The buyback contract coordination for a logistics service supply chain

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Received 1 January 2014, www.tsi.lv

Abstract

This article is about the coordination issue of the logistics service supply chain leading by the functional logistics provider (FLP). The service supply chain is consisted of the risk-neutral FLP and the loss-averse logistics integrator (LI), and the contract model of the wholesale price and buyback contract model are established. The study found that the wholesale price contract cannot coordinate the supply chain, but the introduction of the buyback contract can stimulate the LI to increase the order quantity of the logistics capacity, reaching the level of the centralized logistics service supply chain and finally it is verified through examples.

Keywords: logistics service supply chain, loss averse, buyback contract, coordination

1 Introduction

The logistics service supply chain (LSSC) is a new service supply chain, which is composed with logistics service integrators (LSI) and the functional logistics provider (FLP). LSI integrates all kind of FLPs' resources such as warehouse, transportation, distribution in order to supply integrated logistics services to customers (Choy et al. 2007) [1]. The logistics service supply chain is formed in order to adapt to the needs of the customers and the growth and development of the logistics enterprises. In essence, the LSSC is a service supply chain on the basis of capability collaboration (Lisa et al., 2004) [2], and its key operation problems is coordinating all of the enterprises in the chain. The supply chain contract is an important method to achieve the supply chain coordination [3].

Berglund (2000) researched the cooperation of logistics enterprises, he designed such buyback contract, i.e. when the third party logistics provider provides higher purchase price, the FLP buys back the unused service capacity with certain price discount to encourage the cooperation intent of the third logistics provider [4]. Liu (2008) considered the two-echelon supply chain structure with single period consisting of a FLP and a LI, established the LSI's cost model and the FLP's profits model with or without the capability collaboration restraint respectively, and also gave the capability coordination model under Stackelberg decision [5]. Gui et al. (2009) studied the two echelon logistics supply chain with one logistics service integrator and one functional logistics service provider, and developed the mathematical model of centralized coordination, Stackelberg game coordination and competitive aligned coordination based on the market characterized by a price sensitive random demand [6]. Liu (2010) studied the optimal revenue-sharing coefficient in three echelon logistics service supply chain in a stochastic demand environment [7]. Hu et al. (2011) studied the two echelon logistics supply chain with one logistics service integrator and one functional logistics service provider, and studied the coordination of buyback contract considering different quantity discount [8]. Liu et al. (2012) studied the quantity coordination of capability collaboration for multi-period-oriented two-echelon logistics service supply chain with Stackelberg decision-making [9]. Gui et al. (2012) studied the coordinating problem of logistics service supply chain under uncertain supply capacity, and proposed a payback contract to coordinate logistics service supply chain under deterministic and stochastic demand [10]. All these papers studied the quality coordination contract, quantity discount contract, buyback contract, revenue sharing contract in two or three echelon LSSC, but these models are based on the risk neutrality. They did not consider the behavioural issues in LSSC. Therefore, it is significant to study the coordination of LSSC considering the behavioural issues. This article takes the viewpoint of prospect theory rather than risk neutrality to describe the LSI's decision-making behaviour in a FLP-leading logistics service supply chain [11]. The article studies the wholesale price contract coordination and buyback contract coordination considering LSI as a loss –averse decision maker.

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2 Decision Model of the Logistics Service Supply Chain

2.1 BASIC ASSUMPTIONS

This article takes into consideration of such situation in the logistics service market, i.e. certain FLP has absolute market advantage within its covered area coverage. When it joins in a certain logistics service supply chain as a FLP, the LI must cooperate with this powerful FLP out of the necessity of business development. Therefore, the logistics service supply chain leading by the functional logistics provider is formed [12].

