Impact of risk aversion on price and service decisions under different channel power structures

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Abstract
This paper investigates price and service decisions of a supplier-retailer supply chain under demand uncertainty, in which players are both risk-averse decision-makers. We examine the impact of risk aversion of the players upon price and service decisions under three different channel power structures.

Keywords: Risk aversion; Pricing; Service; Game theory

Introduction
With the intensified market competition and the widespread use of Internet, the retail market changes dynamically and the retailers must focus on more complicated strategies than simply lowering the price. Non-price factors such as service have become more important in affecting consumers' purchase decision (Lu et al. 2011; Tsay and Agrawal 2000; Boyaci and Gallego 2004). Moreover, the market demand uncertainty influences the performance of the firm and brings risk to the firm (Xiao and Yang 2009). The risk attitude of the firm towards demand uncertainty may significantly affects the decisions of supply chain members. Thus far, however, there have been only a limited number of research papers that focus on the impact of risk aversion on the price and service decisions of players under demand uncertainty.

In the marketing literature, typical assumptions have been that the market demand is deterministic and sensitive to price and service. These studies have examined price and service decisions under channel competition (Tsay and Agrawal 2000; Chen et al. 2008; Bernstein and Federgruen 2004), coordination mechanisms among channel members(Bernstein and Federgruen 2007) and effects of the channel power structures (Lu et al. 2011; Tang et al. 2012). A few studies added demand uncertainty to the market demand models(Ray 2005; Bernstein and Federgruen 2007). However, the above literature generally assumed that the players in supply chains were risk neutral in price and service decisions and ignored players’ risk attitude towards uncertainty.

For supply chain members, risk attitude plays a significant role in their decisions (Wu et al. 2010; Choi et al. 2008; Tsay 2002; Xiao and Yang 2008). Tsay (2002) analyzed how risk sensitivity affects both sides of the manufacturer-retailer relationship under various scenarios of strategic power, and how these dynamics are altered by a return policy. Gan et al. (2005)
investigated how a supply chain involving a risk-neutral supplier and a downside-risk-averse retailer can be coordinated with a supply contract. Xiao and Yang (2008) developed a price–service competition model of two supply chains to investigate the effects of the retailers’ risk sensitivity on players’ optimal strategies, where each supply chain consists of one risk-neutral supplier and one risk-averse retailer. Wu et al. (2010) studied a supply contract model in a risk-averse environment with a conditional value-at-risk objective function and investigated the impact of risk aversion on the manufacturer’s optimal decisions. However, the above literature mainly involved the problems between risk-neutral upstream firms and risk-averse downstream firms.

Rare literatures involved in two risk-averse players of a two-echelon supply chain. The risk aversion of a firm may not only affect its own decision but also affect the decision of other supply chain members (Xie et al. 2011). Xie et al. (2011) investigated the impact of various supply chain strategies and risk-averse behaviors of the players on quality investment and price decision in a make-to-order supply chain with uncertain demand. They assumed exogenous wholesale price and studied supplier’s quality and manufacturer’s price decision. The study is supposed to be the first to examine the influence of risk aversion of both the upstream firm and the downstream firm on their decisions.

Our work is different from the above literature. We consider both the supplier and the retailer are risk-averse decision-makers under demand uncertainty. The supplier determines the wholesale price and the retailer determines the retail price and service level. We will study the equilibrium decisions under three models of different power structures, i.e., supplier Stackelberg model (SS), retailer Stackelberg model (RS) and vertical Nash model (VN). We will concentrate on the impact of the risk tolerance of players on the optimal price and service decisions.

The remainder of this paper is organized as follows. Section 2 gives model description. Section 3 analyzes the optimal price and service level decisions under three power structures. Section 4 examines the impacts of players’ risk tolerance on equilibrium decisions. Section 5 concludes the paper.

