# Developing Supply Chain Resilience in the face of Ambiguity

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## Abstract

Extant supply chain literature has neglected ambiguity such as unanticipated threats (i.e. natural disasters), focusing instead on risk. This paper situates and grounds ambiguous threats in a supply chain context and empirically examines its impact on corporate performance using two major natural disasters in a quasi-experiment involving the global automotive industry. Organizational learning and geographic diversification, as dynamic capability factors, are shown to play a positive moderating role in developing the resilience in the face of such ambiguous threats. Instead, demand-driven supply chain leadership and excellence hardly matters. These findings allow us to draw managerial implications about ambiguous events and the role of mitigating strategies to develop supply chain resilience.

**Keywords:** Ambiguous threats, Natural disasters, Dynamic Capability, Resilience.

### Introduction

Extant supply chain literature has neglected ambiguity, focusing instead on risk. Ambiguous threats, as unexpected events, can have a profound impact on managerial decisions and ultimately a firm's supply chain resilience (March, 1994; Roberto et al., 2006). The real world is replete with ambiguous events such as natural disasters, industrial actions, product defects and recalls, that tend to affect enterprises and their supply chain (Aven, 2014; Natarajan et al., 2012; Waters, 2011). The aim of this paper is to review the extant literature to uncover how far this neglect goes and after highlighting its distinct importance, it uses a special case to ground ambiguous threats. In particular, we use two major natural disasters, namely the 2011 Japanese earthquake-tsunami (JET) and Thai flood (TF), as ambiguous threats. We study the impact of such unanticipated threats (i.e. natural disasters) on corporate performance using the global automotive industry as our study sample.

A conceptual framework relating ambiguous threats, supplier chain dynamic capability factors to global auto end assemblers' activities is developed and tested using data for the period 2010Q1-2013Q4 with a before-and-after design. As such we use these events as a basis for a quasi-experiment to explore the ambiguous threat they posed to automotive firms. In addition, drawing from past literature, documenting 'mitigation strategies' for such events, we investigate the

moderating role of supply chain dynamic capability factors. We also consider whether supply chain leadership and excellence, from a demand-driven value view, matter in mitigating the ambiguous threats to ensure firm's supply chain resilience.

First, we theoretically ground ambiguity in the supply chain literature and study it empirically. In particular, with its focus on linking ambiguous threats to corporate performance, this piece relates to Hendricks and Singhal (2005) who study the effect of supply chain glitches on corporate performance or shareholder value, though nothing specific or distinct as unexpected events. There are also firm-level studies quantifying natural disasters on firm performance (Leiter et al., 2009; Gunessee et al., 2018), but not on supply chain ambiguity per se. Although ambiguity has been studied, as highlighted above and will be evident with our review, this has mostly been theoretical in nature. What's more the ambiguous supply disruptions or glitches we study can be far more devastating and thus are too important to ignore. Indeed, they are on the rise (Wagner and Neshat, 2010).

Second, another novel aspect of this study is the examination of dynamic capability factors in mitigating the ambiguity and firm's supply chain resilience link. Though these factors are briefly outlined in the work of Fiksel et al. (2015), we propose to theoretically ground them concretely. In addition, to these factors we examine whether a supply chain that promotes demand-driven leadership and excellence matters. This is more from a practitioner viewpoint where industry analysts such as *Gartner* have used the so-called 'demand driven value network' concept to judge the supply chain of firms and pronounced themselves on their 'excellence' and ranking 'leaders'. Our query is how far this demand driven notion of the supply chain helps in the face of ambiguous supply disruption.

Third, this paper uses a natural setting by deploying a quasi-experiment to study ambiguous threats, proxied by natural disasters. This allows us to draw causal inference of 'ambiguous threats → firm's supply chain resilience, ruling out 'ambiguous threats ↔ firm's supply chain resilience'. This relates to the merits of such before-and-after analysis over the more common cross-sectional approach. This issue is also acknowledged by Hendricks and Singhal (2005) when they use a matched pairing in their study of supply chain glitches.

