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The green bullwhip effect: Transferring environmental requirements along a supply chain

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ABSTRACT

The bullwhip effect has long been recognized as a critical factor that amplifies demand variability as customer orders pass upstream through successive tiers of a supply chain. Like customer demand, environmental requirements also change significantly at times, and are passed along the supply chain to varying degrees, suggestive of what we term, the "green bullwhip effect". Based on field cases exploring changes in three supply chains across three adjacent tiers, we find evidence that such a phenomenon exists. First, ratcheting demands for better environmental performance are passed upstream through successive tiers with significant variation. Second, a green bullwhip effect is created as time to comply with specifications is compressed. Four different managerial responses, namely replace, accommodate, negotiate and collaborate, were observed to amplify or attenuate a green bullwhip effect based on the nature of firm relationships and balance of environmental capabilities at each tier. Of particular interest, the green bullwhip effect can force positive change, triggering the development of new environmental capabilities at multiple tiers in a supply chain.

1. Introduction

Over the last decade, as regional manufacturing has evolved into global supply chains, customer concerns and regulatory changes have increasingly focused on environmental attributes implicitly embedded in raw materials, components and finished goods. These environmental concerns have been enacted into public policies that capture the broader life-cycle of products, and therefore, firms increasingly have faced a wide range of environmental risks linked to their supply chains (Handfield et al., 2005). For instance, the unfortunate position that Sony found itself in 2001 illustrates the complex interplay of factors when product-based regulations are introduced. At that time, Dutch customs agents stopped nearly 1.3 million PlayStation consoles being imported into Europe because the cables contained levels of cadmium that exceeded the Netherlands' new environmental regulations. Sony had to bear significant costs for replacing the parts, storing goods and repackaging the final products (Carlton, 2006). After this incident, Sony accelerated its Green Partnership program in order to integrate environmental considerations across its global supply chain. In a similar manner, original equipment manufacturers (OEMs) have introduced environmental criteria in their supplier selection process (Bai and Sarkis, 2010), required environmental audits and certification schemes (e.g., ISO14001) from suppliers, and provided them with environmental training, education and other support (Rao and Holt, 2005; Lee and Klassen, 2008).

As seen in Sony's case, significant changes that improve the environmental performance of products and suppliers – often initiated by regulation – flow back upstream in the supply chain with uncertain consequences. Moreover, the level of pressure can vary greatly from one tier in the supply chain to another (e.g., OEM, first-tier supplier and second-tier supplier). For example, while upstream suppliers usually face less intense scrutiny from consumers and governments, they are often under considerable pressure from indirect regulations that are conveyed by customer firms (Green et al., 2000). At this point, we have little understanding about how quickly and to what extent more stringent requirements from markets or product-based regulations affect the supply chains of materials, components and subassemblies.

A growing number of studies have examined operational approaches that address environmental issues in supply chains, termed green supply chain management (GSCM). This literature has identified management practices (e.g., Min and Galle, 2001; Vachon and Klassen, 2006), explored internal and external drivers

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of practice, and assessed performance outcomes (e.g., Rao and Holt, 2005; Sarkis et al., 2010; Wu et al., 2012; Zhu and Sarkis, 2004). However, this research has largely adopted a static view, whereby suppliers are simply expected to meet new requirements and improve their environmental performance as new demands are placed on them, possibly coincident with developmental support from next-tier customers (e.g., Lee et al., 1997a; Machuca and Barajas, 2004).

In contrast, the broader supply chain management literature has emphasized the behaviors of buyers and suppliers from a dynamic perspective. In particular, the bullwhip effect is well known to illustrate how and why orders or information change as they pass along a supply chain, and how multiple tiers in the supply chain respond to this distortion of information. By extension, it is conceivable that new insights might be gained by considering potential dynamic behaviors in the context of environmental or social issues.

Given this promise, our research explores several questions. How do focal firms manage their supply base in response to significant changes in environmental requirements? More specifically, how are environmental requirements of customers adjusted as they transfer upstream in supply chains? In addressing these questions, this paper makes three contributions. First, this study extends existing literature by synthesizing earlier research areas, namely environmental management and supply chain dynamics, to propose a dynamic phenomenon whereby environmental obligations flow back upstream in the supply chain with significant variation, termed the green bullwhip effect. Second, this research offers empirical evidence for such a phenomenon from case studies at multiple tiers in three different supply chains. Third, our case studies are combined with the previous literature to construct an integrative framework that illustrates both the dynamics and potential managerial responses to tightening environmental regulations in the supply chain. Thus, the challenges and management actions arising from the green bullwhip effect establish the groundwork for a set of research propositions.

