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International Supply Chain Resilience: a Big Data Perspective

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Gary Graham

Abstract

It was not a natural disaster but terrorism (the September 9/11 attacks) that brought into question the transactional orthodoxy guiding the post-Cold War design configuration of international¹ supply chains. The US government reaction was to put social pressure and introduce trade measures on multi-national enterprises (MNEs), who were importing manufactured products based on scale economies and low factor production costs. They were forced to self-police their supply chains and implement security measures. If they were able to continue to have access to the US market. In order to reduce security risks they had to become involved in public/private partnerships, have C-TPAT accreditation, build up buffer “stock” and offer financial support to domestic manufacturer’s and logistic firms. This was perceived as a cost of production rather than a source of future capability. However security poses only one source of disruption and it became evident that there were many natural as well as man-made disasters confronting international supply chains. Therefore, by 2005, the work of MIT’s Yossi Sheffi with his seminal book “The Resilient Enterprise” brought scholarly attention to the need for firms to have resilient supply chains. A chain robust enough to absorb disruption, keep functioning and return back to normal supply activity in as short a time as possible. In 2015, Sheffi re-emphasized the power of resilience in the supply chain through his latest book “The Power of Resilience: How the Best Companies Manage the Unexpected”. This perceived resilience as a capability for building supply chain competitive advantage. Whilst supply chain resilience has grown as an important scholarly field, one area overlooked by scholars is the role to be played by big data technology. In this technical viewpoint we explore the role that big data could play in the supply chain, to improve its resilience and transform its operational capability. It acknowledges the reasons for the dearth of scholarship and also looks at the “dark side” of big data as well as highlighting the contribution that such technology might play in a radical revision of the resilience discourse. Finally, we propose an initial theoretical framework with examples of the type of operational capabilities that big data could bring with respect to international supply chain resilience.

Introduction

In the supply chain capitalism approach of Tsing (2009) international supply chain configuration decisions were simply a result of economic and exploitative determinants. Even though supply chains proved highly profitable for the multi-national enterprises (MNEs) orchestrating their design, they were also very much based on oversimplified analytics and limited data availability. Globalization exacerbates supply chain risks since the resulting dependencies might lead to risks on the demand side as well as the supply side (Thun and Hoening, 2011). It is thus based on the strategic importance of supply chains that disruptions and the associated operational and financial risks represent the most pressing concern facing firms that compete in today's global marketplace (Craighead et al., 2007). Extant research has confirmed the costly nature of supply chain disruptions, for example, during recent mega-

¹ We use the terms “international” and “global” supply chains interchangeably. An international or global supply chain is a dynamic worldwide network when a company purchases or uses goods or services from overseas. It involves people, information, processes and resources involved in the production, handling and distribution of materials and finished products or providing a service to the customer (Tsing, 2009, p. 148)

disasters, such as the 2011 Great East Japan Earthquake and the 2011 Thailand floods, interdependencies in supply chains caused substantial economic damage (Haraguchi and Lall, 2015). More recently, the port explosions at Beijing's maritime gateway affected most of the 285 'Fortune Global 500' companies with offices in Tianjin, with the automobile sector taking the hardest hit (Mladenow et al., 2016).

Therefore, in order to overcome their vulnerabilities, respond effectively to the negative effects of disturbances (Patil and Kant, 2016) and improve competitiveness (Pourhejazy et al., 2017) international supply chains must be resilient. A resilient international supply chain has adaptive capability to manage disruptions by enabling the supply chain to bend rather than to break and many authors agree that it is a property that increases the sustainable competitive advantage of firms (e.g., Ponis and Koronis, 2012; Melnyk, 2014; Ambulkar et al., 2015).

International Supply Chain Resilience

Whilst the evolution of resilience may have been plagued by competing definitions, there is general consensus that it is a multifaceted concept, which is increasingly being used as a metaphor in diverse fields of study to examine system propensity to adaptation (following a disturbance). According to the systematic review conducted by Annarelli and Nonino (2016), the main subfield of research has been international supply chain resilience.

Indeed, Papadopoulos et al. (2017) have acknowledged that supply chain networks resilience has become one of the most debated subjects among scholars in operations and supply chain field. The significance of international supply chain resilience is validated by the latest Gartner's Supply Chain Top 25 report (Hofman et al., 2011), in which authors identify resilience as being one of the four major themes for 2011 (Ponis and Koronis, 2012). So much importance is attached to resilience perhaps because it is often perceived as highly desirable given that it increases a firm's readiness in dealing with risks that can emerge from the customers' side, the suppliers' side, the internal processes adopted and the supply chain integration mechanisms employed (Purvis et al., 2016). It also often includes examining how a system can restore after a disruption, as opposed to only examining how to prevent disruptions (Taquechel, 2013).