Model Description

Consider a two-echelon supply chain consisting of one risk-averse supplier and one risk-averse retailer facing uncertain demands. We discuss price and service decisions of the two risk-averse decision-makers in different models: supplier Stackelberg model (SS), retailer Stackelberg model (RS) and vertical Nash model (VN).

We have the following notations:

- $\bar{a}$ the stochastic market base for the retailer with mean $\bar{a}$, variance $\sigma^2$;
- $c$ the unit production cost of the supplier, $c > 0$;
- $b$ the demand sensitivity to retail price;
- $\alpha$ the demand sensitivity to the service of the retailer;
- $p$ the retail price;
- $s$ the service level of the retailer;
- $w$ the unit wholesale price;
- $r$ the service cost coefficient.

In this paper, we assume that all model parameters are common knowledge for each player. To maintain analytical tractability, we don’t consider the retailer’s cost.

Similar to the prior literature (Tsay and Agrawal 2000), we assume that the demand
function is
\[ D = \tilde{a} - bp + \alpha s \]  
(1)

Here we assume the demand is more sensitive to price than to service, that is, \( b > \alpha \). Furthermore, we assume that, when the retailer provides a service level \( s \), the service cost is \( rs^2 \) \( /2 \), which assures that the profit function is concave on \( s \), i.e., improving service has a decreasing return on service expenditure (Tsay and Agrawal 2000).

Considering the risk aversion of the supplier and the retailer, we assume that each player assesses his utility via the following Mean-Variance value function of his random profit (Xiao and Yang 2008; Xie et al. 2011):

\[ U_i(\Pi_i) = E(\Pi_i) - \frac{\text{Var}(\Pi_i)}{2R} \]  
(2)

where the first term is expected profit of the player and the second term is the risk cost of the player, and \( R \) is the risk tolerance level of the player. The smaller the risk tolerance \( R \) of the player, the more conservative his behavior will be. Obviously, the player will make a trade-off between the mean and the variance of his random profit.

We can express and derive the utility function of the supplier and the retailer as follows:

\[ U_s(\Pi_s) = E(\Pi_s) - \frac{\text{Var}(\Pi_s)}{2R_s} = (w-c)(a-bp + \alpha s) - \frac{(w-c)^2 \sigma^2}{2R_s} \]  
(3)

\[ U_r(\Pi_r) = E(\Pi_r) - \frac{\text{Var}(\Pi_r)}{2R_r} = (p-w)(a-bp + \alpha s) - \frac{1}{2} rs^2 - \frac{(p-w)^2 \sigma^2}{2R_r} \]  
(4)

With the equations above, we can then study the impact of players’ risk tolerance on price and service decisions in different models.

**Equilibrium decisions under different supply chain structures**

In this section, we will orderly analyze equilibrium results in supplier Stackelberg model (SS), retailer Stackelberg model (RS) and vertical Nash model (VN).

**Supplier Stackelberg model**

In the case of supplier Stackelberg model, the supplier, as the Stackelberg leader, determines the wholesale price firstly. The retailer observes the wholesale price and makes his response to set his optimal retail price and service level as the follower.

Given the wholesale price, the retailer determines \( p \) and \( s \) to maximize his utility:

\[ \text{Max } U_r(\Pi_r) = (p-w)(a-bp + \alpha s) - \frac{1}{2} rs^2 - \frac{(p-w)^2 \sigma^2}{2R_r} \]  
(5)

Hessian matrix of \( U_r(\Pi_r) \) is
\[ H_1 = \begin{bmatrix} -2b - \frac{\sigma^2}{R_c} & \alpha \\ \alpha & -r \end{bmatrix} \]

The utility function \( U_r(\Pi_r) \) is a concave function on \((p, s)\) if and only if Hessian matrix is negatively defined. Define \( B_i = r(2b + \frac{\sigma^2}{R_c}) - \alpha^2 \).

