine the results of Hendricks and Singhal (2003) more closely (515, Table 6), we see that glitches that are more of an operational nature (e.g. parts shortages and production problems) surprisingly trigger very large shareholder wealth reactions of 8.16–13.38%. This is a departure from prior event study results, and warrants further investigation.

In sum, while we expect that for the more recent time period that we study, there will still be a negative stock price reaction, we cannot accurately predict the size of the reaction when we reflect on the prior study by Hendricks and Singhal (2003). Yet, as we showed, it would be very valuable to reassess and replicate the prior findings using a more recent time period. Therefore, we formulate the following general hypothesis:

H1: The announcement of supply chain glitches will have a negative shareholder wealth reaction.

In addition to reassessing the average effect of supply chain glitches on shareholder wealth for a later time period, we will also review and empirically answer two important conceptual questions which will enhance the prior study of Hendricks and Singhal (2003): Does the reason for the supply chain glitch matter? Which moderators and control variables should be added? We will explore these questions theoretically in the next sections.

2.2 Reasons for supply chain glitches

Various frameworks for categorising supply chain glitches have been provided in the literature (e.g. Chopra and Sodhi 2004; Christopher and Peck 2004; Jüttner 2005; Kleindorfer and Saad 2005; Manuj and Mentzer 2008; Svensson 2000). For the purpose of our study, we selected the framework of Wagner and Bode (2008; see Table 1) for several reasons, which we will provide after briefly describing the framework and its use in our study.

The framework of Wagner and Bode (2008) distinguishes between five reasons for supply chain glitches (see Table 1): demand-side reasons, supply-side reasons, regulatory reasons, catastrophic reasons and infrastructural reasons. In our study, we form hypotheses about the latter four reasons and exclude demand-side reasons. We do this because we only focus on production and shipment delays and do not consider glitches that result in excess inventory (i.e. we focus on situations where supply < demand and not where demand < supply). Thus, for example, we do not consider unanticipated additional consumer demand. Furthermore, while there are other demand-side reasons such as poor customer forecasts, firms do not tend to publicly share such problems with customers. As it is highly unlikely that we encounter any demand-side reasons in our study, and as it is impossible to study hypothetical events, we will not include demand-side reasons in the remainder of this study.

We selected the framework of Wagner and Bode (2008) for our study for two main reasons. First, these authors base their framework on an extensive literature review of the most important frameworks in literature regarding sources of supply chain glitches. Second, the framework of Wagner and Bode (2008) makes it possible to consider how financial markets would react to the various reasons for supply chain glitches. For one, the ease with which a glitch could be solved by a firm could be relevant. It can be argued that ‘supply side reasons’, where there is a temporary shortage of

Table 1. Reasons for supply chain glitches (adapted from Wagner and Bode 2008).

<i>Demand-Side risks</i>	<i>Infrastructural risks</i>
<ul style="list-style-type: none"> • Unanticipated or highly volatile customer demand • Insufficient or distorted information from customers about orders or demand quantities 	<ul style="list-style-type: none"> • Downtime or loss of own production capacity due to local disruptions (e.g. labour strike, fire, explosion, industrial accidents) • Perturbation or breakdown of internal IT infrastructure • Loss of own production capacity due to technical reasons (e.g. machine deterioration) • Perturbation or breakdown of external IT infrastructure
<i>Regulatory, legal and bureaucratic risks</i>	<i>Catastrophic risks</i>
<ul style="list-style-type: none"> • Changes in the political environment due to introduction of new laws, stipulations, etc. • Administrative barriers for the set-up or operation of supply chains (e.g. authorization) 	<ul style="list-style-type: none"> • Political instability, war, civil unrest or other sociopolitical crises • Diseases or epidemics (e.g. SARS, Foot and Mouth Disease) • Natural disasters (e.g. earthquake, flooding, extreme climate, tsunami) • International terror attacks (e.g. 2005 London or 2004 Madrid terror attacks)
<i>Supply-Side risks</i>	
<ul style="list-style-type: none"> • Poor logistics performance of suppliers (delivery, dependability, order fill capacity) • Supplier quality problems • Sudden default of a supplier (e.g. bankruptcy) • Poor logistics performance of LSP • Capacity fluctuations or shortages on the supply markets 	

