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Testing Benford's Law for improving supply chain decision-making: A field experiment

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ABSTRACT

Supply chain managers must often trust data reported from suppliers to make decisions about sourcing and product reliability due to the costs or complexity of implementing traditional monitoring systems. Without some form of monitoring, these types of data are vulnerable to manipulation, thus making their suitability for decision-making ambiguous and creating an opportunity for 'supplier opportunism'. Recent practitioner literature suggests one solution to this problem they refer to as 'trust-but-verify'. The purpose of this empirical study is to scientifically examine the feasibility and cost of implementing one 'trust-but-verify' method in a real-world supply chain using a principle called Benford's Law. The results of this two-year study suggest that the technique is feasible and cost effective in identifying supply chain data that have been intentionally manipulated. This finding can allow supply chain managers to segregate suspect data from decision-making until they can be validated and thus mitigate supplier opportunism.

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1. Introduction

The trust of one's suppliers is critical to efficient supply chain management; however, failure to monitor supplier's activity increases the probability that a supplier will act in their own best interests—often to the detriment of other supply chain members. The literature often refers to this as an agency problem—and more specifically as supplier opportunism (e.g. Morgan et al., 2007; Wathne and Heide, 2000). Supplier opportunism takes many forms ranging from price-fixing to supplying poor quality products (Wathne and Heide, 2000). Recent high-profile examples include the melamine poison found in pet food and infant

formula, and the lead paint found in children's toys supplied to the US from Chinese vendors. Melamine, while toxic to humans and animals, was added to pet food ingredients and infant formula to inflate protein content (Kerley and Hartman, 2007); and lead paint, known to cause birth defects, was used in children's toys as a cheap substitute (US CPSC, 2007). The problem with supplier opportunism is that it can lead to huge losses for other supply chain partners such as manufacturers and retailers. In the melamine pet food case, an estimated 8,500 pets died of liver failure caused by the additive—with thousands of others left permanently injured. Diamond Pet Foods estimates losses could exceed \$50 million (US) in lost sales and liability lawsuits. In the infant formula case, Chinese officials report at least 54 thousand serious illnesses and four deaths linked directly to the tainted formula (Associated Press, 2008).

This issue presents a critical problem to operations and supply chain managers because they often trust vendors to ensure the quality of their own products; however, the

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literature promoting trust does not suggest that 'trust' means 'blind'. One approach to dealing with the trust issue is called 'trust-but-verify' (e.g. Adams, 2006). This technique suggests that buyer firms can 'trust' their vendors while also conducting a limited amount of monitoring or auditing to ensure they do not engage in supplier opportunism. In fact, several studies and texts (e.g. Wathne and Heide, 2000; Lambert, 2006) advocate supplier monitoring as a key component to effective supplier management. The way that firms operationalize 'trust-but verify' is to accept incoming goods from vendors without a priori testing, but then audit supplier performance. This approach has shown to mitigate the agency problem (supplier opportunism) among practitioners (Lebow, 2006; Duldner, 2006; Adams, 2006). In a supply chain context, 'trust but verify' can be used as a modified form of 'monitoring' and 'incentives' approach (Wathne and Heide, 2000) to mitigate supplier opportunism. Traditionally, these approaches mitigate supplier opportunism by re-inspecting what a vendor has produced or providing some benefit to suppliers for proper performance. The problem with monitoring approaches, such as acceptance sampling, is that they completely negate the 'trust' while slowing the flow of goods. The 'trust-but-verify' approach has reduced the agency problem in production workers (Lebow, 2006), attorneys (Duldner, 2006), and industrial suppliers (Adams, 2006). Despite its acceptance in industry as one method of mitigating supplier opportunism, there is a paucity of academic research that examines the effectiveness of the 'trust-but-verify' approach in achieving this goal.

The question is, "how can buyers efficiently 'trust but verify' supply chain quality without instilling a sense of distrust among their suppliers?" While there are other approaches to addressing supplier opportunism, selection of techniques is contextual (Stump and Heide, 1996). Traditional monitoring and auditing approaches are problematic in that they explicitly do not rely on trust (e.g. acceptance sampling), are expensive to implement, or require advanced skills to analyze and interpret (e.g. collecting and reading SPC charts from vendors). To address these issues, an exploratory study by Hales et al. (2008) found that a principle called Benford's Law, also known as digital analysis, can be used to audit supplier performance in an operational context. They found that digital analysis led to improved product quality because it identified fraudulent data (suspect data) in SPC charts. While often used as supplier audit tools themselves (Deming, 1986), SPC charts can be problematic because they can be intentionally manipulated to disguise problems (Hales et al., 2008). By identifying suspect data, buyers can strategically allocate scarce resources for limited monitoring while maintaining a sense of trust with their suppliers.

This purpose of this study is to test the feasibility, appropriateness, and usefulness of Benford's Law to mitigating supplier opportunism in the context of supply chain management. It specifically examines one method that can be used to 'monitor', and as an 'incentive' to suppliers that does not violate the 'trust' component, is relatively inexpensive to implement, and does not require

advanced analytical skills to conduct or interpret. This is the first study to address these effects simultaneously and is important because supply chain managers must 'trust-but-verify' a broad range of suppliers from many different industries around the world. From both a managerial and academic perspective we examine:

- The skill level necessary to perform the analysis.
- The level of training required to use and interpret the analysis.
- The cost of training.
- The availability of data necessary to conduct the analysis in a supply chain.
- The time it takes to conduct the analysis.
- The process of justifying the appropriateness of the data.
- The effectiveness of using the method over an extended, 24-month, period.

2. Literature review

2.1. Supplier opportunism

Supplier opportunism refers to a problem created when buyers trust suppliers to self-monitor their own business practices and product quality, and the suppliers fail to adequately do so (Morgan et al., 2007; Wathne and Heide, 2000). Supplier opportunism is caused by the 'agency effect' (Vaaland and Purchase, 2005) whereby suppliers behave in a manner that maximizes their benefits rather than the benefits of their supply chain partners. At a strategic level, Wagner and Johnson (2004) develop a framework for supplier relationship management that includes a portfolio approach—where the selection and management of any single supplier is performed with regard to how it affects the relationships with all suppliers and needs of the firm. This differs with the majority of supplier literature that typically focus only on single, dyadic relationships. They find that strategic supplier portfolios are comprised of three stages of planning, implementation, and monitoring & control. The Wagner and Johnson model is important to this study because it suggests a need for monitoring systems that can be applied to address a broad spectrum of opportunism types and control mechanisms in inter-organizational contexts.

In classifying the forms of opportunism, Wathne and Heide (2000) found that suppliers can exhibit both 'active' and 'passive' behavior in their opportunistic activities. Active opportunism occurs when a supplier performs intentional activities to create a disadvantage for a buyer. Passive opportunism occurs when a supplier fails to perform an activity that may provide an advantage for a buyer. Wathne and Heide also found these behaviors can occur in either new or existing relationships. They term opportunism in existing relationships as either as 'evasion' (an active behavior), or 'violation' (a passive behavior) opportunism. They term opportunism in new

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