Solving the first order condition of Eq.(5), we find that the optimal retail price and service level is

\[
P_{s1} = \frac{ar + (r\sigma^2 + br - \alpha^2)w}{2rb + \frac{r\sigma^2}{R_r} - \alpha^2} \tag{6}
\]

\[
s_{s1} = \frac{\alpha(a - bw)}{2rb + \frac{r\sigma^2}{R_r} - \alpha^2} \tag{7}
\]

After substituting Eqs.(6) and (7) into Eq.(3), the supplier’s optimal problem becomes

\[
\text{Max} \quad U_s(\Pi_s) = (w - c)[a - b \cdot \frac{ar + (r\sigma^2 + br - \alpha^2)w}{2rb + \frac{r\sigma^2}{R_r} - \alpha^2} + \alpha \cdot \frac{\alpha(a - bw)}{2rb + \frac{r\sigma^2}{R_r} - \alpha^2}] - \frac{(w - c)^2\sigma^2}{2R_s} \tag{8}
\]

Solving the first order condition of Eq.(8), we derive the following.

**Proposition 1.** In the supplier Stackelberg model, if \( B_i > 0 \), then the optimal wholesale price is

\[
w^*_{ss} = \frac{1}{2} \frac{r(b + \frac{\sigma^2}{R_r})(a + bc + \frac{\sigma^2}{R_s} + \frac{\sigma^2}{2R_s} + \frac{\sigma^2}{2R_s})}{rb^2 + \frac{rb\sigma^2}{R_r} + \frac{rb\sigma^2}{R_s} + \frac{r\sigma^4}{2R_s} + \frac{\sigma^4}{2R_s}} \tag{9}
\]

and the optimal service level and retail price are

\[
s^*_{s1} = \frac{\alpha(a - bw^*_{ss})}{2rb + \frac{r\sigma^2}{R_r} - \alpha^2} \tag{10}
\]

\[
p^*_{s1} = \frac{ar + (r\sigma^2 + br - \alpha^2)w^*_{ss}}{2rb + \frac{r\sigma^2}{R_r} - \alpha^2} \tag{11}
\]

**Retailer Stackelberg model**
In the case of retailer Stackelberg model, the retailer, as the Stackelberg leader, determines the sales margin and the service level in the first step. The supplier observes the decision made by the retailer and makes his response to set his optimal wholesale price as the follower.

As the retailer’s sales margin is \( m = p - w \) on one unit of a product, the supplier’s utility can be expressed as

\[
\text{Max } U_s(\Pi_s) = (w-c)[a-b(w+m)+\alpha s] - \frac{(w-c)^2 \sigma^2}{2R_s} \tag{12}
\]

Since \( \frac{\partial^2 U_s(\Pi_s)}{\partial w^2} = -b \frac{\sigma^2}{R_s} < 0 \), the utility function is strictly concave on wholesale price.

Solving the first order condition of Eq.(12), we derive the optimal wholesale price

\[
w = \frac{(a-bm+bc+\alpha s)R_s + c\sigma^2}{2br_s + \sigma^2} \tag{13}
\]

After substituting \( m = p - w \) and Eq. (13) into Eq. (4), the retailer’s profit becomes

\[
U_r(\Pi_s) = m(a-b[a-bm+bc+\alpha s]R_s + c\sigma^2 + m) + \alpha s - \frac{1}{2}R_s - \frac{m^2 \sigma^2}{2R_s} \tag{14}
\]

Solving the first order condition of Eq. (14), we derive the optimal sales margin and service level.