components from suppliers, are perceived as relatively easier to address (e.g. by switching to alternative suppliers) compared to glitches where the infrastructure of the firm is damaged (i.e. ‘infrastructural reasons’) or compared to glitches that arise from events that are difficult to influence by a firm such as regulation and catastrophes. Psychological factors should also be taken into account when hypothesising shareholder wealth reaction to glitches. De Bondt and Thaler (1985) found that the stock market reacts more negatively to unexpected and dramatic news (a.k.a. the ‘overreaction hypothesis’). While the actual consequences of two events can be equally severe, the stock market might perceive one event as more severe than another. For example, breakdowns of core IT infrastructures (‘infrastructural reasons’), natural disasters or terrorist attacks (‘catastrophic reasons’), the announcement of new regulation that obstructs a firm’s output (‘regulatory reasons’) might – justly or unjustly – be experienced as more ‘dramatic’ and ‘unexpected’ by financial markets than stock-outs at a supplier (i.e. ‘supply side reasons’). As such, we expect that:

H2: The effect of a supply chain glitch announcement on shareholder value will be more negative for ‘regulatory’, ‘catastrophic’ and ‘infrastructural’ reasons than for ‘supply side’ reasons.

2.3 Moderating and control variables from Hendricks and Singhal (2003)

Hendricks and Singhal (2003) propose that four variables affect the shareholder wealth reaction to supply chain glitches: firm growth prospects, firm size, debt-equity ratio and timing. In Table 2, we summarise the hypotheses regarding these variables. For the conceptual grounding of the hypotheses, we refer to the original paper. In our study, we will reassess the moderating effects of these variables in H3a–H3d (see Table 2 and Figure 1). Please note that the hypotheses are embedded in the table and specifically stated in Hendricks and Singhal (2003).

Table 2. Original hypotheses and results of Hendricks and Singhal (2003).

Moderators	Hypotheses in Hendricks and Singhal (2003) and reasoning
Firm growth prospects	‘Supply chain glitches by high growth prospects firms will have a more negative stock market reaction than low growth prospects firms’. (confirmed by Hendricks and Singhal 2003; to be assessed as H3a in our study)
Firm size	‘The stock market’s reaction to supply chain glitches will be more negative for smaller firms than larger firms.’ (confirmed by Hendricks and Singhal 2003; to be assessed as H3b in our study)
Debt-equity ratio	‘The higher the debt-equity ratio, the less negative will be [the] stock market’s reaction to supply chain glitches.’ (rejected by Hendricks and Singhal 2003; to be assessed as H3c in our study)
Timing	‘More recent supply chain glitches will be penalised more by the market than earlier glitches.’ (rejected by Hendricks and Singhal 2003; to be assessed as H3d in our study)

Figure 1. Research model.

Besides these moderators that are variables of interest, Hendricks and Singhal (2003) included several control variables to assess the robustness of the results: industry, capital intensity, research and development intensity, industry competitiveness and multiple glitch indicator. Only industry yielded significant results. We followed the recommendations of Becker (2005) to only include control variables which have conceptually been argued and empirically supported to affect the dependent variable. Variables that meet these standards may act as suppressors for the effects of the independent variables, and affect the generalisability of the results of our study. Therefore, such variables should be included in our models. However, if variables do not meet these criteria, they should be excluded from the models in order to avoid an unnecessary increase in Type II errors and a loss of statistical power (Becker 2005). Based on the prior results for the control variables, we will, thus, only consider industry as a control variable in our study.

3. Methodology

3.1 Sample

To find relevant announcements, we searched the full articles in the *Wall Street Journal* (WSJ) and the *Dow Jones News Service* (DJNS) in the Factiva database. The search covered US companies and covered the time period from 2000 to 2012. We searched for announcements concerning production or shipment delays. Key words included in the search are: *delay, shortfall, shortage, shutdown, insufficiency, lack, loss, shortcoming, flaw, default, disruption, interruption, hindrance, hold-up, tie-up, stoppage, setback, discontinue, recess, restrain, hinder, production, shipment, delivery, distribution, parts, components, manufacturing, transport, freight, goods, orders, demand, supply, assortment, customer, fabrication, assembly, construction, making, yielding*. The search resulted in 6453 announcements. We scanned the full articles of the search results. We eliminated the following announcements:

