Transportation Research Part E 73 (2015) 152–167

Contents lists available at ScienceDirect

Transportation Research Part E

journal homepage: www.elsevier.com/locate/tre

On returns and network configuration in supply chain dynamics

Roberto Dominguez [a,*], Salvatore Cannella [a,b], Jose M. Framinan [a]

[a] Industrial Management, School of Engineering, University of Seville, Ave. Descubrimientos s/n, Seville E41092, Spain
[b] School of Industrial Engineering, Pontificia Universidad Católica de Valparaíso, Ave. Brasil, 2362807, Chile

ARTICLE INFO

Article history:
Received 21 May 2014
Received in revised form 24 November 2014
Accepted 26 November 2014
Available online 17 December 2014

Keywords:
Returns
Bullwhip Effect
Transport
Divergent supply chain
Serial supply chain
Simulation

ABSTRACT

This research focuses on how two common modeling assumptions in the Bullwhip Effect (BWE) literature (i.e., assuming the return of the excess of goods and assuming a serial network) may distort the results obtained. We perform a robust design of experiments where the return condition (return vs. no return) and the configuration of the Supply Chain Network (SCN) (serial vs. divergent) are systematically analyzed. We find an important interaction between these assumptions: the impact of returns on the BWE strongly depends on the SCN configuration. This study highlights the importance of accurately modeling SCNs to properly assess SCNs managers.

1. Introduction

Bullwhip Effect (BWE) is undoubtedly one of the most widely investigated phenomena in the modern day Supply Chain Network (SCN) management research (Haughton, 2009; Nepal et al., 2012; Cantor and Katok, 2012; Li and Liu, 2013; Zotteri, 2013; Turrisi et al., 2013). In the last decade, several studies have been aimed towards a better understanding of the causes of BWE, as well as their economic consequences and remedies. In order to analyze this phenomenon under real business world conditions, increasingly complex mathematical representations of SCNs (such as multi-product scenarios (Potter et al., 2009; Wangphanich et al., 2010), stochastic lead times (Chatfield et al., 2004; Dominguez et al., 2014), production/distribution capacity constraints (Spiegler and Naim, 2014; Cannella et al., 2014a), reverse logistics (Zhou and Disney, 2006; Turrisi et al., 2013) and so on) have been developed. Despite this, until now, only a few studies have focused on how the modeling assumptions can alter (i.e., overestimating or underestimating) the outcome of the BWE analysis. In this line, the recent work by Chatfield and Pritchard (2013) represents an interesting effort in a relatively new stream on BWE research aimed at improving our understanding of SCN modeling assumptions. These authors analyze the impact of the allowance/disallowance of the return of goods on the BWE in a four echelon serial SCN. Within the former assumption, orders may be negative in size, which essentially model the return of goods. All returns are sent to the upstream partner (i.e., back to the node they originally came from) where they become part of the upstream node's inventory. In the latter assumption orders are truncated at zero units, not allowing the return of goods to the upstream partners.

As underlined by Chatfield and Pritchard (2013), the literature on BWE has almost universally accepted the assumption that orders may be negative in size even though this is an unusual assumption in the literature at large. They prove that SCNs allowing returns may result in a significantly larger BWE. Furthermore, the increase in order variance due to the returns may be quite dramatic at the upper echelons of a SCN. Thus, according to the results of Chatfield and Pritchard (2013), the BWE is

* Corresponding author. Tel.: +34 954488137.
E-mail address: rdc@us.es (R. Dominguez).

http://dx.doi.org/10.1016/j.tre.2014.11.008
1366-5545/

overestimated if a real-life SCN that restrict returns is modeled under the negative orders assumption. Overall, their investigation of the impact of returns on the BWE has questioned the default assumption (practically universal in BWE modeling), that returns are permitted.

One extremely interesting research proposal is to analyze whether this ground-breaking finding continues to hold for more complex and realistic SCN configurations than a simple serial SCN. In fact, the configuration of the SCN is assumed to be serially-linked in most of the existent literature related to the BWE (see Wei et al., 2013; Li and Liu, 2013; Trapero et al., 2012; Cantor and Katok, 2012; Liu et al., 2009; O'Donnell et al., 2009; Ouyang, 2007; Machuca and Barajas, 2004; Chatfield et al., 2004; Dejonckheere et al., 2004, among others). Thus, we contribute to this line of research by analyzing how these two universally adopted modeling assumptions impact on the BWE and transportation issues, and their modeling and managerial implications. To do so, we compare the performance of the classical serial SCN and that of a complex divergent SCN under the assumptions of allowance/disallowance of negative orders. We first model a four-echelon serial SCN using SCOPE, a Multi-Agent Systems (MAS) based SCN simulation tool (Dominguez and Framinan, 2013). Then, we perform a similar computational experience with a four-echelon divergent SCN model (i.e., 8 Retailer, 4 Wholesaler, 2 Distributor and 1 Manufacturer), in which each node is furnished by two downstream nodes. Finally, we analyze the results obtained by performing analysis of variance (ANOVA). The results show a strong interaction effect between the two modeling assumptions under analysis, as the impact of the returns assumption on the BWE is different on the two configurations. More specifically, the divergent SCN is less affected by the return of goods than the serial SCN, due to the lower return of goods observed. This reduction in returns is caused by the compensation of independent demand streams received by nodes of the divergent SCN (portfolio effect).