Competing as the case may be, it seems that more recently some progress has been made in the direction of a mutually acceptable definition. Annarelli and Nonino (2016) have observed that the academic literature has reached a shared consensus on the definition of resilience. An examination of some of the definitions provided for international supply chain resilience seems to support the view that no conceptual differences between the definitions of the supply chain's adaptive resilience capability at the system level are currently apparent in the literature (Scholten et al., 2014). For example, Rajesh (2017) acknowledges resilience as the property of supply chains to handle impending vulnerabilities and potential disruptions, whereas to Kumar et al. (2010, p. 3721) "*resilient* international supply chain networks need to be built having the ability to maintain, resume and restore operations after any disruption." It can thus be thought of in terms of "shock absorption" between stages of the supply chain (Sheffi and Rice, 2005). In this work we adopt the following definition which seems to reconcile both the proactive and reactive view of resilience whilst emphasizing its strategic potential:

International *supply chain resilience is the supply chain's ability to be prepared for unexpected risk events, responding and recovering quickly to potential disruptions to return to its original situation or grow by moving to a new, more desirable state in order to increase customer service, market share and financial performance* (Hohenstein et al. 2015, p. 108)

The importance of global supply chain management to a firm's bottom line has created the impetus for supply chain researchers to channel efforts in unpacking the factors that promote resilient capabilities. However, given the imprint of heterogeneity in its genealogy, the operationalization of international supply chain resilience has proven to be as elusive as its definition. For example, it has been suggested that the early conceptualisation of resilient capabilities was beset with vagueness, imprecision, as well as inconsistencies (Sahu et al., 2017). Furthermore, as Juttner and Maklan (2011) has rightly observed, the divergent concepts from theory building have led to an inconsistent use of terminologies in order to develop international supply chain resilience through antecedents, attributes, capabilities, elements and enhancers. Whilst Annarelli and Nonino are probably right about the mechanics of achieving resilience in practice, scholars seem to have settled on the formative elements of resilience. Increasingly these formative resilience elements are being captured at a capability level (Ponomarov and Holcomb, 2009). Formative resilience capabilities are based on integrating and coordinating resources which often span functional areas and thus may become manifest in the supply chain processes. In the literature, a range of overlapping terminologies for these formative resilience capabilities is suggested (see Ponomarov and Holcomb, 2009 and Briano et al. 2009 for overviews). The four capabilities of flexibility, velocity, visibility and collaboration appear to be the most frequently mentioned and according to Juttner and Maklan (2011) they seem to capture the conceptual essence of all suggestions. In this work we maintain the same line reasoning and such being the case, the rest of this paper interrogates the utility of Big Data technologies in strengthening or developing supply chain resilience capabilities.

Big Data

Big Data can be defined as multimedia-rich and interactive low-cost information resulting from mass communication (Zhan et al. 2016). It was initially characterized in terms of the high volume of data, the high velocity of nearly real-time or real-time data creation, and the high variety of data from different sources. More recently, Wamba and Akter (2015: 61) extended this original characterization by redefining Big Data as: "a holistic approach to manage, process and analyse the 5Vs (volume, velocity, variety, veracity, and value) in order to create actionable insights for sustained value delivery, measuring performance and establishing competitive advantages." This more contemporary definition is implicit in stressing that the value levers of big data are not inherent in the data per se but rather incumbent on how these are managed and embedded within extant organizational processes. The notion of embeddedness is in sympathy with the idea of resource reconfiguration or alternatively capability formation or renewal. Therefore, this bodes well with the notion big data could be viewed a critical building block of supply chain resilience capabilities and its eventual reconfiguration.

Big Data Analytics

Big Data analytics (BDA), on the other hand, is the process of using analysis algorithms running on powerful supporting platforms to uncover potentials concealed in big data, such as hidden patterns or unknown correlations (Hu et al., 2014). Hence, as Russom (2011) observes, BDA is really about two things - big data and analytics - plus how the two have teamed up to create one of the most profound trends in business intelligence (BI) today. Recognising their mutual interdependencies in supply chain management it is now common to speak in terms of Big Data and predictive analytics (Papadopoulos et al., 2017) as an all-encompassing term for techniques destined to handle Big Data. For instance, Markov chains, Markov decision processes (MDPs), queuing theory and discrete state models are widely used analysis, optimization and decision making tools.

