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Value of supply disruption information and information accuracy

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ABSTRACT

In this paper, we examine the factors that influence the value of supply disruption information, investigate how information accuracy influences this value, and provide managerial suggestions to practitioners. The study is motivated by the fact that although accurate disruption information creates benefits, fully accurate disruption information may be difficult and costly to obtain. Furthermore, inaccurate disruption information can decrease the financial benefit of prior knowledge and even lead to negative performance. To perform the analysis, we adopt a newsvendor model within a single product setting where the focal firm can source from a supply network and has a given resilience capacity. The results show that information accuracy, specifically information bias and information variance, plays an important role in determining the value of disruption information. This influence varies at different levels of disruption severity and resilience capacity, and our results imply that higher amounts of resilience capacity actually may be detrimental to a firm without accurate information about a disruption's influence. Thus, for companies with a high resilience capacity, obtaining quality information is critical for effectively coping with disruptions.

1. Introduction

With the growing complexity of current global supply networks, managing supply disruptions is becoming increasingly challenging (Basole and Bellamy, 2014a, 2014b; Hübner et al., 2014). These disruptions largely come from the intricate interactions among suppliers that make supply chains more vulnerable (Wagner and Bode, 2006), and they are often driven by events such as labour strikes, natural disasters, terrorism, and supplier bankruptcies. The situation is further complicated by the fact that 42% of such disruptions have been shown to originate below the first tier of suppliers (Business Continuity Institute, 2013), and most companies have very little visibility into their supply network beyond the first tier (Basole and Bellamy, 2014a, 2014b).

Increasing supply visibility, i.e. obtaining access to disruption information and risk evaluation in the context of supply chain risk management, is widely recognized as an important supply chain risk mitigation strategy (Craighead et al., 2007; Kirilmaz and Erol, 2015; Kleindorfer and Saad, 2005; Saghafian and Van Oyen, 2012; Tang, 2006; Tomlin and Snyder, 2006; Yang et al., 2008). In today's complex and dynamic business environment, researchers and practitioners are looking for different ways to increase supplier visibility, including visual analysis of supply networks (Basole and Bellamy, 2014a), investigation of the supply chain network risk propagation mechanism (Basole and Bellamy, 2014b; Garvey et al., 2015), identification of critical nodes in a supply network, and implementation of new technologies to mine information (Sanders, 2014). A recent example is IBM's announcement in 2015 of a $3 billion investment in its "Internet of Things" (IoT) unit over the next four years (IBM, 2015). This investment aims to provide real-time and accurate information to clients by mining sources of big data. One of IBM's IoT focus areas is supply disruption information.

Given the significance of supply disruption information, obtaining *quality* information is one of the most important investments for practitioners to make (Landwehr and Carley, 2014; Accenture, 2014; Sanders, 2014). Although timely access to accurate disruption information can allow the focal firm in the supply chain to better prepare for or respond to a potential disruption, fully accurate disruption information is hard to retrieve and costly to obtain in reality, and inaccurate disruption information can decrease the financial benefit of prior knowledge and even lead to negative performance. This is because underestimating the disruption influence can make it more difficult to recover from the disruption, while overcautious actions can cost money without providing benefit (Hübner et al., 2014). For example, the 2015 Nepal earthquake was successfully predicted to happen by seismologists (Mazza, 2015), and the World Food Programe (WFP) had supplies stored and a response plan in place (Page, 2015). Nevertheless, WFP still faced challenges in meeting local needs because they underestimated the disruption influence on the transportation network (Page, 2015).

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The trade-off between information cost and information accuracy leads to questions about how much should be invested to increase supply visibility and what the best approach is to making such investments. To answer these questions, we need to clearly understand the value of disruption information given a certain level of accuracy. We thus aim to investigate the relationship between information accuracy and the value of disruption information, in order to gain insights into the managerial implications of investing in disruption information.

In this study, we define "*disruption information*" to be information about the estimated influence of a supply disruption on the focal company. There are many types of information about supply disruptions, including information related to supplier reliability, disruption type, disruption influence, and the timing of the disruption. In particular, it is important to consider the likelihood of a disruption occurring and the influence on the focal company if it does occur. Our approach to determining the extent of this influence will be to calculate the ratio between the unfulfilled supply and the contracted supply from the main supply source. This allows for measuring both the*estimated influence*of a disruption, which is calculated before the impact of the disruption is actually known, and the*actual influence*of that disruption, which can be measured after the disruption's impact has been experienced.

The remainder of the paper is organized as follows: Section 2 provides a review of the literature on supply chain disruption information. Section 3 discusses the modelling framework and the newsvendor model that is used to formally calculate the value of such disruption information. In Section 4, we provide an analysis of the value of the disruption information construct given the estimated influence and the actual influence of the disruption. Then, in Section 5, assuming the information error is a variable, we analyze how the expected value of the disruption information changes with the mean and standard deviation of the information error. Finally, we summarize our findings and discuss a number of managerial implications, along with potential future work, in Section 6.