2. Foundational literature and concept development

To explore the dynamic nature of environmental issues in the supply chain, two broad streams of research are particularly informative: green supply chain management and supply chain dynamics. Combined, the former explores how environmental issues are characterized in the supply chain and the latter provides a basis for understanding the green bullwhip effect.

2.1. Green supply chain management

With the emergence of environment issues as a legitimate business concern in supply chain management, research has examined a wide range of issues under the umbrella of green supply chain management (GSCM), including practices, drivers, and outcomes (Zhu and Sarkis, 2006). More specifically, previous literature has characterized various elements of GSCM practices, ranging from green purchasing (e.g., Min and Galle, 2001), to environmental integration with customers and suppliers (e.g., Vachon and Klassen, 2006, 2008), to a closed-loop supply management (e.g., Kleindorfer et al., 2005). For example, Bowen et al. (2001) distinguished between "practices that green the supply process" and "product-based green supply practices" by differentiating between managing supplier risk and performance, and supply chain integration for sustainable products, respectively. Vachon and Klassen (2006, 2008) addressed two broad sets of GSCM practices: monitoring and collaboration. Monitoring generally relates to supplier and material selection practices, whereas collaboration focuses more on building suppliers' environmental capabilities. Zhu and Sarkis (2004, 2006) proposed a broader perspective of practices, including internal environmental management, green purchasing, investment recovery, eco-design practices, and cooperation with supply chain partners.

Second, several drivers for the adoption of GSCM have been identified. While pressure from multiple stakeholders is important, two groups of stakeholders are of particular relevance: customers and governments (Seuring and Müller, 2008). Green et al. (2000) provided empirical evidence that regulations played the strongest role in influencing environmental improvement, followed by market pressures. Of course, not all firms are exposed to the same types of regulations or pressures. Large, high-profile firms tend to face considerable pressure to improve their environmental performance; in contrast, smaller suppliers or suppliers distant from the end-consumer, have few obvious incentives. Yet, environmental pressures still are often passed upstream to suppliers, including smaller firms, from buying firms (Hall, 2000).

Collectively, the literature on environmental issues and supply chain management clearly has identified that regulatory and customer demands prompt GSCM practices in a focal firm, although with little research into the underlying dynamics. Of note, Hill (1997) recognized the importance of supply chain dynamics and its linkage to environmental pressures. Hall (2000) pointed out that buyer–supplier relationships play a crucial role in transferring environmental pressure and stimulating environmental change within the supply chain.

Some evidence has emerged that both a focal firm's power within the supply chain and its technical capabilities are critical to diffuse the environmental innovation upstream when faced with stakeholder pressure to improve environmental performance. For example, Cousins et al. (2004) took a contingent perspective in characterizing GSCM strategies, and identified four generic strategies based on the level of perceived environmental risks and the resources available to the firm: "why bother", "no choice", "enthusiasts", and "go first". Their model assumed that the greater the level of perceived risks to the firm and available resources, the greater the likelihood that a firm will react in some way to minimize the expectation of the loss related to the risks. Of particular note, their study recognizes that GSCM strategy might be adjusted as circumstances change.

2.2. Bullwhip effect

Within operations and supply chain management, the demand-related bullwhip effect is well known: variability in customer demand often becomes amplified as orders pass upstream in a supply chain. In general, three characteristics are evident: oscillation, amplification and phase-lag (Forrester, 1961; Lee et al., 1997b). Oscillations and amplification occur as orders boom and bust over time, causing excessive inventories, and thus variance in order size increases as orders pass upstream in the supply chain. Phase lags indicate that inventory levels peak, potentially followed by backlogs, delayed to some extent at each subsequent tier in the supply chain. This phenomenon is costly because it causes excessive inventories, unsatisfactory customer service and uncertain production planning.

Previous research on the bullwhip effect has explored both underlying causes and options for its alleviation. The underlying operational causes include the distortion of information, increasing batch size to reduce setup costs, rationing of inventory, and logistics delays (Lee et al., 1997a). Each cause can be complicated by a variety of managerial decision-making heuristics and bounded rationality (e.g., Sterman, 1989). For example, information transferred in the form of orders tends to become distorted as firms seek to protect themselves from demand uncertainty or shipping delays. Also, some members of the supply chain do not adequately account for time delays when ordering, expecting