Int. J. Production Economics 182 (2016) 14–25

Contents lists available at ScienceDirect

Int. J. Production Economics

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

Optimal soft-order revisions under demand and supply uncertainty and upstream information

Pundarikaksha Baruah [a], Ratna Babu Chinnam [a], Alexander Korostelev [b], Evrim Dalkiran [a,*]

[a] Department of Industrial and Systems Engineering, Wayne State University, 4815 Fourth Street, Detroit, MI 48202, USA
[b] Department of Mathematics, Wayne State University, 656 W. Kirby, Detroit, MI 48202, USA

ARTICLE INFO

Article history:
Received 14 January 2016
Received in revised form
14 July 2016
Accepted 5 August 2016
Available online 8 August 2016

Keywords:
Soft-orders
Atypical demand
Supply uncertainty
Upstream information sharing

ABSTRACT

Demand patterns for products with short life cycles or seasonal demand do not follow a discernible pattern for individual sales events and seasons due to uncertainty associated with effectiveness of product promotions, willingness of major retailers to carry product and their support, competition, and other unforeseen marketplace events/factors. These atypical demand patterns can be volatile and unsuitable for traditional demand forecasting. In such cases, buyers utilize market signals to regularly update demand forecasts. Under these settings, sharing early "soft-order" (i.e., order forecast) with the supplier reduces buyer's risk of supply shortages. In this study, we propose an optimal order revision policy for a buyer facing atypical demand and supply uncertainty for a single selling season based on a stochastic dynamic program. We demonstrate the value of soft-orders as well as supplier's inventory position information for the buyer. We make several key contributions: (i) We introduce a decision model for buyer to optimally revise soft-orders under supply uncertainty with or without supplier's inventory position information under a deposit scheme; (ii) We characterize the relationship between the optimal soft-order and final firm-order under demand forecasts and revisions, demonstrating that optimal orders may be aggressive, conservative, or match the demand forecast; (iii) We identify settings under which inventory position information of the supplier is beneficial to the buyer; (iv) We offer a mechanism for identifying the minimum unit deposit cost that will lead to truthful soft-orders from the buyer. A detailed analysis explores the structure of the optimal ordering policies as well as the effect of cost parameters and sources of uncertainty on buyer performance.

1. Introduction

In industries such as fashion, toys, and high-tech electronics, time-to-market and product turnover are vital. These products have relatively short life cycles and are sold in brief well-defined selling seasons (Christopher et al., 2004; Johnson, 2001). Demands faced by such industries are volatile, seasonal by nature, and highly unpredictable (Wong et al., 2005). Even the likes of Walmart, the world's largest chain of discount department stores, are not immune (Rozhon, 2005). In addition, the prevalent practice of manufacturing outsourcing to distant low-cost countries with long transit times creates additional constraints. The potential end result of demand–supply mismatch is higher costs of obsolete inventory and lost sales/markdowns. Early on, Reinmuth and Geurts (1972) studied similar settings combined with promotions and called them "atypical". We broadly define atypical demand settings as settings under which construction of an effective model for demand forecasting is difficult (Hausman, 1969). Suppliers selling products with atypical demand patterns typically incur higher inventory holding costs, lower capacity utilization, and lower order fill-rates, particularly under long lead-times and capacity uncertainty. While they are labeled as atypical situations, they hold opportunity for business: improved collaboration between buyer and seller in the form of sharing early demand forecasts and revisions can reduce the risk of performance shortfalls. Further motivation for this work comes from the knowledge that demand from promotional sales are higher compared to usual sales for many product segments (Blattberg and Neslin, 1990) and out-of-stock problems are more severe during promotional events (VICS, 2004).

Terwiesch et al. (2005) point out that information such as demand forecasts are continually updated as the buyer receives new market information that affects demand, particularly in industries

* Corresponding author.
E-mail addresses: Baruah@gmail.com (P. Baruah), Ratna.Chinnam@wayne.edu (R.B. Chinnam), apk@math.wayne.edu (A. Korostelev), evrimd@wayne.edu (E. Dalkiran).

http://dx.doi.org/10.1016/j.ijpe.2016.08.009
0925-5273/

facing atypical demand. Buyer can share this information in the form of order forecasts, also known as "*soft-orders*", and their revisions in advance with the supplier. Soft-orders are a reflection of buyer's purchase intent and are not legally binding "*firm*" purchase orders. Supplier may use these information signals to achieve better order fulfillment rates with reduced capacity and inventory buffers. Terwiesch et al. (2005) surveyed a soft-order revision process in a semiconductor industry supply chain where the buyer of semiconductor equipment sends soft-orders to equipment manufacturer and revises it periodically as new information is obtained, before issuing a final firm-order. Durango-Cohen and Yano (2006) discuss similar practices in the world of contract manufacturing for the application specific integrated circuits (ASICs) industry. These atypical demand patterns exist in several other industries as well. For example, in the communication and networking electronics industry (e.g., vendors selling routers, switches, customer servers, telephone sets, etc.), product demand can be decomposed into two components. The main demand component is stable and routine with relatively high predictability (a.k.a. run-rate demand) and the other being more sporadic large orders resulting from one-time deals that can take up several weeks to months of production capacity. Safety stocks are appropriate to hedge against fluctuations in routine demand, but are ineffective for atypical demand. Atypical demand, on the other hand, demands an approach that can translate input from account representatives leading the negotiations on large deals/installations into soft-order signals.

