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Financial Hedging Decision on Procurement Risk for Newsvendor Model with Value-at-Risk Constraint

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Introduction

Manufacturers must now deal with increasingly fluctuating procurement prices for commodities and industrial component parts. However, it is hard for them to pass cost increases on to downstream markets efficiently. Therefore, manufacturers have sought to solve this problem with various supply management tactics. While vertical integration of key suppliers or signing long-term contracts is possible, financial hedging emerges as the most effective approach to counter commodities price risks. In situations where market demand uncertainty is still unresolved and often interplays with upstream price volatilities, Value-at-Risk (VaR) can help managers handle the multi-fold uncertainties and their potential interactions, by effectively measuring risk. Its usefulness has led it to become a standard adopted by Basel Accord II and III. In this paper, VaR is employed to capture downside risk aversion as a constraint imposed on the objective of expected profit maximization, i.e. the probability that the profit less than a reserved profit level does not exceed a risk level.

Based on the above scenario, some questions that naturally arise include: 1) What is the optimal financial hedging policy and thereafter the optimal order quantity? 2) How do the optimal decisions depend on the firm's risk aversion, price and demand uncertainty, and their correlation? 3) What is the value of financial hedging?

Two papers are closely related to ours. Chen and Yano (2010) study a seasonal product supply chain, using VaR constraint to capture risk aversion. As the product demand correlates with weather conditions, the manufacturer offers a weather-linked rebate contract that coordinates the channel. The manufacturer can further offset the weather risk transferred from the retailer by buying weather options. Compared with them, we consider a newsvendor problem in a spot market. The firm faces uncertainties of procurement price in addition to market demand. Also, the hedging decision is a portfolio contingent on the procurement price with completed term and strike structure. Oum and Oren (2009) study the hedging decision for a load-serving entity in the electricity market with price and quantity risks. The objective of maximizing expected hedged profit is subject to a VaR constraint. It proposes an approximation method to solve the problem. We, on the other hand, consider joint hedging and ordering decisions for the newsvendor problem, and give the optimal solutions in an explicit form.

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The Model

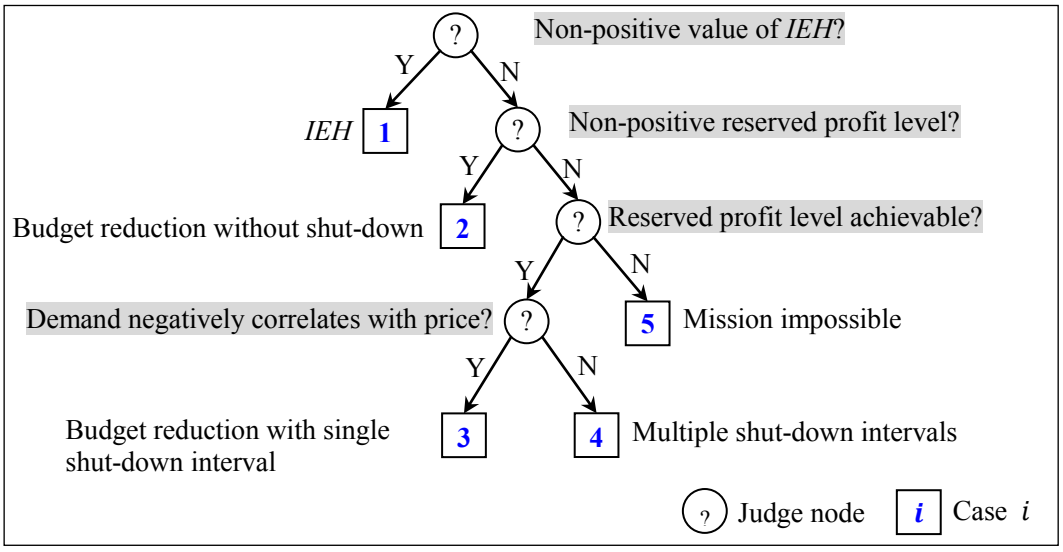
We represent a newsvendor model incorporating both a volatile procurement price and potentially correlated uncertain market demand. At the first stage, the firm may get access to commodity exchanges to write on a tailor-made portfolio of hedging contracts. These contracts are then fulfilled in the second stage and balance the cash flow contingent on spot price. Still facing random market demand, the firm decides order quantity from the spot market, and processes the materials into products for satisfying demand.