Taking into consideration of a system model of LSSC with two stages and single cycle, this supply chain is consisted of two members, including the upstream FLP and downstream LI, and they can only have trade with single logistics capacity. The LI has the random logistics service needs. If the market demand is a non-negative and consecutive random variable, with the mean value of μ, the probability density function of $f(x)$ and cumulative distribution function of $F(x)$. F^- represents the inverse function of the cumulative distribution function of the random demand. All of the market demands of the LI are ordered from the FLP. According to the result of the market demand forecast, the logistics capacity of the LI from the professional logistics provider is q of the order quantity, the FLP transfers the price w with unit capacity to provide such logistics capacity for the LI according to the capacity order requirement of the FLP and uses this logistics capacity to provide the relevant logistics services when it executes the logistics solution of the logistics demander. The costs related to the logistics capacity of the FLP include two parts: one part is the cost caused at the logistics capacity investment, with the discounted present value of c_{sf} and the other part is the logistics capacity operation cost of c_{sv} when the LI provides logistics service. The operation cost of the LI is c_I, when the logistics capacity is excess, the unused logistics capacity of the LI causes no operation cost. At the end of the cycle, the FLP buys back the unused logistics capacity of the LI with the price of b. If there is out of stock, the overall stockout loss of the supply chain is g, the stockout loss of the integrator is g_I and the stockout loss of the provider is g_s. The π represents the profit, U represents utility, $E(\pi)$ represents the expected profit and $E(U)$ represents the expected utility. The subscript c represents the centralized supply chain, I represents the LI, s represents the FLP, sc represents the decentralized supply chain and * represents the optimum strategy of the merchant. If the unit logistics capacity price p of the LI is exogenously given, it assumes that $p > w > c_{sf} + c_{sv}$, $p > w + c_I$, $w \geq b \geq c_{sv}$ in order to guarantee the profit of the integrator and FLP.

2.2 THE DECISION UNDER THE INTEGRATED LOGISTICS SERVICE SUPPLY CHAIN

First, the logistics service supply chain should be considered as a centralized decision system. It is assumed that it is the risk neutral. The cost of the centralized logistics service supply chain is the sum of the integrator cost and function provider cost, that is $c = c_I + c_{sf} + c_{sv}$. If there is any out of stock, the stockout loss of the centralized supply chain is the sum of the stockout loss of integrator and stockout loss of function provider, that is $g = g_I + g_s$. The profit of the centralized logistics service supply chain is

$$\pi_c = \begin{cases} (p - c_I - c_{sv})x - c_{sf}q, x \leq q \\ (p - c_I - c_{sv} - c_{sf})q - g(x-q), x > q \end{cases} \tag{1}$$

The expected profit of the centralized logistics service supply chain is

$$E(\pi_c) = \int_0^q [(p - c_I - c_{sv})x - c_{sf}q] f(x) d_x + \int_q^\infty [(p - c_I - c_{sv} - c_{sf})q - g(x-q)] f(x) d_x \tag{2}$$

Doing the first and second order derivative of q for (2), due to $\frac{\partial^2 E(\pi_c)}{\partial q^2} < 0$, $E(\pi_c)$ is the concave function of q. Therefore, the existing optimum order quantity makes the centralized logistics service supply chain get the maximum expected profit with $\frac{\partial E(\pi_c)}{\partial q} = 0$, and the optimum order quantity q_c^* of the centralized logistics service supply chain meets

$$F(q_c^*) = \frac{p - c_I - c_{sv} - c_{sf}}{p - c_I - c_{sv} + g} \tag{3}$$

The decision of the centralized logistics service supply chain provides an ideal decision result, providing a benchmark for the design of the coordination contract of the logistics service supply chain.

2.3 THE DECISION UNDER THE DECENTRALIZED LOGISTICS SERVICE SUPPLY CHAIN

It is assumed that the decision maker has loss aversion; the initial wealth is w_0 (at the beginning of the cycle). If the profit or loss at the end of the cycle is higher or lower than the initial level, the loss aversion function of the decision maker is piecewise linear.

$$U(w)=\begin{cases} w-w_0, w\geq w_0 \\ \lambda(w-w_0), w<w_0 \end{cases} \quad (4)$$

$\lambda \geq 1$ defines the level of the loss aversion, w is the final wealth at the end of the cycle. If λ=1, the decision maker has the risk neutral. The higher the value of λ, the higher loss aversion level of the decision maker. For easy application, $w_0=0$ is in the literature [13].