- Announcements that include other information relevant to shareholder wealth than just the supply chain glitch (e.g. announcements of sluggish sales due to a bad economy, news items that generally discuss why some industries are facing problems).
- Announcements of firms that were not listed on the US stock exchanges (New York Stock Exchange (NYSE), National Association of Security Dealers Automated Quotations (NASDAQ) or American Stock Exchange (AMEX)).
- Announcements that did not state the reason for the occurrence of the glitch (the glitch reason). This is a deviation from the methodology of Hendricks and Singhal (2003), who did include glitches where no glitch reason was stated. However, to be able to accurately measure the impact of SC glitches (and only SC glitches) on shareholder wealth, we require the glitch reason to be available.

Figure 2. Announcements per year.

Table 3. Glitch announcements by reason.

Glitch reason	Number of observations	%
Catastrophic	28	24.1
Infrastructural	67	57.8
Regulatory	4	3.5
Supply side	17	14.7
Total	116	100

We validated all announcement dates by searching for earlier news articles concerning the glitch in the Factiva database. If the exact announcement date was incorrect or unclear, the announcement was changed to the correct date or removed. In total, we changed the dates of 14 announcements. The distribution of announcements per year is provided in Figure 2.

Table 3 shows the glitches categorised by their glitch reasons. As we already expected, we did not find glitches arising from relevant demand-side reasons (e.g. poor customer forecasts).

3.2 Estimating the effect of glitches on shareholder wealth: the event study methodology

Similar to Hendricks and Singhal (2003), this paper uses the event study methodology to measure the shareholder wealth reaction (a.k.a. stock price reaction) of firms to the events in question. The event study methodology is well established in various academic fields such as business and economics, law, biology and medicine (MacKinley 1997). In the last decade, event studies have also become popular in the field of SCM where topics such as the shareholder wealth effects of various supply chain topics have been addressed through event studies. Examples are as supply chain disruptions (Papadakis 2006), supply chain glitches (Hendricks and Singhal 2003), SCM systems (Hendricks, Singhal, and Stratman 2007), supply chain integration through consortium-based exchanges (Mitra and Singhal 2008) and environmental supply chain sustainability initiatives (Bose and Pal 2012).

We use the Centre of Research in Security Prices (CRSP) database to gather stock price data from US companies stock listed on the NYSE, NASDAQ or AMEX. Compustat is used to gather data on the moderating variables firm size, firm growth prospects and debt-equity ratio.

3.2.1 Market model description

In order to estimate the shareholder wealth reaction from an event, in line with common practice (MacKinley 1997), the market model on daily stock price return of Brown and Warner (1985) is used. The model posits a linear relationship between the return on a stock and the return on a market portfolio (market return) over a given time period. The formula for this relationship is:

$$r_{it} = \alpha_i + \beta_i r_{mt} + \varepsilon_{it} \quad (1)$$

where r_{it} is the return of stock i on day t , r_{mt} is the market return on day t , α_i is the intercept (estimate of the constant daily return for stock i), β_i is the slope ($\beta_i r_{mt}$ is the portion of return for stock i that is attributed to market-wide movements) and ε_{it} is the error term (the part of the stock return that cannot be explained by market movements and captures the effect of firm-specific information).

These parameters are estimated using ordinary least squares (OLS) regression. To calculate the estimated normal returns, stock price data of a period of 200 trading days prior to the event period are used. This is conservative; an estimation period of at least 40 available data points is necessary to make the model statistically sound (Hendricks and Singhal 2003). Because the ‘normal’ estimation period may not include the event period so that the estimators are not influenced by the returns around the event (MacKinley 1997), the estimation period starts 10 days prior to the event period. Just as in the study of Hendricks and Singhal (2003), the market index used is the equally weighted index (including dividends) of all securities traded on the US stock exchanges (NYSE, NASDAQ, AMEX), retrieved from CRSP.

