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Order-Up-To policies in Information Exchange supply chains

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ABSTRACT

Collaboration in Supply Chains (SC) is concerned with the alignment of the decision making process amongst SC partners. This is crucial in the planning and inventory management area where this alignment is enabled by the exchange of information. Several benefits deriving from such effective collaboration exist, such as: excess inventory elimination, lead times reduction, improved customer service, efficient product development, etc. Operations Management literature proclaims the virtues of collaboration and information sharing but academicians and practitioners have recently identified various gaps that still need further work. More specifically it has been shown that several deleterious phenomena as the bullwhip effect; inventory instability and intermittent orders are not completely eliminated in Information Exchange supply chains. The reason is mainly because companies adopt order policies that are prone to create instability along the SC. In this paper we show how the performance of an Information Exchange SC can be improved by shifting from a myopic periodic review Order-Up-To policy to a periodic review Order-Up-To with feedback gain. To do so, we model the SC structure through difference equations and study the system response in term of internal process efficiency and customer service level.

1. Introduction

Supply Chain (SC) Collaboration has been very largely discussed in the scientific literature and the benefit of its application has been strongly advocated by consultant and academic alike since the mid 1990s [1]. Over the past decade, the efforts of Wal-Mart, Target, Procter & Gamble, Sears, Ace Hardware, JC Penney, Cisco Systems, IBM, SUN Microsystems and Dell Computer, amongst others, have shown that such a proactive and anticipatory business model that involves coordination and collaboration between SC partners enhances sales revenues and margins increase [2]. Notorious large-scale SC collaboration projects, such as efficient consumer response [3], vendor managed inventory [4], continuous replenishment [5], collaborative planning, forecasting and replenishment [6], and centralised inventory management [7], have reshaped material and information flows, intensified alliances and transformed strategies, organisations and corporate culture [8].

SC collaboration has been defined through a number of dimensions such as information integration, synchronised planning, work flow coordination, new business models [9]; information sharing, decision synchronisation, incentive alignment [10]; cross functionality, process alignment, joint decision making, shared performance metrics [11]. As reported by Holweg et al. [1] even if SC collaboration comes in a wide range of forms, in general, it has a common goal that is to create a transparent, visible demand pattern that paces the entire SC in order and support supplier for enhancing inventory control. Both strategic information and operational information exchange are important as each contributes at least 50% toward

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improving supply chain performance [12]. Essentially, the adoption of information systems into industry to enhance operational efficiency is a common business strategy [13].

Several authors have shown how SC collaboration allows the increase of SC performance [14], [15], [16–18], [19–22] and improves customer service level [23,24], as it reduces excess inventory and it is essential to avoid the costly bullwhip effect [7,25–27] that is still prevalent in so many sectors [1]. Bullwhip is one of the most important issues in supply chain management [28] and can be reasonable considered a major cause of supply chain deficiencies [29].

However, recent studies have shown that collaboration and information sharing in SC are not always completely able to avoid the demand amplification phenomenon and the inventory instability events [16,17,30,31,32]. The bullwhip effect is only attenuated from exponential to linear when information is shared [16,17], but some part of this deleterious phenomenon always remain even after sharing both inter as well as intra echelon information [31,32]. This is due to the fact that buyers and sellers, despite achieving information transparency, often regulate their inventory control and material flow by using classical decision rules that create distorted information in the SC [21]. An important illustration on how the benefit of the collaboration can be overshadowed or even disregarded by the adoption of such order policies is detailed in the paper by Dejonckheere et al. [30]. The authors have shown how, in a collaborative SC, bullwhip effect can be reduced, but it is not eliminated when orders are realised by the current largely used order policies in practical applications: the periodic-review Order-Up-To (S,R) [33]. Given the common practise in retailing to replenish inventories frequently (daily, weekly, monthly) and the tendency of manufacturers to produce to demand, this replenishment strategies persist [34]. As Chen and Disney [35] state, at least 60% of the sales value of two of the four largest UK grocery retailers is controlled by this policy. Furthermore the Order-Up-To (OUT) policy is very easy to understand. The system's inventory position (on-hand inventory + outstanding orders + backorders) is reviewed every period and an 'order' is issued to bring the inventory position 'up-to' a defined level [35]. More specifically, in a classical OUT the order quantity is generated to satisfy the demand and to recover the gap between the target stock level and the current level of available inventory [8].

OUT systems will always result in the bullwhip effect as stated by Dejonckheere et al. [36]. The reason is mainly because, target stock levels, safety stocks, and demand forecasts are only updated in face of new information or deviations from targets. These "rational" adjustments create erratic responses [34]. Academics have been focused on the investigation of specific replenishment rules that are able to limit the tiers' over-reaction/under-reaction to changes in demand [24]. Among these decision rules, a widely discussed rule is the Automatic Pipeline Variable Inventory and Order Based Production Control System (APVIOBPCS) smoothing replenishment rule with proportional controller [36,37]. It describes a periodic review, base-stock OUT $(S,1)$ policy, where the proportional controller or feedback gain is a smoothing term of the discrepancy between actual and target levels of net stock and pipeline stock [8]. The crucial difference with the classical (S,R) OUT policy, is that the entire deficit between the OUT level and the available inventory is not completely recovered in a review time [38]. In other words, in the APVIOBPCS net stock order inventory discrepancies are only fractionally taken into account [36].

To the authors' knowledge, the benefit of the adoption of smoothing replenishment rules has mainly been shown for Traditional SC structures. Moreover, the few studies dealing with the smoothing replenishment rule in collaborative SC have been manly realised by creating *ad-hoc* experimental design to perform stress tests analysis on SC performance, also known as "Towill et al. [39] shock lens analysis" (see e.g. [8,21]. Using a mathematical modelling, the shock lens aims to infer on the performance of SCs for an intense and violent solicitation in market demand. This approach is useful to determine the stability and the resilience of a given SC structure [8,27,40,41]). However, to understand how SC works under typical marketplace conditions, further demand models should be assumed, such as the classical identically distributed (i.i.d) demand model.

Motivated by the above-mentioned observations, this paper attempts to provide an assessment of the impact of a classical periodic review OUT policy and of an APVIOBPCS policy in an Information Exchange SC under a normal demand model. To fulfil the research objective, we model a collaboration SC structure, the Information Exchange SC [1]. This considers a multi-echelon structure in which members receive real-time information on marketplace demand. On this model we test the classical OUT and three designs of the APVIOBPCS in term of demand amplification and inventory stability. The model is represented by a set of difference equations, implemented through Vensim software. More specifically, we adopt the System Dynamics modelling approach, advocated by [42] as a method of investigating the dynamical effects in large non-linear systems. System Dynamics (SD) modeling method can play a crucial role in advancing knowledge supply chain management, where mathematical modeling cannot accommodate the associated dynamic complexity [43]. The simulation model evaluates the system state every constant time interval (Δt), then the new system state is recorded and statistics collected [44].

Results show how, in a collaborative SC, a classical periodic review OUT policy create instable demand patterns and fluctuation in inventories and how these damaging consequences can be avoided by adopting the APVIOBPCS smoothing replenishment rule. In this fashion we extend the results of Cannella and Ciancimino [8] in which the features of the APVIOBPCS are provided under the "Towill et al. [39] shock lens analysis".

The remainder of the paper is organised as follows. In Section 2, the mathematical formalism of the studied SC is detailed. Section 3 presents the experimental design, numerical analysis and discussion. Finally, Section 4 presents conclusions and limitations.