## Literature Review

*Ambiguous threats, risk and the supply chain: A review*

Ambiguity as per economics and finance literature is totally different from risk as decision makers cannot assign exact probabilities to randomness (Natarajan et al., 2012). Risk as per finance literature is a situation in which all alternate possibilities are known and the probability of occurrence of each states of nature can be accurately ascertained. On the other hand uncertainty refers to probability of occurrence of each state that cannot be foreseeable with complete confidence (Knight, 1921, p.198). Using the psychology literature, Ellsberg (2001) defined a terminology known as ambiguity which is a quality on the amount, type, reliability and unanimity of information giving rise to one's degree of confidence in an estimate of relative likelihoods and it is a condition that lies between complete ignorance and risk (see Martinez-Correa, 2012).

Global supply chains tend to be more susceptible to ambiguous events than localized product supply chains because they are long, globally dispersed and heavily influenced by different government regulation (Harrington et al., 2016). Ambiguous events create difficulties for both executives who attempt to cope with threats and surprises and also society which may need urgent action due to natural disasters or political upheaval. The spectrum of threats varies from known unknowns which refer to obvious threats such civil unrest where supply chains may be able to

formulate an adequate response to totally unknown unknowns. These are referred to as ambiguous threats where warning signals and the severity of consequences are unclear (Roberto et al., 2006). In addition contemporary supply chains are forced to make decision with incomplete information and lack of future knowledge, even though in the era of big data and computing technologies (Teece and Leih, 2016). Popular examples of such ambiguous events/threats are earthquakes and other climatological, biological, hydrological, meteorological and technological disasters, but also man-made occurrence such as security, political and technological threats.

*Dynamic capability and uncertainty*

Dynamic capabilities in general refers to a firm which is capable to integrate, build and reconfigure the internal and external resources as per the rapid changes (Teece and Leih, 2016). However, in the modern era supply chains are interconnected and they face deep uncertainty, where the occurrence and consequences of events are hard to predict (Teece and Leih, 2016). Hence, it is essential for supply chains to be agile and flexible to learn and manage global resources during an uncertain event and it should possess entrepreneurial and imaginative capabilities. It is also strongly argued that supply chain having strong seizing and transformational capabilities are resilient (Teece and Leih, 2016). Based on the above review we propose the conceptual framework as shown in Figure 1, which we call 'Ambiguous Threats-Dynamic Capability-Performance' framework.

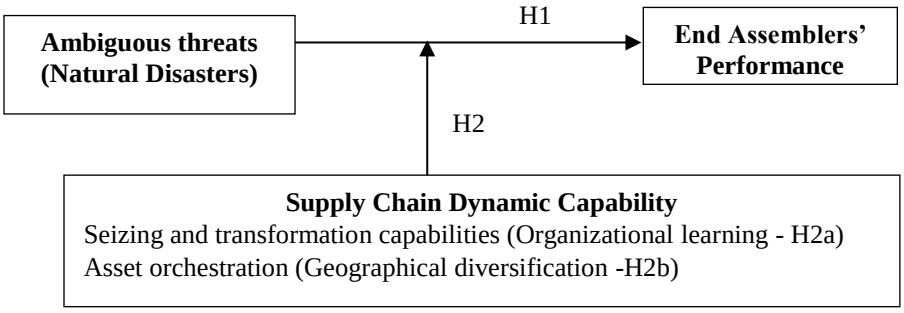


**Figure 1: Ambiguous Threats-Dynamic Capability-Performance framework**

The framework suggests a link connecting ambiguous treats to end assemblers' performance. To be precise we expect a negative relationship. We are also interested to connect dynamic capabilities with ambiguity in the supply chain. The hypothesis here is dynamic capabilities moderate the ambiguity-performance relationship. To be precise we expect a mitigating effect of such capabilities. These are defined as transformation capabilities, with organizational learning as an example, and asset orchestration, of which geographical dispersion/diversification is a manifestation. We expect such supply chain dynamic capability factors to play a moderating role and thus build/develop supply chain resilience in the face of ambiguous threats.