The abnormal return (A_{it}) is the difference between r_{it} (the actual return of stock i on day t) and $\alpha_i + \beta_i r_{mt}$ (the normal return of stock i on day t):

$$A_{it} = r_{it} - \hat{\alpha}_i - \hat{\beta}_i r_{mt} \quad (2)$$

After calculating the abnormal returns, the abnormal returns can be averaged across the sample firms on any day t . This average abnormal return ($\bar{A}_t$) reflects the shareholder wealth reaction on a certain day t . The average abnormal return is calculated as follows for day t considering the N events:

$$\bar{A}_t = \sum_{i=1}^N A_{it} / N \quad (3)$$

In order to be able to assess the significance of $\bar{A}_t$ on day t , each abnormal return A_{it} is divided by its estimated standard deviation, to calculate a standardised abnormal return:

$$A_{it}^s = A_{it} / \hat{S}_{ei} \quad (4)$$

The z -test statistic (z -value), for any average abnormal return ($\bar{A}_t$) on day t is given by:

$$TS_t = \sum_{i=1}^N A_{it}^s / \sqrt{N} \quad (5)$$

As we are interested in the shareholder wealth reaction due to the event, we assess the average abnormal return and its significance on the event day (thus testing H1). It is recommended to assess the abnormal return on the event day itself unless there are theoretical reasons to expect information leakage prior to the event day or slow dissipation of information on and after the event day (MacKinley 1997). In our study, we do not have such theoretical reasons and therefore, we assess the abnormal return on the event day itself (i.e. day 0). We also show the abnormal returns five days prior to, and five days after the announcement of participation. We exclude holidays and non-trading days from this event window. If the glitch occurred when the stock exchange was closed (e.g. during the weekend), we use the first trading day after the event as the ‘announcement day’ (i.e. day 0). The same holds for a multiple day closure of the stock exchanges (e.g. during the closure of the stock exchange after the WTC attack on 9–11).

3.2.2 Testing the reason for supply chain glitches

Taking ‘supply side’ reasons as the reference category, we created dummy variables for each of the remaining three glitch reasons, thereby testing if regulatory, catastrophic and infrastructural reasons for supply chain glitches have more significant negative outcomes as compared with supply-side reasons (H2). All 116 glitches were categorised in the categories of Wagner and Bode (2008) by each of the researchers. The researchers agreed on the appropriate categories in 100% of the announcements. Market and/or accounting data necessary for the regression could not be found for five glitches, thus reducing the number of announcements which was used in the OLS regression to 111.

3.2.3 Sensitivity check: mean model

In order to make sure that our results are robust, identical to Hendricks and Singhal (2003), we also include the alternative to the market model in our analyses: the mean model. The mean model calculates the abnormal returns by subtracting the mean return of a stock over the estimation period from its event day return. The advantage of this method is that it can account for biases due to differences in the operating performance of companies. Yet, the market model is usually preferred over the mean model as market movements are considered very important for explaining stock price movements (this is also referred to as ‘systematic risk’ of a firm; see MacKinley 1997). For more information on the mean model, we refer to MacKinley (1997).

3.3 Estimating the effect of moderating variables

In order to capture the effect of the variables mentioned in H2 and H3a–d, we perform an OLS regression in which we enter these variables as independent variables. We use the average abnormal return on the event day (i.e. day 0) as the dependent variable. To ensure rigidity of our results, we provide the results for both the average abnormal return calculated through the market model and the mean model. Adding all independent variables to the model is similar to the approach by Hendricks and Singhal (2003); the only difference is that they added industry as a control variable in a second model. As industry is known to influence the results, a second model was evaluated and included in our analysis.

The moderating variables growth prospects (H3a), size (H3b) and debt-equity ratio (H3c) are measured in accordance with the study of Hendricks and Singhal (2003). First, the market-to-book ratio is used as a measure for growth prospects because it signals the ability of a firm to enhance book values through future earnings (Penman 1996). To calculate this ratio, we use the market value of equity (i.e. the stock price times number of outstanding shares) and the book value of equity. We use the market value of equity 10 days prior to the announcement (i.e. the last day of the ‘normal estimation period’). For the book value of equity, we use the value reported in the most recent fiscal year prior to the announcement date. Second, we use sales in the most recent fiscal year ending prior to the announcement date as a measure of firm size. The natural logarithm ($\ln$ sales) is used in order to remove potential skewness from the distribution. Third, the debt-equity ratio is calculated by dividing the book value of debt by the sum of book value of debt and book value of equity. The book value of debt and book value of equity of the fiscal year prior to the announcement date are used. Descriptive statistics for these variables can be found in Table 4. Finally, we use the year of the announcement in order to capture the importance of timing (H3d); as Hendricks and Singhal (2003) lay out, announcements in earlier years may trigger a different effect from announcements in later years. While Hendricks and Singhal (2003) chose to split the data-set in two (one half is considered early years and the other half late years) and use a binomial variable, capturing a time trend can be done more accurately by adding the actual year in which the announcement was done as and treating time as a continuous variable. We thus used this second approach to capture the effect of timing in our paper.