In addition, the divergent SCN experiences a lower increase in transportation costs as compared to those in the serial SCN under the returns assumption. In case of allowing the return of goods, the increase in the volume of transportation due to the two-way transport (and its associated costs) is lower in the divergent SCN than in the serial SCN. In case of a restriction in the return of goods, the "lumpy" demands generated (one or more zero-sized orders separating positive orders) and its associated costs derived from the inactive periods of transport facilities are also lower in the divergent SCN than in the serial SCN.

The rest of the paper is organized as follows: Section 2 presents a background on BWE. Section 3 briefly describes the methodological approach and the model verification. Section 4describes the serial SCN and the divergent SCN models. Section 5 is the measurement system and the design of experiments. Section 6 presents the results and findings. Section 7 is a summary of modeling and managerial implications and finally Section 8 is the conclusion and limitations of the research.

2. Background: BWE and modeling assumption

Managing a SCN is a dynamic decision task shown to be prone to systematic errors, collectively referred to as the BWE (Cantor and Katok, 2012). The BWE refers to the tendency for order variability to increase within a SCN as orders move upstream from customer sales to production (Croson et al., 2014). BWE is observed frequently in industries (Chen and Lee, 2012), and it has been estimated that the economic consequences of this phenomenon can be as much as 30% of factory gate profits (Metters, 1997). Moreover, the recent, sudden, severe and synchronized trade collapse has led to an exasperation of BWE on several manufacturing sectors (Dooley et al., 2010; Cannella et al., 2014b). Considering the transmission mechanism of global SCN, this exasperation has created a detrimental "domino effect" throughout the world economy. Due to the magnitude of this phenomenon, it has received a lot of attention by SCN managers and researchers (Zotteri, 2013; Li and Liu, 2013).

Forrester (1961) was among the first researchers to describe this phenomenon and called the effect "demand amplification" (Disney and Lambrecht, 2008). Yet, the research into the 'BWE' problem started even prior to Forrester's seminal contribution, and a wide range of seminal works were made prior to its 'rediscovery' in the late 1990's (Holweg and Disney, 2005). In fact, Mitchell (1924), an economist at the Federal Trade Commission, first identified the mechanisms through which retailers, caught short of supply, increase their orders to suppliers. At the end of the 21st century, Lee et al. (1997a,b) published two of the most popular papers in the field of SCN management. Based on a case study, they identified four causes of Mitchell's *false demand* phenomenon and renamed it "BWE".

Due to the magnitude of the BWE problem, since Mitchell's work (1924) numerous studies have been generated to better understand causes, economics consequences and remedies to this effect. The investigation into this phenomenon has passed through diverse phases (Holweg and Disney, 2005), producing several streams of research (Holweg et al., 2005). Zotteri (2013) identifies three main streams (i.e., theoretical, empirical and natural experiment). The theoretical stream is devoted to the identification of the causes and potential solutions, with a specific focus on information as a potential remedy for the BWE (e.g., Baganha and Cohen, 1998; Chen et al., 2000; Cachon and Fisher, 2000; Lee et al., 2004). In the second stream, some contributions use the classic Beer Game (see e.g., Croson and Donohue, 2005, 2006) or one of its variants (Anderson and Morrice, 2000; Cantor and Katok, 2012; Croson et al., 2014) to create empirical data in a controlled environment and test hypothesis on the technical and behavioral causes of the BWE and its potential remedies. Finally, the natural experiment provide evidence for the existence, size and consequences of the BWE in several companies (e.g., Cachon et al., 2007; Dooley et al., 2010; Altomonte et al., 2012; Zavacka, 2012; Bray and Mendelson, 2012; Shan et al., 2014).

Similarly, Trapero et al. (2014) identify two different streams. The former concerns the theoretical analysis, which is based on initial assumptions about the underlying demand process and the stock policy in order to develop different