**Proposition 2.** In the retailer Stackelberg model, the optimal sales margin and service level are

\[
m^*_{\text{ret}} = \frac{rR_s(bR_s + \sigma^2)(2br_s + \sigma^2)(a-bc)}{R_s(2br - \alpha^2)(bR_s + \sigma^2)^2 + 2rbR_s(bR_s + \sigma^2)(2\sigma^2 + bR_s) + r\alpha^6} \tag{15}
\]

\[
s^*_{\text{ret}} = \frac{aR_s(bR_s + \sigma^2)(a-bc)}{R_s(2br - \alpha^2)(bR_s + \sigma^2)^2 + 2rbR_s(bR_s + \sigma^2)(2\sigma^2 + bR_s) + r\alpha^6} \tag{16}
\]

and the optimal wholesale price is

\[
w^*_{\text{ret}} = \frac{(a-bm^*_{\text{ret}}+bc+\alpha s^*_{\text{ret}})R_s + c\sigma^2}{2br_s + \sigma^2} \tag{17}
\]

**Vertical Nash model**

In the case of vertical Nash model, the supplier determines the wholesale price and the retailer determines the sales margin and the service level simultaneously.

After substituting \( m = p - w \) into Eqs.(3) and (4), we have

\[
\text{Max } E(U_s) = (w-c)(a-b(w+m)+\alpha s) - \frac{(w-c)^2 \sigma^2}{2R_s} \tag{18}
\]
By taking the first order conditions of Eqs.(18) and (19), we derive the following.

**Proposition 3.** In VN model, the optimal wholesale price is

$$w^*_{ss} = \frac{r(bR_s + \sigma^2)[R_s(a+bc)+cR_s(bR_s + \sigma^3)k(br-\alpha^2)]}{bR_s(3br-\alpha^2)+\sigma^2R_s(2br-\alpha^2)+r\sigma^2(2bR_s+\sigma^2)}$$

and the optimal sales margin and service level are

$$m^*_{ss} = \frac{r(bR_s + \sigma^2)(aR_s-bR_s c)}{bR_s(3br-\alpha^2)+\sigma^2R_s(2br-\alpha^2)+r\sigma^2(2bR_s+\sigma^2)}$$

$$s^*_{ss} = \frac{aR_s(bR_s + \sigma^2)(a-bc)}{bR_s(3br-\alpha^2)+\sigma^2R_s(2br-\alpha^2)+r\sigma^2(2bR_s+\sigma^2)}$$

The impacts of risk tolerance on players’ decisions and utility

**The impacts of \( R_s \) and \( R_r \) on optimal decisions**

We study the effect of risk tolerance on the optimal wholesale price, the retail price and the service level in the three different models. Solving the first-order conditions of equilibrium decisions, we derive the following.

**Proposition 4.** Regardless of power structure, the wholesale price and the retail price both increase with the risk tolerance of the supplier, while the service level decreases with the risk tolerance of the supplier. Namely \( \frac{\partial w^*_{ss}}{\partial R_s} > 0 \), \( \frac{\partial p^*_{ss}}{\partial R_s} > 0 \) and \( \frac{\partial s^*_{ss}}{\partial R_s} < 0 \).

Proof. In SS model, from \( \sigma^2 \in [0, \infty), R_s \in (0, \infty) \) and \( B_l = r(2b + \frac{\sigma^2}{R_r}) - \alpha^2 > 0 \), it follows that \( 2br-\alpha^2 > 0 \) when \( R_r \to \infty \). Thus, the condition \( 2br-\alpha^2 > 0 \) guarantees the existence of optimal equilibrium decisions. When the supplier and the manufacturer are both risk-neutral decision makers, we have

$$p^*_N = \lim_{R_s \to \infty} \frac{ar+(\frac{r \sigma^2}{R_r}+br-\alpha^2)w^*_{ss}}{2rb+r\frac{\sigma^2}{R_r}-\alpha^2} = \frac{ar+(br-\alpha^2)w^*_{ss}}{2rb-\alpha^2}. \text{ With all other conditions being equal, the increase of wholesale price results in a rise in retail price. So}$$

$$\frac{\partial p^*_N}{\partial w^*_{ss}} = \frac{br-\alpha^2}{2rb-\alpha^2} > 0.$$ Furthermore, we have \( br-\alpha^2 > 0 \).