## Methodology & Data

Following Gunessee et al. (2018), the empirical strategy to test the above two hypotheses entails testing a direct effect and an indirect effect. With 'natural disasters' proxying for ambiguous threats we deploy before-and-after research design to examine to specific ambiguous events, namely, the

2011 Japanese earthquake-tsunami (JET) and Thai flood (TF), as ambiguous events. We use *JET* as a dummy variable to indicate discontinuity due to the *Japanese earthquake-tsunami*, taking a value of 1 for observations after the event and 0 before. Similarly, *TF* represents an event dummy defined as 1 for observations after the *Thai flood* and 0 before it happened. We use a Panel Regression model where the regression equation considered is:

$$Y_{it} = \alpha + \lambda_1 JET + \lambda_2 TF + \beta X_{it} + \eta_i + \phi_{it} + \varepsilon_{it} \quad (1)$$

where $Y_{it}$ denotes the dependent variable(s) for firm *i* and at time *t*, being *quarterly* time period. The explanatory variables $X_{it}$ are to be only included when addressing the questions of moderation and role of dynamic capability factors only. Additionally, the terms $\phi_{it}$ and $\eta_i$ are included to control respectively for *time varying* firm-specific and *time-invariant* factors (that affect performance).

Without specific context of a *Y-X* relationship, the parameters of first interest are the $\lambda$s, as they capture the *direct* effect (thus related to hypothesis H1). The *indirect* effect of dynamic capability factors, related to hypothesis H2, is studied through the interactions of the explanatory variables with the event dummies (i.e., *JET* and *TF*). We expect, as highlighted above, a positive link for the first and negative for the second.

We study these effects using quarterly data for the period 2010Q1-2013Q4. Quarterly data is used to better the post-disaster effect, which is less apparent in yearly. Monthly data would have been ideal but company data are rarely reported on a monthly basis. So to construct our chosen dataset, the selection of firms to form the sample of end assemblers is dictated by the following logic. Based on information about which industries were most affected by these disasters, the Auto-motive industry is chosen. Then, companies with quarterly reports dating back before the events, at least one year covering four quarters, are chosen. The list of end assemblers was retrieved from the *Morning Star* filings and websites of some of these companies. We classify a company as an 'end assembler' if its final products are mostly meant for consumers and as supported by industry reports. Based on the available data, the leading 26 Automobile companies were selected.

Table A.1 describes the variables and data sources. The dependent variable $Y_{it}$, sales ratio, is measured as sales to total assets. Sales is drawn from quarterly reports of the auto-companies spanning the period 2010Q1-2013Q4. Sales as a proxy for performance is driven by the rationale that the most directly measurable impact on firms would be felt on revenue first (see Manners-Bell, 2014, p.89).

**Results and discussion**

Table 1 depict direct effects of the two events, so-called ambiguous threats. The two regression results are reported. The first reports the results from both events, while the second specification reports the influence of JET only, by looking at two periods after the JET. Our results are partially supportive of the first hypothesis. H1 finds some support especially related to the JET. Both reported coefficients are negatively signed and statistically significant. Noting that that these point estimates show the 'controlled influence' of these ambiguous threats, unlike any uncontrolled effects one could find in the literature. It is also clear the effect is still robust when we focus solely on the JET, in the immediate aftermath of the event. As such this figure could be said to be illustrate immediate or 'short-term' effect two quarters after the event, while the first point estimate highlights the 'long-term' effect.