Integrating big data with international supply chain resilience

Roberta-Pereira et al., (2014) have noted that scant attention has been paid to investigating relevant issues orientated to the enhancement of resilience in supply chains in spite of the efforts of some researchers to explore ways to better adapt to unforeseen disturbances. Perhaps what is even less forgiving, particularly in the context of the digital revolution era, is the serious lack of research efforts to examining the value digital information and communication technologies (DICT) brings to this debate. This is surprising given that the potential of DICT in enhancing supply chain resilience is widely recognised by SCM practitioners and commentators alike. For example, writing in Forbes, Culp (2013) acknowledges that when configured correctly, DICT can increase supply chain resilience through analytics, data and information sharing, scenario modeling, and pre-programmed responses. Of all the emerging and new DITCs, Big Data and predictive analytics (BDPA) appear to be the technology of choice for supply chain optimization.

There may be reasons for this lack of scholarly focus. Most works on big data have focused downstream on forecasting, market intelligence, last-mile logistics or on inventory management and process improvement. Therefore the focus has typically been with realising new market opportunities, efficiency or cost reduction. Another focus is with privacy and security issues and the risks to supply chain actor confidentiality of big data (“dark side”). Although big data has been glamorised as the information “bloodstream” or “*key strategic asset*” of future city design (smart cities) and connected car transport (i.e. mobility services) it’s social as well as economic value to society and citizens is not as well popularised. Certainly neither resilience nor supply chain resilience has not been a key topic in “big data” strategy.

Big Data-Supply Chain Resilience Model

In beginning to answer the research question of how big data can be used to improve supply chain resilience we have opted for a capability approach. Based on a detailed review of relevant empirical literature developed the following framework that is presented in Figure 1. The framework is set up to demonstrate how big data could be leveraged to respond to the

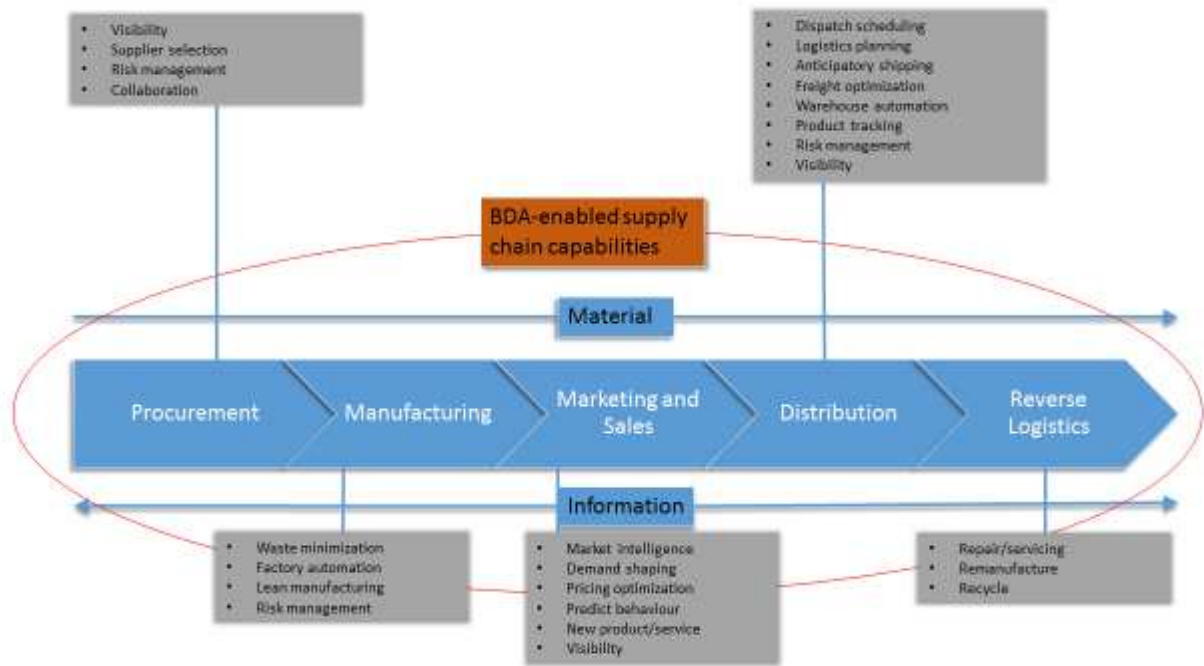


Figure 1 Big Data Resilience Model

challenges of climate change, protectionism and sustainability.