1) Solving the first-order conditions of \( w^*_{ss}, p^*_{ss} \) and \( s^*_{ss} \) with respect to \( R_s \), we get

$$\frac{\partial w^*_{ss}}{\partial R_s} = \frac{r \sigma^2(a-bc)(r \sigma^4+R_s \sigma^2(3br-\alpha^2)+R_s^2 b(2br-\alpha^2))}{[2brR_s(bR_s+\sigma^2)+\sigma^2R_s(2br-\alpha^2)+r\sigma^4]}>0.$$
\[ \frac{\partial w^*_{sw}}{\partial R_r} = \frac{-ab}{2br + ra - \alpha^2} \frac{\partial w^*_{sp}}{\partial R_r} < 0 \]

\[ \frac{\partial p^*_{sw}}{\partial R_r} = \frac{ra^2}{2br + ra - \alpha^2} \frac{\partial w^*_{sp}}{\partial R_r} > 0 \]

2) Solving the first-order conditions of \( w^*_{sw} \), \( p^*_{sw} \) and \( s^*_{sw} \) with respect to \( R_r \), we get

\[ \frac{\partial w^*_{sw}}{\partial R_r} = \sigma^2 r(\sigma^2 + 2brb)(a - bc)[R_r(2br - \alpha^2) + r\sigma^2] + 2R_r\sigma^4 - \frac{(5rb - 2a^2) + R_r^2\sigma^2(3rb - \alpha^2)}{(2br + \sigma^2)^2}[R_r(2br - \alpha^2)(bR_r + \sigma^2) + 2rbR_r(bR_r + \sigma^2)(2\sigma^2 + bR_r) + r \sigma^6] > 0 \]

\[ \frac{\partial p^*_{sw}}{\partial R_r} = \sigma^2 r(\sigma^2 + 2brb)(a - bc)[R_r(2br - \alpha^2) + r\sigma^2] + 2R_r\sigma^4 - \frac{(3rb - 2a^2) + R_r^2\sigma^2(2br - \alpha^2)}{(2br + \sigma^2)^2}[R_r(2br - \alpha^2)(bR_r + \sigma^2) + 2rbR_r(bR_r + \sigma^2)(2\sigma^2 + bR_r) + r \sigma^6] < 0 \]

\[ \frac{\partial s^*_{sw}}{\partial R_r} = -2R_r\sigma^4 br(\sigma^2 + bR_r) + bR_r(bR_r + 2\sigma^2)(a - bc) \leq 0 \]

3) Solving the first-order conditions of \( w^*_{sw} \), \( p^*_{sw} \) and \( s^*_{sw} \) with respect to \( R_r \), we get

\[ \frac{\partial w^*_{sw}}{\partial R_r} = \sigma^2 r(\sigma^2 + 2brb)(a - bc)[R_r(2br - \alpha^2) + r\sigma^2] + 2R_r\sigma^4 - \frac{\sigma^2 r(a - bc)(\sigma^2 + bR_r) + R_r(2br - \alpha^2) + r\sigma^2}{(2br + \sigma^2)^2} > 0 \]

\[ \frac{\partial p^*_{sw}}{\partial R_r} = \sigma^2 r(\sigma^2 + 2brb)(a - bc)[R_r(2br - \alpha^2) + r\sigma^2] + 2R_r\sigma^4 - \frac{\sigma^2 r(a - bc)(\sigma^2 + bR_r) + R_r(2br - \alpha^2) + r\sigma^2}{(2br + \sigma^2)^2} > 0 \]

\[ \frac{\partial s^*_{sw}}{\partial R_r} = -R_r^2\sigma^4 br(a - bc) + bR_r(bR_r + 2\sigma^2)(a - bc) \leq 0 \]

Proposition 4 implies that the higher the risk tolerance of the supplier is, the higher the wholesale price and retail price will be, while the lower the service level will be. The reason is that, when the supplier becomes less risk-averse, the supplier will increase the wholesale price to gain more utility. As a result, the retailer will set a higher price. Since the demand is more sensitive to the retail price than to the service level, the retailer will provide lower service level as the risk tolerance of the supplier increases. Otherwise, the lower the risk tolerance of the supplier, the lower the wholesale price and retail price will be, while the higher the service level will be. The results show that a risk-averse supplier sets a lower wholesale price than that of a risk-neutral supplier.