We followed the recommendations of Becker (2005) only to include control variables which have conceptually been argued and empirically been shown to affect the dependent variables. Variables that meet these standards may act as suppressors for the effects of the independent variable, and affect the generalisability of our study. Therefore, such variables should be included in models. However, if variables do not meet these criteria, they should be excluded from the models in order to reduce the possibility of Type II errors and a loss of power (Becker 2005). As only the control variable ‘industry’ in Hendricks and Singhal (2003) was statistically significant, due to the ‘empirical’ recommendation of Becker (2005) we only included industry. Based on the announcement data-set, similar to Hendricks and Singhal (2003), we created the following industry groups of similar industries: *Industry 1* (SIC digits 10,12,13): mining/extraction of metal, coal, oil and gas; *Industry 2* (SIC digits 25,26,28,29,30,31,33): production of wood products, furniture, paper, chemicals, petroleum products, coal products, rubber products, leather products and primary metal; *Industry 3*

Table 4. Descriptive statistics data moderating variables.

Measurement (million US\$)	Minimum	Maximum	Mean	SD
Market value of equity	14.5	596,509	47,925	93,560
Book value of equity	0.3	148,013	22,881	29,334
Sales	0.0	368,056	71,152	78,850
Book value of equity (Property, Plant, Equipment)	1.6	285,525	50,692	61,831
Book value of debt	1.2	300,279	39,874	69,257

(SIC digits 35,36): industrial machinery and equipment, electronic equipment; *Industry 4* (SIC digits 37): transportation equipment; *Industry 5* (SIC digits 38): instruments and related products; *Industry 6* (SIC digits 42,45): transportation and public utilities; *Industry 7* (SIC digits (SIC digits 73): business services. We used industry 7 as reference industry and created dummy variables for each of the six remaining industries.

4. Results

This section presents the results and is divided in two parts. First, we will present the event study results and thus test H1. Second, we will present the results for the moderating variables and thus test H2 and H3a–d.

4.1 Event study results

This section will present the results of H1. Table 5 and Figure 3(a) and (b) clearly show a significant abnormal return on the event day (i.e. day 0). As previously mentioned, it is possible that there is some leakage prior to the announcement or that the market is slow to adapt to information. Therefore, we do not only present the results on the event day in Figure 2(a) and (b), but also provide average abnormal returns (and 5% confidence bounds) for the surrounding days, namely, the five days before and after the announcement.

Table 5. Average abnormal returns for the market and mean model for day 0.

		Market model Day 0	Mean model Day 0
Average abnormal return	Mean AR	−1.94%	−1.97%
	Z-value	−8.63***	−7.78***

***Significant at $\alpha = 0.01$.

Figure 3. Average abnormal returns for (a) market model and (b) mean model for the event window −5 to +5 days. Note: The 5% confidence intervals are indicated by the dotted lines.

As can be seen from Figure 2(a), the average abnormal return on day 0 calculated with the market model crosses the 5% confidence bounds. There is a significant abnormal stock price reaction of -1.94% on the event day ($p < 0.01$). The mean model supports this result; the average abnormal return on day 0 calculated with the mean model is -1.97% . This confirms hypothesis H1. There are no significant abnormal stock price reactions in the surrounding days, which imply no leakage and no delayed market response.

4.2 Results of the moderating variables

Table 6 shows the results of the OLS regression. The r^2 value of the regression model is 30.0% (market model) and 27.8% (mean model), respectively. This r^2 value is quite high, indicating that our explanatory variables explain a relatively large portion of the variance of the dependent variable. We will first discuss the control variable industry. Thereafter, we will discuss H2–H3d.

There are no large differences in average abnormal returns across industries; an exception to this seems to be industry 4 (transportation equipment). In this industry, the market punishes glitch announcements on average with a 3.6% (market model) to 3.8% (mean model) lower shareholder wealth compared to the reference industry (see Table 6). The remaining industries do not differ significantly from the reference industry (an exception to this is industry 5, yet this result is only significant for the market model).

