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Transfer of newsvendor inventory and supply risks to sub-industry and the public by financial instruments

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ABSTRACT

We consider a two-stage newsvendor model of a sub-industry in which suppliers have short lead-time capacity to produce goods for retailers that are selling non-identical products. We argue that the inventory and supply risks of the newsvendors due to demand uncertainty can be pooled and shared among different supply chains by treating reserved capacity as commodities and trading them as futures and options on futures to hedge the risks. The risks will be further shared with and transferred to the public if speculators are allowed to play the game. We show that this new mechanism of combining operational and financial risk hedging strategies offers industries a new way to more efficiently meet demand and improve profit.

1. Introduction

The management of the newsvendor's inventory and supply risks due to demand uncertainty is a fundamental issue in the inventory literature. The problem is particularly important for items with significant demand volatility, and large inventory and lost sales costs such as fashions, seasonal products, and fancy electronic devices. Frazier (1986) estimates that the inventory carrying cost, shortage, and excess supply for the U.S. apparel industry is 25% of the annual retail sales. In fact, for fashions items, lost sales alone can be as high as 18–20% of the total inventory (Hunter et al., 1996; Mattila et al., 2002). Therefore, it is worthwhile to devise a better strategy for the industry to minimize the costs that arise from demand uncertainty.

Jain and Silver (1995) introduce the postponement strategy that permits "newsvendor-type" retailers to use reserved capacity options to replenish short life-cycle inventory during the selling season. Their single-period two-stage model provides an opportunity for a retailer to correct its inventory position according to updated forecast so that the problem of supply–demand mismatch can be alleviated when the option of placing additional orders is available. The strategy is favorable to the retailer because it can adjust its inventory level during the selling season to better match demand. However, it might erode the supplier's profit because part of the mismatch risk is shifted along the single supply chain from downstream to upstream (Donohue, 2000).

In this paper we argue that the inventory and supply risks can be pooled and shared among different supply chains, and they can also be transferred to the public via *futures* and *options on futures*, provided that suppliers' short lead-time capacities allow retailers to replenish in the season. We treat such reserved capacity as a commodity and refer to it as *super capacity*. We propose that super capacity can be decoupled from its physical goods and can have its own market price to reflect its value because retailers can hold it as an alternative form of inventory in order to reduce the cost of mismatch between supply and demand. Therefore, the super capacity market allows different suppliers in a sub-industry to pool their capacities to reduce demand variability. We define a sub-industry as a group of retailers and suppliers that sell products that are produced by similar facilities and capabilities within the cluster. For example, the women's fashion skirt market is basically divided into the woven and knitted skirt sub-industries according to the materials used in the products (Joseph, 1986). A woven skirt supplier can make different styles and colors of woven products to fulfill the orders from different customers. However, they cannot make knitted skirts because woven fabrics and knitted fabrics require different machinery and know-hows for garment production. Consequently, the appeal market can be divided into several sub-industries.

Therefore, retailers can exchange their residual super capacities after realization of demand in the selling season. Thus the imbalance between aggregate demand and aggregate supply within a sub-industry is improved and the mismatch cost of the sub-industry is mitigated.

2. Literature review

The transshipment study that is initiated by Krishnan and Rao (1965) is closed to our concept of super capacity trading. The joint

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profit can be improved by transshipping goods among a group of newsvendors to adjust their inventory positions after demand realization. Most papers limit their investigation to a single product, e.g., Rudi et al. (2001), Dong and Rudi (2004), and Sosic (2006), since the strategy is concerned with the exchange of physical products.

Even transshipment combines the postponement and risk pooling strategies, no financial instrument is used to transfer the risk of demand uncertainty among players. A few papers have considered integration of financial and operational risk management tools to hedge inventory risk for short life-cycle products. Nevertheless, these studies either only combine risk pooling with financial hedging or postponement with financial hedging. Ding et al. (2007) investigate the risk pooling effect of global firms that have production capacity in different countries and obtain an optimal joint capacity and financial option decision. Gaur and Seshadri (2005) use different underlying financial assets to hedge inventory risk. Caldentey and Haugh (2006) extend their work to study the problem of continuous hedging of profit risk. Chod et al. (2010) examine the relationship between capacity flexibility and the value of financial hedging with a view to minimizing the risk of stochastic demand.

Hung et al. (2011a) propose a model with two newsvendors that play a co-opetition game between them in order to reduce and hedge against capacity risk and inventory risk by trading "super capacity" futures. They show that Pareto-improvement can be attained under this mechanism. Hung et al. (2011b) extend the model by permitting the trading of super capacity futures among more than two risk-neutral supply chains in the sub-industry to regulate their inventory positions. They prove that the inventory and capacity risks in newsvendor supply chains can be mitigated among different supply chains selling different products.