2.4 THE LI AND FLP'S DECISION UNDER WHOLESALE PRICE CONTRACT

In the logistics service supply chain managed by the FLP, the FLP is predominant. According to the viewpoint of behavioural agency theory, the diversity can be employed to decrease the risk, so it is assumed that the FLP is risk neutral. Whereas the LI is in the bad situation and cannot diversify, so it is assumed that the LI is loss aversion. It is assumed that the FLP first offers the wholesale price for the LI; the LI determines the logistics capacity order quantity according to the wholesale price [14].

When the logistics capacity order quantity of the LI is q, the profit of the LI is

$$\pi_I(x,q,w)=\begin{cases} (p-c_I)x-wq, x\leq q \\ (p-c_I)q-wq-g_I(x-q), x>q \end{cases} \quad (5)$$

It is assumed that the corresponding market demand of the profit break-even point of the LI is q_I, $\pi_I(x,q,w)=0$, the profit break-even point of $q_I=\frac{w}{p-c_I}q$ and $q_I=\frac{p-c_I-w+g_I}{g_I}q$ can be got. If $k_1=\frac{w}{p-c_I}$, $k_2=\frac{p-c_I-w+g_I}{g_I}$, when $x\in[0,k_1q)$ and $x\in(k_2q,\infty)$, $\pi_I<0$.

The expected profit function of the LI is

$$E[\pi_I(x,q,w)]=\int_0^q[(p-c_I)x-wq]f(x)dx+ \int_q^\infty[(p-c_I-w)q-g_I(x-q)]f(x)dx \quad (6)$$

The expected utility loss of the LI is

$$L_I(q,w)=(\lambda_I-1)\int_0^{k_1q}[(p-c_I)x-wq]f(x)dx +(\lambda_I-1)\int_{k_2q}^\infty[(p-c_I-w)q-g_I(x-q)]f(x)dx \quad (7)$$

The expected utility of the LI is

$$E[U(\pi_I(x,q,w))]=E[\pi_I(x,q,w)]+L_I(q,w) \quad (8)$$

The decision goal of the LI is to maximize its expected utility in the context of given wholesale price by the function provider and doing the first and second derivative of q for (8).

$$\frac{\partial E[U(\pi_I(x,q,w))]}{\partial q}=(p-c_I-w+g_I)[\overline{F}(q)+(\lambda_I-1)\overline{F}(k_2q)] -w[F(q)+(\lambda_I-1)F(k_1q)] \quad (9)$$

$$\frac{\partial^2 E[U(\pi_I(x,q,w))]}{\partial q^2}=-(\lambda_I-1)\frac{w^2}{p-c_I}f(k_1q) -(p-c_I+g_I)f(q)-(\lambda_I-1)\frac{(p-c_I-w+g_I)^2}{g_I}f(k_2q)<0 \quad (10)$$

$E[U(\pi_I(x,q,w))]$ is the concave function of q, if $\frac{\partial E[U(\pi_I(x,q,w))]}{\partial q}=0$ in (9), the gained optimum logistics capacity order quantity q_I^* of the LI under the wholesale price contract meets

$$(p-c_I-w+g_I)[\overline{F}(q_I^*)+(\lambda_I-1)\overline{F}(k_2q_I^*)] -w[F(q_I^*)+(\lambda_I-1)F(k_1q_I^*)]=0 \quad (11)$$

Using the optimum order quantity q_I^* under the wholesale price contract of the LI to do the derivative for the stockout loss g_I can get

$$\frac{\partial q_I^*}{\partial g_I}=\frac{\partial^2 E[U(\pi_I(x,q,w))]/\partial q_I^*\partial g_I}{-\partial^2 E[U(\pi_I(x,q,w))]/\partial q_I^{*2}}>0 \quad (12)$$

Equation (12) shows that the optimum order quantity of the LI will increase along with the increase of the stockout loss under the wholesale price contract.