While statistical significance is one thing, the economic significance or size effect of these ambiguous threats is as important if not more. Such quantitative evidence provides valuable insights into an 'economic' interpretation of our results. So, given the dependent variable is sales

normalized by total assets, we could multiply sales ratio by 'average total assets', which should allow the interpretation of the point estimates in terms of sales (in millions of $). The average total assets for automobile firms in our sample are respectively 74657.49. The numbers after this short calculation are (for short-term and long-term effects respectively): $1721.42m and $2132.42m. This suggests an average sales of $2132.42m less after the JET in the short term compared to a long-term reduction of $1721.42m post-disaster.

**Table 1: Results on influence of ambiguous events**

| | Dependent Variable: Sales ratio | |
|---|---|---|
| | Automobiles | |
| | (1) | (2) |
| | Both events | Pre-Thai Flood |
| *Japanese Earthquake-Tsunami* | -0.023** | -0.029*** |
| | (0.010) | (0.011) |
| *Thai Flood* | 0.009 | - |
| | (0.006) | |
| Time Trend X Fixed Effects | Yes | Yes |
| *Number of Observations* | 416 | 182 |
| *Wald* $\chi^2$ | 1033.51*** | 693.80*** |
| $R^2$ | 0.728 | 0.818 |

Note: ***, **, * indicate that the coefficient is significant at the 1, 5, and 10% levels, respectively. Robust standard errors in parentheses.

One explanation why the Thai Flood is insignificant and in fact positively signed is that after the sudden occurrence of the JET which had a negative impact on industrial activity in general, including our sample of firms in the Automobile industry, there was some 'degree of preparedness' for such event in that firms learnt from such event. This is *organizational learning*. As such 'once bitten twice shy'. Anecdotal evidence confirm this to be the case. We highlight as supporting hypothesis H2 and that such organization learning to be a manifestation of dynamic capability resources within that help cope with ambiguous threats that epitomize in the words of Teece and Leih (2016), deep uncertainty. These are transformation capabilities as it's about seizing the opportunity to learn and adapt in the face of deep uncertainty.

Table 2 report how further dynamic capability factors moderate and thus mitigates the effect of ambiguous events/threats. In particular, asset orchestration/deployment as proxied by geographical dispersion. To study this question we interact the event dummies with explanatory variables that measure firms having alternative facilities in neighboring countries. Having such alternate production facilities can mitigate the negative influence of such catastrophic events as production grounds to a halt in the affected countries. This happens when production could be shifted in case of emergencies to these alternative production facilities by the firm in countries neighboring Japan and Thailand in Asia.

When focusing on the 'explanatory' variable *on its own or its non-interactive form*, the non-significant but negatively signed coefficient on 'alternate facilities' in an Asian country outside Japan and Thailand doesn't seem to matter that much. The negative sign could be capturing potential complexity costs of coordinating activities in multiple locations, such as forgone benefits of clustering/agglomeration.

**Table 2: Results on the moderating role of alternate facilities**

| | Dependent Variable: Sales ratio | | |
|---|---|---|---|
| | Automobiles | | |
| | (1) Both events | (2) Pre-Thai Flood | (3) Explanatory as dummy |
| *Japanese Earthquake-Tsunami* | -0.078** | -0.097** | -0.112*** |
| | (0.031) | (0.040) | (0.043) |
| *Thai Flood* | 0.039*** | - | 0.056*** |
| | (0.013) | | (0.009) |
| *Explanatory* | -0.036 | -0.018 | -0.115 |
| | (0.036) | (0.041) | (0.092) |
| *Explanatory* x *JET* | 0.037** | 0.045** | 0.097** |
| | (0.017) | (0.022) | (0.044) |
| *Explanatory* x *TF* | -0.020** | - | -0.051*** |
| | (0.008) | | (0.011) |
| Time Trend X Fixed Effects | Yes | Yes | Yes |
| *Number of Observations* | 416 | 182 | 416 |
| *Wald* $\chi^2$ | 1103.60*** | 799.21*** | 1155.61*** |
| $R^2$ | 0.742 | 0.840 | 0.751 |

Note: ***, **, * indicate that the coefficient is significant at the 1, 5, and 10% levels, respectively. Robust standard errors in parentheses. JET stands for Japanese earthquake-tsunami and TF for stands Thai flood. The *explanatory* variable here is having alternate facilities in neighbouring countries in Asia, which is an ordinal variable expect for column 3.

