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Research Article

Capability Coordination in Agricultural Products Logistics Service Supply Chain with Revenue-sharing Contract

[1]Meiling He, [2]Qifan Hu and [1]Xiaohui Wu
[1]School of Automotive and Traffic Engineering, Jiangsu University, Zhenjiang 212013, China
[2]College of Business Administration, Nanchang Institute of Technology, Nanchang 330099, China

Abstract: To solve the capability coordination in logistics service based on the agricultural products industry, a two-stage agricultural products Logistics Service Supply Chain (LSSC) was established with one agricultural products logistics service integrator and one functional logistics service provider. Based on the non-storage property of logistics service capability, the revenue-sharing contract model was built under the uncertain demand. The optimal logistics capability order quantity and the revenue-sharing coefficient were calculated when the agricultural products LSSC achieved coordination. Revenue-sharing contract can coordinate the agricultural products LSSC effectively compared with no contract. A numerical simulation was taken by MATLAB 7.0. The change of purchase price has no influence on the optimal logistics capability order quantity and the expected profit of agricultural products LSSC. It achieves a redistribution of members' profits. With the increases of penalty cost, the optimal logistics capability order quantity and the expected profit of provider increase, while the expected profit of integrator and agricultural products LSSC decrease.

Keywords: Agricultural products, capability coordination, logistics service supply chain, revenue-sharing contract

INTRODUCTION

Due to the short freshness of agricultural products, convenient transportation and reasonable distribution network are very important to reduce the loss and improve the circulation efficiency of agricultural products. With the development of logistics industry, agricultural products LSSC appear. It is a new type of supply chain. The agricultural products logistics services integrator plays a dominant role, by providing flexible logistics services, to ensure the operation of product supply chain.

Revenue-sharing contract plays an important role in the management of supply chain (Krishnan and Winter, 2011; Yao *et al*., 2008a). It causes the wide attention of researchers and managers. The existing literatures mainly focus on product supply chain coordination. Supply chain coordination contracts include common wholesale price contract, buyback contract, revenue-sharing contract, quantity flexibility contract and sales rebate contract etc., (Cachon, 2003; Cachon and Kok, 2010). The revenue-sharing provides only a small improvement over the administratively cheaper wholesale price contract (Cachon and Lariviere, 2005; Gerchak and Wang, 2004). Advantages over mechanisms with a new type of revenue-sharing contracts are discussed (Van der Rhee *et al*., 2010). In manufacturer-retailer channel coordination, it requires cost and revenue-sharing via a revenue sharing rate and marketing effort participation (Kunter, 2012; Yao *et al*., 2008b).

Based on the previous research, the study is different from the traditional manufacturing supply chain coordination. It takes the LSSC of agricultural products industry as the research object. Considering the characteristics of logistics services, coordination of LSSC under the revenue-sharing contract is researched. It has a strong practical significance for the automotive industry resources integration and coordination.

MATERIALS AND METHODS

Materials: Agricultural products logistics mainly include primary agricultural products logistics, fruits and vegetables logistics, meat logistics and so on. Agricultural products LSSC is in the above logistics process. According to the structure of the supply chain, agricultural products LSSC are composed by functional logistics service provider, agricultural products logistics service integrator and logistics service demand, as shown in Fig. 1.

The core task of agricultural products LSSC is the procurement of logistics service. In its operation process, agricultural products logistics services integrator is in core position, which doesn't have its own logistics resources, or have a very small proportion

Corresponding Author: Meiling He, School of Automotive and Traffic Engineering, Jiangsu University, Zhenjiang 212013, China

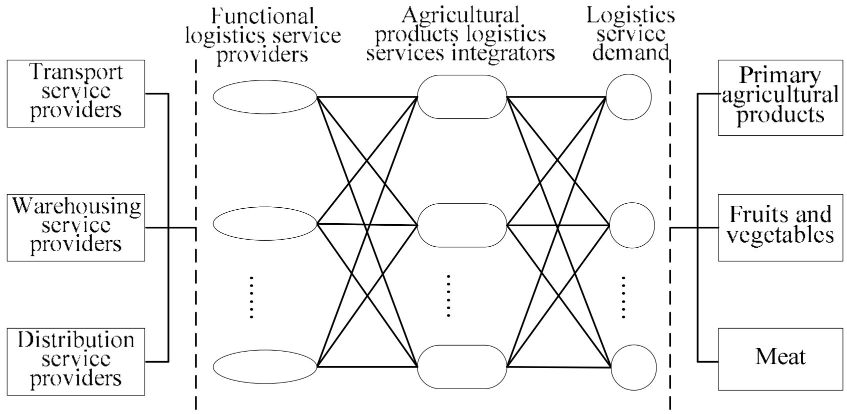

Fig. 1: The constitution of agricultural products LSSC

resource to meet the needs. It has strong management and integrated ability, buying logistics capability from functional logistics service provider, integrating and providing professional logistics services for the logistics service demand.