When the logistics capacity order quantity of the LI is q_I^*, the profit of the FLP is

$$\pi_s(w)=\begin{cases} wq_I^*-c_{sf}q_I^*-c_{sv}x, x\le q_I^* \\ (w+g_s-c_{sf}-c_{sv})q_I^*-g_s x, x>q_I^* \end{cases} \quad (13)$$

If the FLP is the risk neutral, the expected profit of the FLP is

$$E[\pi_s(w)]=\int_0^{q_I^*}[(w-c_{sf})q_I^*-c_{sv}x]f(x)dx + \int_{q_I^*}^{\infty}[(w+g_s-c_{sf}-c_{sv})q_I^*-g_s x]f(x)dx \quad (14)$$

The decision goal of the FLP is to offer the wholesale price for the LI to make its profit maximum. The order quantity q of the LI is the function of the wholesale price w, using the expected profit of the FLP $E[\pi_s(w)]$ to do the first derivative for w, can get

$$\frac{\partial E[\pi_s(w)]}{\partial w}=q_I^*+[w-c_{sf}+(g_s-c_{sv})\overline{F}(q_I^*)]\frac{\partial q_I^*}{\partial w} \quad (15)$$

The optimum wholesale price w^* of the FLP meets (16).

$$q_I^*+[w^*-c_{sf}+(g_s-c_{sv})\overline{F}(q_I^*)]\frac{\partial q_I^*}{\partial w}=0 \quad (16)$$

Theorem 1 If the LI and FLP both have the optimum strategy, the order quantity of the LI will decrease along with the increase of the wholesale price.

It can be known from (16), the first item on the left side is positive number and the second item is positive number, so $\partial q_I^*(w)/\partial w<0$, the order quantity decreases along with the increase of the wholesale price.

If the order quantity of the loss-averse LI $q_I^*=q_c^*$, there must be

$$(p-c_I-w+g_I)[\overline{F}(q_c^*)+(\lambda_I-1)\overline{F}(k_2q_c^*)] - w[F(q_c^*)+(\lambda_I-1)F(k_1q_c^*)]=0 \quad (17)$$

$$A(g_I)=(p-c_I-w+g_I)[\overline{F}(q_c^*)+(\lambda_I-1)\overline{F}(k_2q_c^*)] - w[F(q_c^*)+(\lambda_I-1)F(k_1q_c^*)]$$

when $g_I\to 0$, $k_2q_c^*\to+\infty$, $\overline{F}(k_2q_c^*)\to 0$, if you want $A(g_I)<0$, then $w<[(p-c_I)\overline{F}(q_c^*)]/[(\lambda_I-1)F(k_1q_c^*)+1]$, let $w_0\in[c_{sf}+c_{sv},(p-c_I)\overline{F}(q_c^*)]/[(\lambda_I-1)F(k_1q_c^*)+1]$, $w=w_0$, then $\lim_{g_I\to 0}A(g_I)<0$.

When $g_I\to+\infty$, $A(g_I)\to+\infty$, then $\lim_{g_I\to+\infty}A(g_I)>0$, because the optimum order quantity of the LI increase along with the increase of the stockout loss, for w_0, g_I^0 must exist and $A(g_I^0)=0$. When $g_I\in(0,g_I^0)$, the logistics capacity order quantity of the LI $q_I^*<q_c^*$; when $g_I\in(g_I^0,+\infty)$, the logistics capacity order quantity of the LI $q_I^*>q_c^*$. Now, people pay much attention to $g_I\in(0,g_I^0)$, the wholesale price contract cannot coordinate LSSC, so consider to introduce the buyback contract to know whether it can coordinate the supply chain.

2.5 THE LI AND FLP'S DECISION UNDER BUYBACK CONTRACT

When the wholesale price contract cannot coordinate the LSSC, consider introducing the buyback contract (w_b,b), b represents the buyback price of the FLP and the coordination condition of the LSSC under the contract is researched.