With regard to H2, our results indicate that the financial markets react more severely to catastrophic glitch reasons and regulatory glitch reasons than to supply-side reasons. Both the market model and the mean model confirm this: catastrophic reasons decrease shareholder wealth by 2.0% (in the market model) and 2.6% (in the mean model), respectively, compared to supplier-side reasons, regulatory reasons decrease shareholder wealth by 3.8% (in the market model) and 5.0% (in the mean model) compared to supplier-side reasons. The results for infrastructural glitch reasons are mixed; while the market model does not indicate that infrastructural glitch reasons provoke a lower reaction than supply-side reasons (1.2% lower, n.s.) the mean model indicates a lower reaction of 1.7% ($p < 0.10$). Overall, there is moderate support for H2.

Based on the results, we reject H3a as the coefficient for growth prospects is insignificant in both the market and the mean model. Regarding H3b, the results indicate that the size of the firm has a statistically significant effect on the average abnormal return on the event day (both in the market model and the mean model). The positive sign of the coefficient indicates that the average abnormal return is higher (i.e. less negative) for larger firms than for smaller firms. Thus, H3b is supported. With regard to H3c, our results indicate that the debt-equity ratio has a statistically significant effect on shareholder value. The positive coefficient indicates that the effect of a supply chain glitch announcement on

Table 6. Regression results for moderating variables.

Explanatory variables	Average abnormal return on day 0 (market model)		Average abnormal return on day 0 (mean model)	
	Coefficient	<i>t</i> -statistic	Coefficient	<i>t</i> -statistic
Constant	−0.78	−0.59	−.16	−0.87
Industry 1	−0.015	−1.27	−0.012	−0.85
Industry 2	−0.015	−1.35	−0.013	−1.01
Industry 3	−0.018	−1.47	−0.021	−1.42
Industry 4	−0.036***	−2.94	−0.038***	−2.73
Industry 5	−0.029**	−1.75	−0.024	−1.24
Industry 6	0.014	0.89	0.021	1.10
Size (ln sales)	0.0036***	2.68	0.0033**	2.10
Growth prospects (M-to-B ratio)	0.00	1.40	0.00	1.47
Debt-equity ratio	0.021*	1.95	0.023**	1.86
Catastrophic glitch reasons	−0.020**	−2.26	−0.026**	−2.58
Infrastructural glitch reasons	−0.012	−1.53	−0.017*	−1.81
Regulatory glitch reasons	−0.038**	−2.40	−0.050***	−2.68
Timing (Year)	0.000	0.53	0.000	0.52
Explanatory value (R^2) model	0.30 (30.0%)		0.278 (27.8%)	

*Significant at $p = 0.10$.

**Significant at $p = 0.05$.

***Significant at $p = 0.01$ (two-tailed).

shareholder value will be higher (i.e. less negative) for firms with a high debt-equity ratio than for firms with a low debt-equity ratio. Therefore, H3c is supported. Finally, there was no statistical support that announcements in earlier years differ from latter years, rejecting H3d.

5. Discussion

While SCM has received a lot of attention in the literature, little is known about the financial effects of (in)effective SCM. In this paper, we studied how shareholder value is affected when supply chains are ineffectively managed and thus suffer from supply chain glitches. In particular, we were interested if different reasons for supply chain glitches have different effects on shareholder wealth.

Through an event study, we first showed that supply chain glitch announcements cause a negative shareholder wealth reaction (-1.94% , $p < 0.01$). Second, we performed an OLS regression to investigate the moderating effect of supply glitch reason, growth prospects, firm size, debt-equity ratio and timing. Our results regarding supply glitch reasons derived from the mean model indicate that infrastructural glitch reasons are evaluated more severely than supply-side reasons. Furthermore, we found that growth prospects and timing do not significantly moderate shareholder wealth reaction due to glitches. Yet, we found that firm size and debt-equity ratio moderate this effect: larger firms and firms with a higher debt-equity ratio derive a less negative shareholder wealth reaction to supply chain glitches.