We make two assumptions in our model: **(A.1)** Following Gaur and Seshadri (2005), the financial market is arbitrage-free and has a risk-neutral pricing measure (RNPM); **(A.2)** If there is no feasible solution for ordering quantity Q, then assume $Q = 0$.

The analysis started from developing the optimal order policy for firm without hedging, so as to investigate the influence of VaR constraint on the ordering decision, and highlight the value of hedging. After finding the gaps of optimal order quantity between risk averse and risk neutral, we define *Initial Efficient Hedge* (*IEH*) that can fully achieve risk-neutral efficiency, such that the firm's anxiety of loss is adequately relieved and always orders to the unconstrained optimal order quantity for any spot price. However, if *IEH* is unaffordable due to budget limitations, the corresponding payoff function is cut down in a two- or three-tier balance reduction process. The basic rule for the reduction is: release the most budgets from the lowest profit margin, so as to retain the optimal edge. Once the budget constraint satisfies the firm's risk constraint, the optimal decisions can be found. Based on Carr and Madan (2001), the optimal hedging payoff function can be replicated as a portfolio of discount bonds, forward, call and put options with continuum of strike prices.

Main Results

Without hedging, due to downside risk aversion, the firm's order quantity deviates from (but is not necessarily less than) the risk-neutral benchmark, deteriorating the firm's overall profitability. This result differs from the analysis of risk aversion by utility or mean-variance risk measures, which state that risk aversion will always lead to a lower order quantity.



Then the close form of joint optimal hedging portfolio and optimal order quantity are derived. The solution map is shown in the figure above with five cases:

Case 1: IEH is affordable and thus the firm achieves risk neutral efficiency.

Case 2: IEH is unaffordable and the hedging budget must be reduced according to the balance condition. The firm determines the order quantity from a range of spot prices based on where the firm operates the business, but the range of spot price does not shrink.

Case 3: the firm not only adjusts the order quantity, but also shuts down businesses on the range of spot price from right hand side.

Case 4: commence multiple shut-down intervals.

Case 5: profit goal cannot be achieved. The only feasible solution is to quit the business.

This paper offers answers to the three questions addressed at the beginning, and sheds light on the integration of financial hedging and procurement management with a VaR constraint, which contains two-dimension heterogeneous risks (demand and price). We show how hedging turns risk into reward by rebalancing the cash flow among different spot prices, and thus show the value of hedging. But the interaction between hedging and ordering decisions also implies a need for cross-functional cooperation to counter comprehensive risks. The two values that define the firm's risk aversion, namely the reserved profit level and risk level, play important yet quite different roles in the decision making process. In short, the risk level divides the price horizon into an over-spending region and a lack-of-earning region. The order line is above a *risk-break-even order line* on the first region, but beneath it on the second region. Besides, the reserved profit level lowers the order line in the first region, but raises it in the second region. We also show the impact of price, demand uncertainties and their correlation on the firm's performance. Numerical results demonstrate that demand uncertainty notably deteriorates the firm's performance, but hedging can lessen the degree. This is because demand fluctuation not only reduces profits, but also makes the VaR constraint tighter. Therefore, the gap between risk aversion and risk neutrality gets larger as the value of hedging becomes more significant. Yet, the price fluctuation may improve the firm's performance, due to truncated and left-skewness effects of the price distribution. As the correlation of demand and price becomes negative, the firm's profit is jeopardized, but hedging is allowed to shine in these moments of demand uncertainty.

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