When the FLP offers the contract (w_b,b), the logistics capacity order quantity of the LI is q_b and the profit of the LI is

$$\pi_I(x,q,w_b,b) = \begin{cases}(p-c_I-b)x-(w_b-b)q_b, x\le q_b \\ (p-c_I-w_b+g_I)q_b-g_I x, x>q_b\end{cases} \quad (18)$$

It is assumed that the corresponding market demand of the profit break-even point of the LI is q_I, $\pi_I(x,q,w_b,b)=0$, the profit beak-even point of $q_I=\frac{w_b-b}{p-c_I-b}q_b$ and $q_I=\frac{p-c_I-w_b+g_I}{g_I}q_b$ can be got. If $k_{1b}=\frac{w_b-b}{p-c_I-b}$, $k_{2b}=\frac{p-c_I-w_b+g_I}{g_I}$, when $x\in[0,k_{1b}q_b)$ and $x\in(k_{2b}q_b,\infty)$, $\pi_I<0$.

The expected profit function of the LI is

$$E[\pi_I(x,q_b,w_b,b)] = \int_0^{q_b}[([p-c_I-b)x-(w_b-b)q_b]f(x)dx + \int_{q_b}^{\infty}[(p-c_I-w_b+g_I)q_b-g_Ix]f(x)dx \quad (19)$$

The expected utility loss of the LI is

$$L_I(q_b,w_b,b)=(\lambda_I-1)\int_0^{k_{1b}q_b}[(p-c_I-b)x-(w_b-b)q_b]f(x)dx + (\lambda_I-1)\int_{k_{2b}q_b}^{\infty}[(p-c_I-w_b+g_I)q_b-g_Ix]f(x)dx \quad (20)$$

The expected utility of the LI under the buyback contract is

$$E[U(\pi_I(x,q_b,w_b,b))]=E[\pi_I(x,q_b,w_b,b)]+L_I(q_b,w_b,b) \quad (21)$$

The decision goal of the LI is to maximize its expected utility in the context of given wholesale price and buyback price by the FLP and doing the first and second derivative of q_b for (22)

$$\frac{\partial E[U(\pi_I(x,q_b,w_b,b))]}{\partial q_b}=(p-c_I-w_b+g_I)[\overline{F}(q_b)+(\lambda_I-1)\overline{F}(k_{2b}q_b)] -(w_b-b)[F(q_b)+(\lambda_I-1)F(k_{1b}q_b)] \quad (22)$$

$$\frac{\partial^2 E[U(\pi_I(x,q_b,w_b,b))]}{\partial {q_b}^2}=-(\lambda_I-1)\frac{(p-c_I-w_b+g_I)^2}{g_I}f(k_{2b}q_b) -(p-c_I+g_I-b)f(q_b)-(\lambda_I-1)\frac{(w_b-b)^2}{p-c_I}f(k_{1b}q_b) \quad (23)$$

It can be known from (23) that $\frac{\partial^2 E[U(\pi_I(x,q_b,w_b,b))]}{\partial {q_b}^2}<0$, $E[U(\pi_I(x,q_b,w_b,b))]$ is the concave function of q_b, if $\frac{\partial E[U(\pi_I(x,q_b,w_b,b))]}{\partial q_b}=0$ in (21), the gained optimum logistics capacity order quantity q_b^* of the LI under the buyback contract (w_b,b) meets (24) that is

$$(p-c_I-w_b+g_I)[\overline{F}(q_b^*)+(\lambda_I-1)\overline{F}(k_{2b}q_b^*)] -(w_b-b)[F(q_b^*)+(\lambda_I-1)F(k_{1b}q_b^*)]=0 \quad (24)$$