Overall, in line with Hendricks and Singhal (2003), our findings confirm that financial markets respond negatively to supply chain glitch announcements. Furthermore, our findings on the moderating role of firm size are also congruent with the original study. Yet, there are also important differences between our results and the findings of Hendricks and Singhal (2003). First, we found a much lower shareholder wealth reaction compared to the original study (-1.94% vs. -10.28%). Second, as compared with the original study, we did not find that growth prospects significantly influence the shareholder wealth reaction to glitches. Third, contrary to Hendricks and Singhal (2003), we found that the debt-equity ratio significantly influences the shareholder wealth reaction to glitches. Finally, we extended the original study and found that the reason of the supply chain glitch reason is of importance when explaining shareholder wealth reactions to those glitches.

5.1 Theoretical implications

Our study has several theoretical implications. First, we contribute to the literature on the effect of supply chain glitch announcements (resulting in a production or shipment delay) on shareholder value. Previously, Hendricks and Singhal (2003) reported a relatively large stock market reaction of -10.28% to such glitch announcements. Although we can confirm that the shareholder wealth effect is still negative for a more recent time period, our results indicate that this effect may not be as severe as previously stated. As indicated in the theory section, it is possible that due to increased awareness of and knowledge about supply chain risk, vulnerability and disruptions (Craighead et al. 2007; Ganesan et al. 2009; Jüttner 2005; Wagner and Bode 2006, 2008), firms may currently be better able to manage and recover more quickly from supply chain glitches. If financial markets anticipate this increased capability of managing glitches, then as indicated by our findings compared to the results of Hendricks and Singhal (2003), the shareholder wealth decreases due to glitches should be less negative than in decades where there was less understanding of efficient SCM.

Second, to increase the understanding of the valuation of glitches, we investigated the role of four moderators which were reported in the original study. While the effect of firm size and timing was in line with the study of Hendricks and Singhal (2003), the influence of the other two moderators was different than in the original study: we found an insignificant effect for growth prospects and a significant effect for debt-equity ratio. Our findings for firm size, timing and debt-equity are, thus, in congruence with the argumentation presented in the theory section. Regarding growth prospects, one explanation for the insignificant results might be that there may be a difference between what investors perceive versus what the literature states as critical value drivers for different supply chains. In line with Wagner and Bode (2006), it is possible that due to fiercer competition across industries, anticipating and appropriately counteracting supply chain glitches have become more important for firms in general, and not just for firms with high-growth prospects.

Third, we found support that different supply chain glitch reasons are valued differently by financial markets. As such, our study provides an application of the framework of Wagner and Bode (2008) on objective data and increases the understanding of the valuation of glitches. We show that glitch reasons are very important for the shareholder wealth reaction; as predicted, glitch reasons that are more difficult to manage for firms (i.e. catastrophic, regulatory and infrastructural reasons) seem to trigger a more negative financial reaction than glitch reasons that can be circumvented and potentially easier to address (i.e. supply-side reasons), among other reasons further discussed in the following section. As such, although most of the supply chain literature focuses on preventing and addressing problems arising at suppliers

(see e.g. van der Vaart and van Donk 2008, for an overview of supply chain integration literature), it seems that financial markets consider non-supplier-related reasons as much more important. To increase the practical contribution of research, we would encourage further research on how the other supply chain glitch reasons can be anticipated, counteracted before they occur and managed whenever they do occur.

5.2 Practical implications

In this paper, we aim to provide useful insights for practitioners who want to assess the effect of supply chain failures. We showed that supply chain glitches negatively impact shareholder value. As such, our findings indicate that supply chain glitches arising from improper supply chain failures are still a valid concern for firms, although this importance is lower than previously indicated in the literature.

