European Journal of Operational Research 230 (2013) 527–538

Contents lists available at SciVerse ScienceDirect

European Journal of Operational Research

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

Production, Manufacturing and Logistics

A rewarding-punishing coordination mechanism based on Trust in a divergent supply chain

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ARTICLE INFO

Article history:
Received 15 September 2012
Accepted 25 April 2013
Available online 9 May 2013

Keywords:
Supply chain management
Coordination
Divergent supply chain
Contract design
Trust
Monte Carlo simulation

ABSTRACT

Coordination of decentralized supply chains using contract design is a problem that has been widely addressed in the literature. We consider a divergent supply chain including a supplier and several retailers producing fashion products with short sale seasons. The retailers cooperate with the supplier as sales agents; i.e., they work in the framework of revenue sharing contracts. Because of their proximity to the market, retailers can provide more accurate demand forecasts to the supplier that is used to decide on issues such as capacity building and market prices with regard to retailers stiff due dates, different lead times and different price-dependent demand functions. To ensure abundant supply and cope with the demand variability, the retailers have an incentive to exaggerate their private forecast information. In this study, we propose a new rewarding-punishing coordination mechanism based on trust between supply chain tiers, considered as a differentiation factor between honest and deceptive partners. An optimization model is developed as a building block of this mechanism. An approximation method is used to simplify and solve the problem. The model is then implemented using Monte-Carlo simulation in four different situations, according to 10 different strategies for forecast information sharing. The findings from the tests show that the mechanism including trust as a decisional factor performs better than 'No Trust' mechanism in all situations. These results suggest that taking into account Trust in designing coordination mechanism may have significant influence on the financial performance of the supply chain.

1. Introduction and literature review

In a centralized supply chain, a central planner tries to optimize the total supply chain profits (or costs) considering different decision variables. The central planner can use information from any supply chain echelon to develop optimal decisions since all information gathered belong to a single body. This case is referred as 'Symmetric Information' mechanism. In a decentralized supply chain, a member's decision is based on his own interests and individual rationality, which can be in conflict with others' ones. Conflicts of interest can severely damage information sharing and can have serious damages on the entire chain's performance. Creating a partnership among the members and sharing credible information throughout the supply chain can improve its efficiency (e.g., Cachon and Lariviere, 2001; Viswanathan and Qinan, 2003; Chen et al., 2010). A well-designed contract can align the members' decisions to achieve optimal performance for the entire chain as well as fairly sharing profits and risks among them (e.g., Donohue, 2000; Serel et al., 2001; Wu et al., 2002; Erkoc and Wu, 2005; Jin and Wu, 2007). Cachon (2003) provide a comprehensive literature review on coordination with contracts. The development of coordinating contracts has led to the hope that these methods are adopted extensively in practice and they can significantly improve the performance of the decentralized supply chain, which has not been achieved yet. The main possible reason is that most of the existent literature has tended to focus on optimizing the main decisions based on financial aspects and assuming that players are Bayesian decision makers, rather than trying to understand the actual behaviors of decision makers and designing coordination mechanisms based on identified characteristics.

Several attempts have been made to coordinate divergent supply chains. Some studies investigate the identical retailers such as Lau et al. (2008), Sarmah et al. (2008) and Qin et al. (2007), where the former work considers a deterministic and price-dependent

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http://dx.doi.org/10.1016/j.ejor.2013.04.055

Nomenclature

Acronyms

NLC Non-Linear Constrained optimization model
QA Quadratic Approximation model
DMP Discretization Model of Price
AQMI Approximated Quadratic Mixed Integer optimization model
SI Symmetric Information model (used for comparison in simulation)
NT No Trust model (used for comparison in simulation)

Indexes

t the time period index, $t = 1, 2, \ldots, s$
i the retailer index, $i = 1, 2, \ldots, n$
j the price level, $j = 1, 2, \ldots, m_i$
l linearization variables, $l = 1, \ldots, 4$