Basic model: There are one agricultural products logistics service integrator and one functional logistics service provider in two-stage agricultural products LSSC. Agricultural products logistics services integrator faces stochastic demand D, here, $D \geq 0$. The probability density function of demand is $f(x)$ and the distribution function is $F(x)$, $F(0) = 0$, $\overline{F}(x) = 1 - F(x)$. $\mu = E(x) = \int_0^\infty x f(x) dx$ is the mean value of D. The logistics capabilities that the agricultural products logistics service integrator buys from the functional logistics service provider is q and the price is r. When $q<D$, the penalty cost g appears. The costs of functional logistics service provider include logistics capabilities holding cost m_{S1} and operating cost m_{S2}. The operating cost of agricultural products logistics service integrator is m_I. When $q>D$, logistics capability which is not being used does not have the operation cost. Logistics capability sales price p is exogenous. The revenue coefficient under revenue sharing contract is ϕ, $0<\phi<1$. For agricultural products logistics services integrator, the expected logistics capability sales is $S(q)$ and the expected logistics capability loss is $L(q)$.

When there is no contract, the expected profit of agricultural products logistics services integrator is:

$$\pi^I(q) = (p - m_I)S(q) - gL(q) - rq \tag{1}$$

where, $S(q) = \int_0^\infty (q \wedge x) f(x) dx$, $\wedge$ means to choose the lesser one.
Then,

$$\begin{aligned} S(q) &= qF(q) - \int_0^q F(x)dx + q - qF(q) \\ &= q - \int_0^q F(x)dx \end{aligned} \tag{2}$$

The expected logistics capability loss of agricultural products logistics services integrator can also be obtained:

$$\begin{aligned} L(q) &= E[D-q]^+ \\ &= E[\max\{0, D-q\}] \\ &= \mu - S(q) \end{aligned} \tag{3}$$

According to Eq. (1) to (3), the expected profit:

$$\pi^I(q) = (p - m_I - r + g)q - (p - m_I + g)\int_0^q F(x)dx - g\mu \tag{4}$$

For functional logistics service provider, the expected profit is:

$$\pi^S(q) = (r - m_{S1} - m_{S2})q + m_{S2}\int_0^q F(x)dx \tag{5}$$

According to Eq. (4) and (5), the expected profit of LSSC is:

$$\pi^{SC}(q) = (p - m_I - m_{S1} - m_{S2} + g)q - (p - m_I - m_{S2} + g)\int_0^q F(x)dx - g\mu \tag{6}$$

Agricultural products logistics services integrator is dominated. It makes an optimal order quantity of logistics capability, q_0^*, which maximizes the expected profit of logistics service supply chain:

$$\frac{\partial \pi^I}{\partial q} = p - m_I - r + g - (p - m_I + g)F(q_0^*) = 0 \tag{7}$$

When the parameters meet Eq. (7), the LSSC achieves equilibrium.

Revenue-sharing contract: On the revenue-sharing contract, in order to gain more profits, functional logistics service provider sells the logistics capability to agricultural products logistics service integrators with low price r and gets parts sales revenue. The proportion is 1- ϕ.

Then, the expected profit of agricultural products logistics service integrators is:

$$\pi^I(\phi,q) = p\phi S(q) - m_I S(q) - gL(q) - rq$$
$$= (p\phi - m_I - r + g)q - (p\phi - m_I + g)\int_0^q F(x)dx - g\mu \quad (8)$$

and the expected profit of functional logistics service provider is:

$$\pi^S(\phi,q) = (r - m_{S1})q - m_{S2}S(q) + (1-\phi)pS(q)$$
$$= (r - m_{S1} - m_{S2} + (1-\phi)p)q + (m_{S2} - (1-\phi)p)\int_0^q F(x)dx \quad (9)$$

Under the competitive alliance coordination strategy, for agricultural products logistics service integrators, it determines an optimal order quantity of logistics capability q_1^*, from the viewpoint of maximum own benefit:

$$\frac{\partial \pi^I(\phi,q_1^*)}{\partial q} = p\phi - m_I - r + g - (p\phi - m_I + g)F(q_1^*) = 0 \quad (10)$$

Then,

$$q_1^* = F^{-1}\left(\frac{p\phi - m_I - r + g}{p\phi - m_I + g}\right) \quad (11)$$

For functional logistics service provider, it also determines an optimal order quantity of logistics capability q_2^*:

$$\frac{\partial \pi^S(\phi,q_2^*)}{\partial q} = r - m_{S1} - m_{S2} + (1-\phi)p + (m_{S2} - (1-\phi)p)F(q_1^*) = 0 \quad (12)$$

Then,

$$q_2^* = F^{-1}\left(\frac{m_{S1} + m_{S2} - r - (1-\phi)p}{m_{S2} - (1-\phi)p}\right) \quad (13)$$

When the Eq. (11) and (13) are simultaneously satisfied, the agricultural products LSSC achieve an optimal coordination state.