**Table 3: Results on the moderating role of supply chain leadership**

| | Dependent Variable: Sales ratio | |
|---|---|---|
| | Automobiles | |
| | (1) Above Average Inventory ratio | (2) Gartner |
| *JET* | -0.023** | -0.028** |
| | (0.09) | (0.011) |
| *TF* | 0.009 | 0.011 |
| | (0.006) | (0.007) |
| *Explanatory* | 0.690** | -0.052 |
| | (0.294) | (0.037) |
| *Explanatory* x *JET* | 0.152 | 0.020 |
| | (0.187) | (0.025) |
| *Explanatory* x *TF* | -0.088 | -0.008 |
| | (0.235) | (0.013) |
| Time Trend X Fixed Effects | Yes | Yes |
| *Number of Observations* | 416 | 416 |
| *Wald* $\chi^2$ | 1150.72*** | 1073.90*** |
| $R^2$ | 0.750 | 0.737 |

Note: ***, **, * indicate that the coefficient is significant at the 1, 5, and 10% levels, respectively. Robust standard errors in parentheses. JET stands for Japanese earthquake-tsunami and TF for stands Thai flood. The columns depict the *explanatory* variables used for that regression.

Of interest to us are the interactive terms. Focusing on *Explanatory x JET*, we see that post-JET influence of having operations elsewhere seem to play a positive role. This suggests after the JET some companies decided to shift operations abroad. Anecdotal evidence suggests Toyota led

by example in doing so. A stress test of this result by focusing on the immediate aftermath of JET and using alternate facilities as a dummy (see regressions 2 and 3 respectively), instead of an ordinal measure, is in keeping with this finding.

However, looking at the post *TF* influence of having alternate facilities reveals a negative influence. An explanation of this result can be found by looking at both *TF* and *Explanatory x TF*, which are respectively positively and negatively signed and significant. This is in line with a net positive but insignificant influence, we reported earlier for TF influence. As such our story of learning effects and some degree of preparedness is still at work here. In short, though there was a negative post-disaster effect, possibly due to an immediate supply chain disruption, it was offset by organization learning from experience, such as the need to keep sufficient inventory.

Table 3 presents our results related to another type of moderating influence and as stress test of nature of ambiguity in the supply chain context. We use *inventory* as a proxy of supply chain flexibility and thus a capability type. This is measured as *above average inventory ratio* (see Appendix Table A1). In the context of natural disasters or ambiguous events we argue it helps to have adequate inventory, meaning an excess inventory ratio and lower inventory turnover (both relative to some average) can help. The second factor we consider is supply chain leadership or excellence. Supply chain excellence and leadership is proxied by a company being ranked in Gartner's Top 50 Supply Chain Globally over our sample period. In a way it captures a highly performing supply chain which should be flexible and possibly resilient to such unforeseen events like natural disasters. We expect a positive post-event effect if firms have resilient supply chains (aka Gartner interactive dummies with JET and TF).

Looking at specification (1) we find that generally firms that keep above average inventory (i.e. excess inventory) seems to enjoy higher sales. However, the influence we are interested in, namely the after-event effect, seems absent. Though there is a positive sign for auto-makers post-JET, but negative sign post-TF.

Results with respect to 'supply chain leadership-excellence', offer no conclusive evidence that having a 'highly performing' supply chain matter – as defined by industry analysts – (all interactive intercepts for Gartner with the event dummies being insignificant). This suggests that even highly well performing supply chain in normal circumstances are not well equipped to deal with ambiguity, stressing the need to capture ambiguity in a firm's strategy as concern the firm's supply chain.