When the logistics capacity order quantity of the LI is q_b, the profit of the FLP is

$$\pi_s(w,b)=\begin{cases}(w_b-c_{sf}-b)q_b-(c_{sv}-b)x, x\le q_b\\(w_b+g_s-c_{sf}-c_{sv})q_b-g_sx, x>q_b\end{cases} \quad (25)$$

The expected profit of the FLP is

$$E[\pi_s(w_b,b)]=\int_0^{q_b}[(w_b-c_{sf}-b)q_b-(c_{sv}-b)x]f(x)dx + \int_{q_b}^{\infty}[(w_b+g_s-c_{sf}-c_{sv})q_b-g_sx]f(x)dx \quad (26)$$

Theorem 2 The buyback contract can coordinate the logistics service supply chain leading by the FLP.

Demonstration: in the buyback contract (w_b,b), put $q_b^*=q_c^*$ into (23) can get (26)

$$b(w_b)=\frac{(p-c_I-w_b+g_I)[\overline{F}(q_c^*)+(\lambda_I-1)\overline{F}(k_{2b}q_c^*)]}{F(q_c^*)+(\lambda_I-1)F(k_{1b}q_c^*)} - \frac{w_b[F(q_c^*)+(\lambda_I-1)F(k_{1b}q_c^*)]}{F(q_c^*)+(\lambda_I-1)F(k_{1b}q_c^*)} \quad (27)$$

Put $b(w_b)$ into (26), when $\frac{\partial E[\pi_s(w_b,b)]}{\partial w_b}=0$, you can get the value of w_b^* and b^*. It shows that the buyback contract can coordinate the logistics service supply chain.

According to the above-mentioned process, the analytic solution of the optimum wholesale price and buyback price can be got.

3 Numeric Analysis

It is assumed that the market demand is object to the uniform distribution $x\in U[0,5000]$, the retail price $p=14$, the stockout loss of the LI $g_I=2$, the operation cost of the integrator $c_I=1$, the stockout loss of the FLP $g_s=2$, the unit logistics capacity discount cost of the FLP $c_{sf}=3$, the unit logistics capacity operation cost $c_{sv}=1$, the loss aversion coefficient of the LI λ_I and the FLP is risk neutral. If the loss aversion coefficient of the LI λ_I is 1.5, 2, 2.5, 3, 4 respectively, it can be calculated that the optimum order quantity q_c^* of the centralized logistics service supply chain is 2,183 and the expected profit is 1,3905.4. You can get the optimum order quantity and optimum wholesale price under the wholesale price contract from (11) and (16), please see Figure 1, from which you can know that the order quantity of the LI is less than the optimum order quantity of the centralized supply chain. Figure 1 verifies the theorem 1.When the LI and FLP both have the optimum strategy under the wholesale price contract, the order quantity of the LI decreases along with the increase of the wholesale price.

Under the buyback contract, the wholesale price and buyback price can be got through calculation, please see Figure 2. Along with the increase of the loss aversion coefficient, the wholesale price increases and the buyback price decreases.

The expected utility of the FLP under the wholesale price contract can be got through the calculation of (14), and the expected utility of the FLP under the buyback contract can be got through the calculation of (26), see Figure 3, which shows that under these two contracts, the expected utility of the provider increases along with the increase of the loss aversion coefficient of the LI; when the loss aversion coefficient is identical, the expected utility of the FLP under the wholesale price contract is smaller than that under the buyback price contract.