In many ways, the findings from our study provide some initial positive evidence that firms may be learning how to create more resilient supply chains (Ponomarov and Holcomb 2009; Sheffi 2005), which are subsequently leading to the dampening of the detrimental effects that are experienced when supply chain glitches arise. Supply chain resilience, from an organisational perspective, has been defined as ‘the ability to bounce back from disruptive events or hardships’ (Ponomarov and Holcomb 2009, 129). Due to our inability to attain the prior data-set of firms investigated by Hendricks and Singhal (2003), it is not feasible for us to surmise if the frequency of supply chain glitches is more or less prevalent. However, our findings do strongly suggest that the financial impact of those glitches have a significantly less detrimental impact to firm financial performance than in the recent past. From the growth of study on the subjects of supply chain vulnerability, risk and disruptions, in conjunction with the plethora of reports touting how organisations have worked towards creating more robust and flexible supply chains, we believe that this manuscript provides evidence that the markets perceive that firms are better understanding how to manage and quickly recover from disruptions and glitches in their supply chains. Further, many of these studies (Wang, Gilland, and Tomlin 2010; Wu, Blackhurst, and Chidambaram 2006; Zsidisin and Wagner 2010) and descriptions of company practices (Burnson 2014; Partida 2013) have focused their attention on supply chain risk and glitches that stem from supply-side reasons. Our findings indicate that financial markets react more severely to catastrophic and regulatory glitch reasons, which are usually outside the control of most firms, as compared with supply-side reasons, may be better controlled by firms through process improvements (Wang, Gilland, and Tomlin 2010) and early identification (Zsidisin, Melnyk, and Ragatz 2005). At first glance, these findings indicate that managers should allocate their mitigation priorities to regulatory and catastrophic reasons as these seem to have the highest impact. Yet, managers should not just consider the severity of events, but also their expected occurrence. It may be possible that combined, many low-impact events have a much more severe effect on shareholder wealth than a few high-impact events. Future research should determine if it is justified that most managers currently give more attention to low-impact, high-likelihood events compared to high-impact, low-likelihood events (Chopra and Sodhi 2004), and particularly, those which they can influence such as process improvements.

5.3 Limitations and future research opportunities

Our study carries several limitations that provide directions for future research. First, we only incorporated US glitch announcements announced in the WSJ and DJNS. These outlets are considered important news databases for the US market and are closely followed by investors. However, there may be a selection bias in the reported announcements by the WSJ and DJNS. Schmidt and Raman (2012) studied how the WSJ news agency selects which glitches it reports. They found that the news agency would only report an announcement if they would expect it to cause a change in stock prices. This limitation is not only important for our study, but also for previous studies (e.g. Hendricks and Singhal 2003). It would be beneficial if future work would be able to provide insights into which news is not picked up by the established media and what the financial effects are of such announcements.

Second, our study did not incorporate demand-side reasons (e.g. an inability to meet demand due to poor forecasts by customers). While it is difficult to capture the shareholder wealth effects of demand-side reasons because firms do not make such announcements because they reflect negatively on their customers, this glitch reason may be very important for firm performance. Therefore, although it is challenging to obtain publicly available data about demand-side reasons, this topic would deserve further investigation. Perhaps researchers could collect private firm data and investigate how operational performance has been affected by glitches arising from demand-side reasons.

Third, we applied a very strict glitch announcement sampling, excluding all announcements that contained any other information than the glitches that we wanted to capture. We noticed that supply chain glitch announcements were frequently combined with ‘bad news’ such as direct sales warnings and more speculative announcements that the bad economy might have an effect on sales in the future. It is possible that our sampling frame was stricter than the method

applied by Hendricks and Singhal (2003), potentially contributing to the divergence in findings between studies. Future studies may want to consider including controlling for due announcements as a moderator variable, along with others previously described variables such as non-traditional media outlets and demand-side glitches, in order to obtain a more holistic understanding of the drivers that create supply chain glitches and their respective effect on firm performance.²

5.4 Conclusion

In summary, we argued and showed through an event study that a supply chain glitch announcement still has a negative effect on shareholder value (−1.94%). Yet, this effect is much lower for the period which we investigated compared to the period covered by Hendricks and Singhal (2003) (−10.28%). Through an OLS regression, we found that firm size and debt-equity ratio significantly moderate this relationship. However, growth prospects and timing do not significantly influence shareholder wealth reaction. Finally, we showed the importance of glitch reasons, glitches arising from supply-side reasons tend to be evaluated much less severely compared to glitches from catastrophic, regulatory and infrastructural reasons. These findings show promise with regard to the evolution of SCM theory and practice. Perhaps our supply chain is evolving and becoming more robust, even with the greater demands firms place on their global supply networks today. However, much work is left to be done for understanding how firms can better prevent and mitigate supply chain disruptions and glitches.

Acknowledgements

We would like to thank graduate students Eva Kraak and Felix Joehnk for their contribution in the data gathering process.

Notes

1. We attempted to include the initial data-set but were not able to obtain the data from the authors.
2. We wish to thank and acknowledge one of the reviewers for providing this suggestion.

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