Our analysis of the empirical work already conducted suggests that while companies do not set out to achieve supply chain resilience, the adoption of various big data technologies has inevitably led to the development of resilience capabilities along the supply chain. Drawing on the findings, scholars generally recognised that BDA could be leveraged in different parts of the supply chain in order to create value. In other words, there is widespread acceptance that BDA is valuable when it is used to create distinct capabilities as previously argued. In the main, the findings reveal that organizations are making use of the predictive proclivities of BDA to strengthen their decision making capabilities (Schoenherr & Speier-Pero, 2015) in a number of key supply chain activities. Some of these big-data enabled capabilities include market sensing (Chae, 2015; Lee, 2016; Li et al., 2015; Liu and Wang, 2016), planning and forecasting in different areas such as in logistics (Liu and Wang, 2016; Zhong et al., 2015) and demand and sales (Schoenherr and Speier-Pero, 2015), risk management (Papadopoulos et al., 2015; Wu et al., 2015; Zhao et al., 2015; Zou et al., 2016) and innovation (Tan et al., 2015) and most importantly visibility across the whole supply chain. These capabilities along with others depicted in the framework above can be themed around the four formative supply chain resilience elements of flexibility, velocity, visibility and collaboration. .

Firms may also, for example, design their supply chain in order to take advantage of operational synergies and therefore plan their network to enhance individual capabilities by merging operations (Chae, 2015); to manage imbalances between supply and demand (Zhao et al., 2015); or to manage uncertainty of the supply of input resources (Liu and Wang, 2016).

Summary

Adopting the global supply chain capitalism approach of Tsing (2009) or the transaction economics approach of Williamson (2010) big data would provide more sophisticated and enhanced resources for the international capitalist to squeeze even more value from chain configuration. It would provide far more superior optimization, accurate forecasting, track and trace capability and sophisticated means for accurately measuring the value contribution of each node (i.e. value added, efficiency and costs).

Running counter to the notion of a rampant supply chain capitalism piggy backing on the back of global free trade, there is evidence in the West of a more protectionist stance, in particular in the US, with the rise of President Donald Trump and in the UK with Brexit. Re-shoring, industrial strategy and localization of production is back on the political agenda in many Western economies as they seek to rebalance their financial and service driven economies and also strive to deal with an ever increasing productivity crisis and stagnant growth. As well as political pressure, new technologies are emerging which are facilitating less international production such as 3DP, additive manufacturing, robotics and drone technologies. Such technologies could facilitate shorter supply chains, with value pushed closer to the consumer and retained by the city where the goods are consumed rather than the value being globally diverted by the MNE's into a tax haven. Much shorter supply chains could by their nature be more resilient.

However if we take a more neutral capability approach (Teece, 2007) one can observe that driven by the needs to be efficient and scale economies, most global supply chains have been designed using economic and operational factors such as cost, quality, flexibility, speed and delivery. These configuration decisions were based on oversimplified analytics and limited data availability. The consequences of inaccurate data analysis meant a failure to fully optimize supply chain nodal capabilities. These capabilities are increasingly needed to deal with the rapidly increasing threat say of climate change and its negative performance impact. For instance, supply chain nodes being located in vulnerable areas (a decision based on cost not by climate vulnerability), the production technology misfit with product modularity, and the product not matching local customer expectations. Big data if managed carefully could be adopted to improve international supply chain configurations so that they are both resilient and economically viable.

Whilst growing attention in the supply chain discipline is now with the threat of "last mile" logistics to resilience: as firms seek to exploit digital economy technologies, gig workers (self-employed, freelanced, minimum wage rates) and deregulated city transportation policies. This is a short run phenomenon and the real long run threat is that of climate change and the need for resilience to permeate throughout the global supply chain. Big data could play a role in enabling supply chains to be configured by resilient capabilities rather by scale economies and the (low) costs of production/logistics. Rather than exploit workers in the last mile, digital technology can and should be used to improve: nodal location decisions; worker conditions; the carbon footprint, wastage and pollution. We need as supply chain scholars and practitioners to recognize that we are no longer in the 20th century design configuration era of "time-space" compression, but rather we are in a 21st century era of "big data-climate change". It is time to critically rethink our scholarship and offer 21st century resilient solutions for 21st century issues, challenges and problems.

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