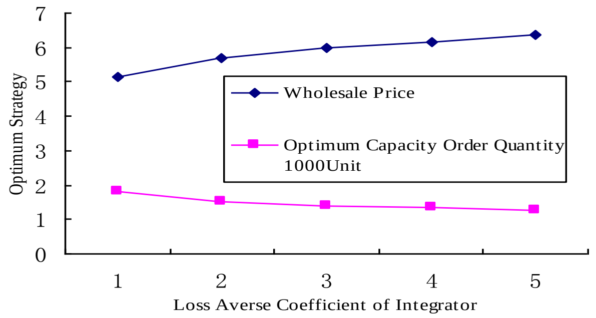

FIGURE 1 Optimum strategy under wholesale price contract

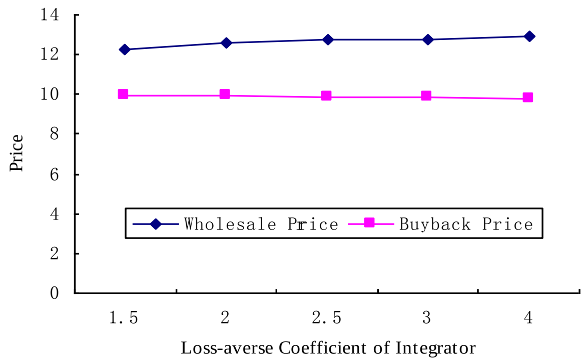

Figure 2 Loss-averse Coefficient and Price

FIGURE 2 Loss-averse coefficient and price

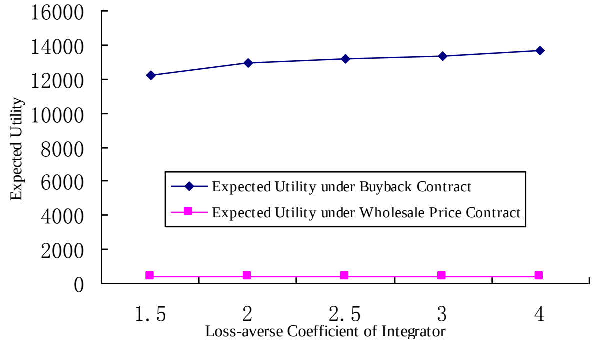

FIGURE 4 Loss-averse coefficient of LI and expected utility of FPL

The total expected utility of the supply chain under the two contracts can be got through calculation, please see Figure 4, from which we can know that, 1) the total expected utility of the whole supply chain decreases along with the increase of the loss-averse coefficient under these two contracts, 2) when the loss-averse coefficient is identical, the total expected utility of the supply chain under the wholesale price contract is smaller than that under the buyback contract.

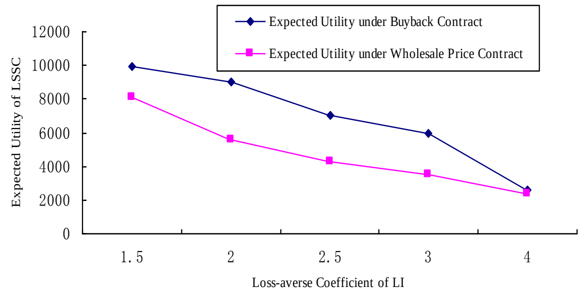

FIGURE 4 Loss-averse coefficient of LI and expected utility

This example shows that the buyback contract can coordinate the logistics service supply chain and encourage the LI to order according to the optimum logistics capacity order quantity of the centralized logistics service supply chain and verifies the theorem 2.

4 Conclusions

This article researches the coordination issue of the buyback contract with two-layer logistics service supply chain and single stage managed by the FLP and the LI is considered to be the decision maker with loss aversion. The research finds that due to the loss–averse characteristic of the LI, its capacity order quantity is lower than the optimum capacity order quantity of the centralized supply chain under the wholesale price contract. The introduction of the buyback contract can encourage the LI to order according to the optimum capacity order quantity of the centralized supply chain to coordinate the logistics service supply chain. The FLP gets more utilities by using its predominant role. The two-layer logistics service supply chain coordination leading by the LI taking into consideration of the behaviour factor, three-layer logistics service supply chain coordination taking into consideration of the behaviour factor, multiple stages coordination of the logistics service supply chain coordination taking into consideration of the behaviour factor and the logistics service supply chain coordination taking into consideration of the behaviour factor of the decision maker under the condition of information asymmetry can be further researched in future.

Acknowledgment

This work was financially supported by Soft Science Key Project in Zhejiang under grant No. 2012C25099，the National Natural Science Foundation of China under grant No. 71271191 and No. 70871111.

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