**Managerial implications**

It is obvious from our findings that ambiguous threats affected firms within the global automotive supply chain. In terms of micro level it also had a huge impact on firms and their supply chain. Based on this we explain how firms have to build their dynamic capabilities to be more resilient based on an interpretation using our findings and on studies by Fujita (2012) and the World Bank's 2012 Sendai report; related to ambiguity which is represented as supply chain vulnerability in general (Pettit et al. 2012; Fujimoto and Park, 2014; Matsuo, 2015).

First, end to end global supply chain need to have an alternate production option to virtually divert their attention in the event of ambiguity by having business continuity plans and backup systems. If it is not possible to virtually disperse by orchestrating their asset by geographical diversification to alternative facilities in their own country of operations or neighbouring countries depending on demand and market size. It is also effective to decentralize worldwide operations into different continents to gain orchestration flexibility with an additional cost certainly lesser than the ambiguity disaster after-effects.

Second in addition to orchestration the global supply chain should develop their seizing and transformation capabilities and in related vein, each end assembler need to identify the critical elements/bottleneck links to avoid failures and increase resilience. In the era of shared resources economy the global supply chains can enhance horizontal collaboration with their competitors to ensure higher resilience.

Third, with the support national and regional governments global supply chains can develop their organizational learning through frequent training to the firms susceptible to ambiguous threats, promote incentives along with sharing common pool of emergency management expertise to gear up firms during threats. Regional government can build confidence in these firms by way of expanding financial support, social nets, safety nets and community driven development programs.

We collected data from world leading automotive suppliers and end assemblers based on availability of quarterly reports. We excluded few prominent firms due to the non-availability of their quarterly reports. In future researchers can develop a comprehensive secondary data base to collect monthly or quarterly reports to precisely understand the micro details of various variables considered in such study. In addition future research can consider other variables from each functions of the supply chain such as production, supply, inventory, location, transportation and information flow.

## Concluding remarks

In this study we pay attention towards the relationship between ambiguous events and firms' performance. Similarly we empirically see the influence of supply chain dynamic capability factors such as seizing and transformation capabilities in terms of learning and orchestration of assets. The contribution of this paper is made to the supply chain resilience literature by highlighting the role of dynamic capability in the face of ambiguous threats.

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## Appendix

**Table A.1: Variables description and data sources**

| Variable Name | Description | Source |
|---|---|---|
| *Dependent variable(s)*: Sales ratio | Sales as a ratio of total assets (with original variables both being in US$ millions) | Quarterly reports of companies between 2010Q1-2013Q4. |
| *Independent variables*: Japanese Earthquake-Tsunami (JET) | Dummy to identify time before and after JET taking value of 1 after and 0 before | - |
| Thai Flood (TF) | Dummy to identify time before and after TF taking value of 1 after and 0 before | - |
| Above average Inventory ratio | Inventory as a ratio of total assets. Above average inventory ratio is constructed by subtracting the industry's average inventory ratio | Quarterly reports of companies for 2009Q4-2013Q3 |
| Above average Inventory turnover | Cost of sales as a ratio to Inventory. Above average inventory ratio is constructed by subtracting the industry's average inventory turnover | Same as above |
| Gartner | | Gartner's website |

| | | |
|---|---|---|
| | Dummy to identify if the firm appears in Gartner Top 50 Supply Chain over the period 2011-2013 | |
| Alternative facilities | Defined as an ordinal variable taking values 0, 1 and 2 to measure the presence of a firm in a country contiguous to Thailand and Japan | Companies' website |

Notes: 1) All independent variables are lagged by one period with respect the regressand. If the variable is unavailable we use two periods. 2) Some reports using local currency for the accounting variables were converted to US $. 3) Accounting variables were originally in US$ millions. 4) We use an ordinal measure and lump Thailand and Japan together to create *alternate facilities* because all PC makers has a plant neighboring Japan. 5) For our purposes we also created interactive terms, not reported above, between several explanatory variables and the two events dummies.