Decision variables

W_i the quantity of product to be delivered to retailer i
X_i the safety reservation quantity corresponding to retailer i
p_i the price for retailer i
C_1 the available production rate that should be set up for the next period
C_2 the extra production rate that should be built for the next period
W_{ij} the quantity of products to be delivered to retailer i with price level j
X_{ij} the safety reservation quantity of retailer i if the retailer's price value is p_{ij}
Z_{ij} a binary decision variable defined clearly in expression (14)
Y a binary decision variable used to build mathematical optimization model
X_{ijl} variables used for linear approximation
Y_{ijl} binary decision variables used to build mathematical optimization model
$S(X_i)$ expected quantity of sale of retailer i if X_i is concerned
$\varepsilon_{s,i}$ supplier's belief about stochastic demand quantity
$\varepsilon_{TB,i}$ supplier's Trust-based belief about stochastic demand quantity
α_i level of the supplier's trust in retailer i which is between zero and one and updated in each period

Stochastic parameters

ε_i stochastic demand which has a truncated normal distribution over interval $(\underline{\varepsilon}_i, \bar{\varepsilon}_i)$

Deterministic parameters

n number of retailers
s number of periods
m_i number of price levels for retailer i
d number of periods which is considered to run Matched-Pairs t-test
μ_i, σ_i mean and standard deviation of stochastic demand of retailer i
$\tilde{\varepsilon}_i$ the actual superior information of retailer i about stochastic demand
$\hat{\varepsilon}_i$ the reported information as the retailer i's private forecast information about stochastic demand
$\varepsilon_{TB,i}$ the supplier's Trust-based belief about the retailer i's stochastic demand
a_{1i} the extent to which the product is accepted in the market in region i
a_{2i} the coefficient of the demand responsiveness in region i
L_i the deterministic retailer i's lead time
k maximum available time to produce and deliver the products for each period
c_A available amount of capacity used as an upper bound for C_1
c_B an upper bound for C_2
$h_{s,i}$ holding cost per product unit per time unit which only attributed to supplier due to his ownership
$u_{s,i}$ the supplier's production, transportation and operational costs per product unit including operational costs regarding retailer i
λ_1, λ_2 set up cost for the available capacity and building cost for the extra required capacity respectively
r_i the amount paid for each reserved product in advance by the retailer to the supplier under revenue sharing contract
φ_i the retailer i's revenue share from sales
p_{ij} value of price of retailer i at jth level
ρ agents' forecast accuracy based on interval length
α_{i-min} the minimum value for α_i
$Score_{i,init}$ the initial value for score of retailer i, at the beginning of the first period
$Score_i$ retailer i's score which updates at the end of each period
SL_1, SL_2, SL_3 values of significance levels respectively used for first, second and third Matched-Pairs test
η^{++} points that a retailer gets if Null hypothesis is failed to be rejected at a significance level of SL_1
η^{+} points that a retailer gets if Null hypothesis is failed to be rejected at a significance level of SL_2
η^{-} points that a retailer gets if Null hypothesis is failed to be rejected at a significance level of SL_3
η^{--} points that a retailer gets if Null hypothesis is rejected at a significance level of SL_3
β a coefficient with values between zero and one to restrict the share of X_i in W_i

demand, the second study investigates a stochastic demand, while the latter work with a constant demand. A number of studies investigate divergent supply chains with heterogeneous retailers such as Jin and Wu (2007), Cachon and Lariviere (2005), Bernstein and Federgruen (2005), Klastorin et al. (2002), and Anupindi et al. (2001). Sarlak and Nookabadi (2011) investigate a three level supply chain with several retailers with stochastic demand using a timing discount contract to synchronize the timing of retailers' orders with the supplier's order cycle. However, the demand structures in these works are either deterministic or stochastic or price-dependent; there are few studies which consider coordination in a divergent supply chain with stochastic and price-dependent demand (Pezeshki et al. (2013)).

In a different stream of research, some works, especially in the field of behavioral economy address the behavior of decision makers in business. In their seminal work, Özer et al. (2011) study a cheap talk mechanism in a dyadic supply chain in which the supplier requests private forecast information from a supplier to take his capacity investment decision under a simple wholesale price contract. The supplier has an incentive to exaggerate her forecast information in such a costless and nonbinding interaction called as "cheap talk". No cooperation is the equilibrium point for this