However, there is a lack of study in the literature on how risk-averse players transfer their risk beyond the sub-industry. We need to consider transferring risk outside the sub-industry because speculators cannot be ignored in the game in real life, particularly in the case where retailer and supplier can be hedger and speculator alternatively or they play a dual role at the same time to make extra profits.

The purposes of this paper are to study whether a unique best response strategy exists for the players to pool, hedge, and transfer mismatch risk to a sub-industry. Our research focuses on the development of a mechanism to mitigate such risks and re-distribute them among a group of supply chains, as well as to the public in both non-cooperative and cooperative settings.

3. The setup

We consider a group of m suppliers and n retailers that form a sub-industry with n supply chains. Our assumptions are:

a. Each supply chain sells a different short life-cycle product to the market that has only one retailer but one or more suppliers.
b. The m suppliers have the same facilities and similar capabilities to produce different goods for some of the n retailers with a very short lead-time.
c. The retailers place orders and receive goods before the selling season (stage 1).
d. All the suppliers do not keep inventory and will deliver the goods that are requested by the retailers under forced compliance (Cachon and Lariviere, 2001). They do not hold any unsold capacity on hand in stage 2 either. Otherwise, we treat them as speculators.
e. A minimum order is not required by the suppliers.
f. A retailer can order additional goods after demand is realized at the beginning of the selling season (stage 2) if it has reserved super capacity on hand or it can buy super capacity from the spot market.
g. The retailers cannot replenish inventory by transshipment because each retailer is selling a non-identical product (Rudi et al., 2001).
h. The aggregate demand is $D>0$. All the supply chains face stochastic demand, $D_i>0$, $i=m+1,\ldots,m+n$. We denote $\mu_i=E[D_i]$ and $\sigma_i^2=\mathrm{Var}[D_i]$.
i. Each supply chain demand has a probability density function $f_i(y)$ and a cumulative distribution function $F_i(y)$, $i=m+1,\ldots,m+n$. Let $\overline{F_i}(y)=1-F_i(y)$ and $F_i(0)=0$. All the distribution functions are continuous, invertible, and double differentiable.
j. All the investors do not have cash flow pressure to liquidate the capacity futures at any time.
k. There are zero transaction costs and no institutional restrictions on trades.

The players of the super capacity futures game are made up of three types of investors, namely suppliers, retailers, and speculators. We call all the n retailers and m suppliers hedgers. Hedgers intend to make or take delivery of the futures market position, unless they suffer from inaccurate forecasting such that the residual part of the futures position will be liquidated at some time prior to expiry. We have η speculators who are the sellers of option contracts and/or they merely offset their positions at some point before the date set for the futures delivery.

We use the following notation throughout the paper:

q_i^P	physical inventory quantity of player i
q_i^C	super capacity quantity of player i
q_i	total inventory position on hand of player i
p_i	unit inventory price of retailer i
c_{ik}	unit inventory cost of a supplier, where $i=1,\ldots,m$ represents suppliers and $k=m+1,\ldots,m+n$ represents retailers
ω_{ik}	unit inventory wholesale price of a supplier, where $i=1,\ldots,m$ represents suppliers and $k=m+1,\ldots,m+n$ represents retailers
g_i	goodwill penalty cost of retailer i
v_i	salvage value of leftover inventory of retailer i
h	unit price of super capacity futures in stage 1
$\overline{h}$	weighted average price of super capacity with different financial instruments and option exercise is determined
Π^H	total payoff of hedgers from super capacity
Π^S	total payoff of speculators from super capacity
Π^T	total payoff of all the players from super capacity

This super capacity futures game $\Gamma=(\pi_i,S_i)_{i\in I}$ with a finite set of players $I=\{1,2,\ldots,m+n+\eta\}$ has a strategy set $S_i=\Re_+$, $i\in I$. This game has the payoff function $\pi_i:S_i\times\Re_+\to\Re$, which is the profit due to super capacity trading that includes the extra income from merchandise sales and the reduction in mismatch costs after exchanging residual capacities among supply chains in the form $\pi(q_i^C,q^C)$, where $q_i^C\in S_i$, $q^C=\sum_1^{m+n+\eta}q_j^C$. The strategies of the players can be aggregated in an additive way and the payoff of each player is a function of the player's own actions. This super capacity futures game is, therefore, an aggregative game.

In stage 1, the retailers determine their order quantities, $q_i^P=(q_{m+1}^P,\ldots,q_{m+n}^P)$ units, to build physical inventory and consider buying super capacity $q_i^C=(q_{m+1}^C,\ldots,q_{m+n}^C)$ units to reserve capacity to substitute inventory in order to gain a total inventory of $q_i=q_i^P+q_i^C$ units for the whole season. In stage 2, the retailers will adjust their super capacity on hand by trading the