**Proposition 5.** Regardless of power structure, the wholesale price decreases with the risk tolerance of the retailer, while the retail price and the service level increase with the risk tolerance of the retailer. Namely \( \frac{\partial w^*}{\partial R_r} < 0 \), \( \frac{\partial p^*}{\partial R_r} > 0 \) and \( \frac{\partial s^*}{\partial R_r} > 0 \).

Proof. 1) Solving the first-order conditions of \( w^*_{sw} \), \( p^*_{sw} \) and \( s^*_{sw} \) with respect to \( R_r \), we get

\[ \frac{\partial w^*_{sw}}{\partial R_r} = \frac{-rR_r\sigma^2 (a - bc)(br - \alpha^2)}{[2brR_r (bR_r + \sigma^2) + \sigma^2 R_r (2br - \alpha^2) + \sigma^4 R_r]^2} < 0 \]
\[
\frac{\partial p^*_w}{\partial R_x} = (r\sigma^2(a-bc)[2R_xb^3r^1(R_x^2b^3) + 2R_xb^3r(R_x^2b^3)] + 2R_xb^3r(2rb-\alpha^2)^2 + 2R_xb^3r(\alpha^2 + 2R_xb^3r(2rb-\alpha^2)^2 + 2R_xb^3r(br-\alpha^2)(R_x^2 + 2R_xb^3r(2rb-\alpha^2)^2 + 2R_xb^3r(br-\alpha^2)(2rb-\alpha^2)^2)]/(2brR_x(bR_x + \sigma^2) + \sigma^2R_x(2rb-\alpha^2) + \alpha^2R_x(2rb-\alpha^2) + \sigma^2R_x(2rb-\alpha^2) + \sigma^2r^2) > 0
\]

\[
\frac{\partial w^*_m}{\partial R_x} = \frac{\sigma^2(a-bw_m)(2br-\alpha^2)^2 + \sigma^2R_x(2rb-\alpha^2) + \alpha^2R_x(2rb-\alpha^2) + \sigma^2R_x(2rb-\alpha^2) + \sigma^2r^2)}{(2br-\alpha^2)^2 + \sigma^2r^2) > 0
\]

2) Solving the first-order conditions of \( w^*_m \), \( p^*_w \) and \( s^*_m \) with respect to \( R_x \), we get

\[
\frac{\partial w^*_m}{\partial R_x} = \frac{\sigma^2(a-bw_m)(2br-\alpha^2)^2 + \sigma^2R_x(2rb-\alpha^2) + \alpha^2R_x(2rb-\alpha^2) + \sigma^2R_x(2rb-\alpha^2) + \sigma^2r^2)}{(2br-\alpha^2)^2 + \sigma^2r^2) > 0
\]

3) Solving the first-order conditions of \( w^*_m \), \( p^*_w \) and \( s^*_m \) with respect to \( R_m \), we get

\[
\frac{\partial w^*_m}{\partial R_m} = \frac{-R_x\sigma^2r^2(a-bc)(2br-\alpha^2)^2 + \sigma^2R_x(2br-\alpha^2) + \alpha^2R_x(2br-\alpha^2) + \sigma^2r^2)}{(2brR_x(3br-\alpha^2) + \sigma^2R_x(2br-\alpha^2) + \alpha^2R_x(2br-\alpha^2) + \sigma^2r^2)} < 0
\]

\[
\frac{\partial p^*_w}{\partial R_m} = \frac{\sigma^2r^2(a-bc)(2br-\alpha^2)^2 + \sigma^2R_x(2br-\alpha^2) + \alpha^2R_x(2br-\alpha^2) + \sigma^2r^2)}{(2brR_x(3br-\alpha^2) + \sigma^2R_x(2br-\alpha^2) + \alpha^2R_x(2br-\alpha^2) + \sigma^2r^2)} > 0
\]