2. Literature review

Current research in supply chain risk management emphasizes the importance of supply disruption information using both qualitative (Craighead et al., 2007; Kleindorfer and Saad, 2005) and quantitative methodologies (Saghafian and Van Oyen, 2012; Tomlin and Snyder, 2006; Yang et al., 2008).

The qualitative studies tend to develop conceptual frameworks to derive new insights into supply chain risk management. For example, Kleindorfer and Saad (2005) highlight the importance of specifying the disruption source and assessing the disruption influence on managing supply chain disruption risks. Similarly, Craighead et al. (2007) present six propositions that relate to the severity of a supply chain disruption. One of the propositions states that a disruption in a supply chain with certain warning capabilities is less likely to be severe than one impacting the same supply chain with little or no capability to warn.

Comparatively, the quantitative studies tend to focus on mathematical modelling and on estimating the quantitative impact of the disruption information. Tomlin and Snyder (2006) build an inventory model to investigate how inventory systems can take advantage of a threat advisory system. Their study shows that supplier capacity and the structure of the disruption risk process significantly influence the value of a threat advisory system. Yang et al. (2008) take a different approach by studying the value of symmetric supply reliability information in a mechanism design theory framework. They investigate how the value of risk management strategies changes with asymmetric information. Finally, Saghafian and Van Oyen (2012) develop a newsvendor model to quantify the value of flexible suppliers and disruption risk information.

In this current study, we also apply a newsvendor model and investigate the relationship between information accuracy and the value of disruption information. This work falls into the category of quantitative research, and is expected to contribute to the literature in the following ways:

First of all, existing studies on the value of disruption information (Saghafian and Van Oyen, 2012; Tomlin and Snyder, 2006; Yang et al., 2008) define disruption information as information about supply reliability and assume an all-or-nothing influence of the disruption on the supply chain (i.e., the supply chain only has two states: fully functioning or non-functioning). In contrast, our work focuses on the fractional amount by which a disruption influences supply flow, and thus disruption influence is a continuous number between 0 and 1. By incorporating fractional disruption influences in the model, our study is able to better reflect reality and mainstream supplier disruption classifications. For example, many conceptual and empirical studies (Oke and Gopalakrishnan, 2009; Simchi-Levi et al., 2014) classify disruption risks into three categories: low-impact & high-likelihood, medium-impact & moderate-likelihood, and high-impact & low-likelihood. Such a classification scheme requires the consideration of different fractional levels of disruption influence.

Secondly, our study focuses on how information *accuracy* influences the value of disruption information. Although qualitative studies emphasize the importance of disruption identification and risk evaluation (Craighead et al., 2007; Kleindorfer and Saad, 2005; Tang, 2006), few quantitative studies consider the impact of information accuracy about disruptions. The disruption information (i.e., disruption influence, in this context) depends on many elements, including cognitive limitations and capabilities, the information source, the information perception process, and the decision maker's subjectivity. With the existence of information error, companies tend to be either overly cautious or not cautious enough in their actions. Both of these responses can cause potential economic loss, and thus studying the impact of disruption information error on the value of disruption information can have great practical significance.

To the best of our knowledge, among the quantitative studies on disruption information, only Saghafian and Van Oyen (2012) touch on the area of inaccurate disruption information. Defining the disruption information to be the estimated disruption reliability, Saghafian and Van Oyen (2012) briefly show that the value of disruption information is non-increasing with the absolute value of information error. Our work, on the other hand, views disruption information as a variable of the estimated disruption influence, and thus we can measure how the information bias and information variance influence the value of disruption information. This approach supports the development of a number of managerial implications that can be used to further improve decision making in this context.

As a third significant contribution to the literature, our study fills a gap in supply chain disruption research by focusing on disruption information from suppliers. Literature about inaccurate information in supply chains has two streams. One stream focuses on inaccurate internal information, specifically information about inventory (Cannella et al., 2015; Fleisch and Tellkamp, 2005; Kang and Gershwin, 2005; Kwak and Gavirneni, 2015; Sahin and Dallery, 2009; Sahin et al., 2008); the other focuses on the demand side, which is the quality of forecasted demand information (Chen et al., 2000; Forslund and Jonsson, 2007; Kerkkänen et al., 2009; Zhao and Xie, 2002). None of this existing literature addresses inaccurate supply disruption information and how information quality influences supply chain performance.

3. Modelling framework

In the following analysis, we apply a newsvendor model to calculate the value of disruption information. This supply chain model consists of one focal company that sources from one main supplier with known resilience capacity. This main supplier can be viewed as a black box of