While soft-orders present an opportunity for suppliers, they have to be effectively incorporated into the production planning cycle. Premature production on any given soft-order might lead to significant future adjustment costs. For example, Durango-Cohen and Yano (2006) discuss the practice of buyers submitting unrealistically high forecasts and orders in the ASICs industry, concerned that suppliers would likely fill only a portion of their order due to capacity shortages. If the supplier happens to be a contract manufacturer, as in the ASICs industry, apart from final order uncertainty, it also needs to consider uncertainty in production capacity. Usually, inventory and safety capacity are used to protect firms against both sources of uncertainty, but can be an expensive proposition (Hu et al., 2003). These options may not even be relevant for contract manufacturers that may not build the same product twice and lack reasonable salvage options.

Under atypical demand, the procurement process becomes difficult for buyers facing an unreliable supplier with long lead-times. To start the planning process, buyers assimilate all the relevant market information and estimate an early demand forecast. By issuing realistic soft-orders based on these early demand forecasts, buyer allows the supplier to better plan for and support the sales event. If the buyer is a trustworthy player or agrees to purchase at least a portion of the soft-order or makes a meaningful upfront deposit, the supplier can start building inventory based on these early soft-orders. This practice is routine in industries with long product life cycles and stable demand, that employ MRP systems to share order forecasts and revisions. However, the literature is very limited when it comes to products with atypical demand patterns. The primary objective of this study is to investigate soft-ordering decisions and their consequences under atypical demand. Baruah (2006) showed that soft-orders can decrease costs for suppliers while improving the order fill-rate. We investigate here the optimal soft-ordering policies under atypical demand settings exclusively from the buyer's perspective. Our key contributions are as follows: (1) We offer a two-stage stochastic dynamic program framework that generates an optimal early soft-order signal under a deposit scheme and a final firm-order given a demand forecast evolution model and supply uncertainty model. (2) We offer a mechanism for identifying the minimum unit deposit cost that will lead to truthful soft-orders from the buyer. (3) An extended model explores the setting where the supplier shares inventory position information before the buyer issues a firm-order. This is the first study to jointly consider both soft-order signals as well as upstream information sharing. We also characterize the proposed policy and study the effects of cost parameters as well as soft-orders and supplier inventory position information on buyer performance.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. Section 3 introduces the dynamic programming model for soft-order and final firm-order determination, and Section 4 establishes the benefits of upstream inventory information sharing and soft ordering using mathematical analysis. Section 5 discusses optimal threshold values for the unit deposit cost. Section 6 presents results and insights from numerical analysis. Section 7 offers some concluding remarks and directions for future research.

2. Literature review

2.1. Ordering under demand and supply uncertainty

While there is a large body of production/inventory control literature involving demand side uncertainties (Yano and Lee, 1995; Gullu et al., 1999), there is growing literature accounting for supply side uncertainties and their significance (Silver, 1976; Vollman et al., 1997; Lee, 2002; Karabuk and Wu, 2003; Yeo and Yuan, 2011; Schmitt and Snyder, 2012; Kenne et al., 2012). Kouvelis and Milner (2002) studied the interplay of demand and supply uncertainty in capacity and outsourcing decisions in multistage supply chains. One of their findings is that greater supply uncertainty increases the need for vertical integration while greater demand uncertainty increases the reliance on outsourcing. Wu and Lin (2004) studied an (r, Q) inventory model under lead-time and ordering cost reductions when the receiving quantity is different from the ordered quantity. Yang et al. (2004) extended the newsvendor approach to study multi-supplier sourcing with random yields, whereas Jiang et al. (2011) studied a generalized model of competing newsvendors under asymmetric information. Kim et al. (2011) proposed a decision model for ordering quantity considering uncertainty in supply-chain logistics operations. Lin and Hou (2005) have considered an inventory system with random yield in which both the set-up cost and yield variability can be reduced through capital investment. Hu et al. (2013) studied a flexible ordering policy to coordinate a supply chain with yield and demand uncertainty using a single-period inventory model. For the decentralized setting, they proposed a revenue sharing policy with an order penalty and rebate contract, which fully coordinates the supply chain. Giri and Bardhan (2015) investigated a two-echelon supply chain involving one retailer with uncertain demand, a primary manufacturer with random yield and prone to complete disruption, and a perfectly reliable but costly secondary manufacturer and proposed a penalty-contract for coordination. Giri et al. (2016) studied a three-echelon supply chain with stochastic demand and random yield in both stages. In their setting, a composite contract involving a buyback contract and a sales rebate and penalty contract coordinated the supply chain, whereas buyback alone was not sufficient for coordination. None of these works consider order forecast revisions.

2.2. Value of upstream information

Upstream information sharing research has received relatively less attention in comparison with downstream information sharing (Chen, 2003). Examples of upstream information sharing