\[
\frac{\partial s^*_m}{\partial R_m} = \frac{-R_x\sigma^2r^2(a-bc)(2br-\alpha^2)^2 + \sigma^2R_x(2br-\alpha^2) + \alpha^2R_x(2br-\alpha^2) + \sigma^2r^2)}{(2brR_x(3br-\alpha^2) + \sigma^2R_x(2br-\alpha^2) + \alpha^2R_x(2br-\alpha^2) + \sigma^2r^2)} > 0
\]

Proposition 5 shows that the higher the risk tolerance of the retailer, the lower the wholesale price will be, while the higher the retail price and service level will be. The reason is that, when the risk tolerance of the retailer increases, the retailer will set a higher retail price and higher service level. As a result, the demand will decrease as the demand is more sensitive to the retail price than to the service level. The expected decreased demand will induce the risk-averse supplier to lower wholesale price to spur the demand. The results show that a risk-averse retailer sets a lower price and lower service level than those of a risk-neutral retailer.

The impacts of \( R_x \) and \( R_m \) on players’ utility

Since the expression of the equilibrium utilities are very complicated, we will use several numerical examples to illustrate the effects of risk tolerance of the supplier and the retailer on players' equilibrium utilities and compare the results in different models. The default values of parameters are given as follows: \( a = 100, \ b = 6, \ a = 4, \ c = 3, \ r = 3, \ \sigma = 10 \).

We first demonstrate the impact of \( R_x \) on the utility of the supplier and utility of the retailer. We allow \( R_x \) to vary in the range of [20,220] and set \( R_m \) as a constant, \( R_m = 50 \).

Figs. 1 and 2 illustrate the impacts of the risk tolerance of the supplier on the utility of the supplier and the utility of the retailer, respectively. The utility of the supplier increases with \( R_x \), while the utility of the retailer decreases with \( R_x \). This implies that when the supplier is more conservative, the utility of the supplier will become less while the utility of the retailer will become more.
Then we examine the impact of $r_R$ on the equilibrium utility of the supplier and utility of the retailer. We allow $r_R$ to vary in the range of $[20,220]$ and set $r_S$ as a constant, $r_S = 50$.

Figs. 3 and 4 illustrate the impacts of the risk tolerance of the retailer on the utility of the supplier and the utility of the retailer, respectively. The utility of the supplier decreases with $r_r$, while the utility of the retailer increases with $r_r$. This implies that when the retailer is more conservative, the utility of the retailer will become less while the utility of the supplier will become more.

Figs. 1 and 3 show that the utility of the supplier is the largest for SS, the second for VN and the least for MS. Moreover, Figs. 2 and 4 show that the utility of the retailer is the largest for MS, the second for VN and the least for SS. Therefore, the supply chain players can take
The advantage of power structure to gain more utility.

**Conclusion**

This paper studies price and service level decisions of a two-echelon supply chain under demand uncertainty, in which players are both risk-averse decision makers. By means of game theory, we analyze three models of different channel power structures and then study the impact of risk tolerance of the supplier and the retailer upon the equilibrium decisions and discuss our results using a numerical experiment.

Our results show that both the risk tolerance of the supplier and the risk tolerance of the retailer have influence on the price and service level decisions. We find that, regardless of power structure, the wholesale price and the retail price both increase with the risk tolerance of the supplier while the service level decreases with the risk tolerance of the supplier. Furthermore, the wholesale price decreases with the risk tolerance of the retailer while the retail price and the service level increase with the risk tolerance of the retailer. This paper also suggests that the utility of the supplier and the utility of the retailer both increase with its own risk tolerance and decrease with the risk tolerance of the other player. Besides, the players can take advantage of power structure to gain more utility.

For future research, we can extend this case to the supply chain which consists of two competitive retailers or two competitive supply chains.

**References**