Make $q_1^* = q_2^*$ and the optimal revenue coefficient can be got:

$$\phi^* = \frac{r(p - m_{S2}) + (m_I - g)(m_{S1} - r)}{pm_{S1}} \quad (14)$$

NUMERICAL SIMULATION

There is a two-stage LSSC composed of one agricultural products logistics services integrator A and one functional logistics service provider B. It provides professional fruits and vegetables logistics services for supermarket. Agricultural products logistics services integrator A faces demand D which obeys uniform distribution (0, b). b = 1100, p = 550, m_I = 60, g = 45, m_{S1} = 50, m_{S2} = 55. If it is on the revenue-sharing contract, r = 30; otherwise, r = 190. By MATLAB 7.0 programming model, we can get the following results, as shown in Table 1 to 5.

From Table 1 we can see that the logistics capability order quantity on the revenue-sharing contract is more than no contract. It is same to the expected profit of A, B and LSSC.

From Table 2 we can see that if r changes, q^* is invariant. But if g increases, q^* increases too. It means when g increases, A will order more logistics capability from B to pay less penalty cost.

From Table 3 we can see that if r increases, ϕ^* increases; if g increases, ϕ^* decreases. It means when r increases, the cost of A increases correspondingly. In order to ensure their own profits, A will ask for increasing revenue share. Then it makes ϕ^* increase. When g increases, A will order more logistics capability from B and B will ask for increasing revenue share, in this condition, ϕ^* decrease.

From Table 4 we can see that if r increases, A's expected profit π^I increases; if g increases, π^I decreases. It means that when r increases, revenue coefficient enlarges. It makes A's expected profit increases. When g increases, A will pay more cost and revenue coefficient reduces. It makes A's expected profit decreases.

From Table 5 we can see that if r increases, B's expected profit π^S decreases; if g increases, π^S increases. It means that when r increases, B's revenue share reduces. It makes B's expected profit decreases. When g increases, in order to pay less cost, A will order more logistics capability. Then B's revenue share enlarges. It makes B's expected profit increases.

From Table 6 we can see that if r changes, π^{SC} is invariant; if g increases, π^{SC} decreases. It means when r increases, revenue coefficient enlarges. It makes A's expected profit increase and B's expected profit decrease. When the other parameters are constant, the expected profit of chain is only related to logistics capability order quantity. Because when r changes, there is no influence on logistics capability order quantity, the expected profits of chain is invariant. When g increases, the decreased range of π^I is greater than the increased range of π^S. So π^{SC} decreases.

Table 1: The comparison between the results of the revenue-sharing contract and no contract

	q^*	ϕ^*	π^I	π^S	π^{SC}
No contract	709	-	97612	72874	170486
Revenue-sharing contract	985	0.55	102369	84746	187115

Table 2: The influence on the logistics capability order quantity q^* with the changes in the purchase price r and penalty cost g

	r							
g/q^*	24	26	28	30	32	34	36	38
35	983	983	983	983	983	983	983	983
45	985	985	985	985	985	985	985	985
55	988	988	988	988	988	988	988	988
65	990	990	990	990	990	990	990	990
75	992	992	992	992	992	992	992	992
85	994	994	994	994	994	994	994	994

Table 3: The influence on the revenue-sharing coefficient ϕ^* with the changes in the purchase price r and penalty cost g

	r							
g/ϕ^*	24	26	28	30	32	34	36	38
35	0.46	0.49	0.52	0.56	0.59	0.63	0.66	0.69
45	0.45	0.48	0.52	0.55	0.59	0.62	0.66	0.69
55	0.44	0.47	0.51	0.54	0.58	0.61	0.65	0.69
65	0.43	0.46	0.50	0.54	0.57	0.61	0.65	0.68
75	0.42	0.45	0.49	0.53	0.57	0.60	0.64	0.68
85	0.41	0.45	0.48	0.52	0.56	0.60	0.64	0.67

Table 4: The influence on A's expected profit π^I with the changes in the purchase price r and penalty cost g

	r							
g/π^I	24	26	28	30	32	34	36	38
35	79834	88091	96348	104605	112862	121119	129376	137633
45	76945	85420	93894	102369	110843	119318	127793	136267
55	74057	82749	91441	100134	108826	117518	126210	134903
65	71170	80080	88990	97900	106810	115720	124630	133540
75	68284	77412	86540	95668	104795	113923	123051	132179
85	65399	74745	84091	93437	102782	112128	121474	130820

Table 5: The influence on B's expected profit π^S with the changes in the purchase price r and penalty cost g

	r							
g/π^s	24	26	28	30	32	34	36	38
35	107341	99084	90827	82570	74313	66056	57799	49542
45	110170	101695	93220	84746	76271	67797	59322	50848
55	112999	104307	95615	86922	78230	69538	60846	52153
65	115830	106920	98010	89100	80190	71280	62370	53460
75	118662	109534	100406	91278	82151	73023	63895	54767
85	121495	112149	102803	93458	84112	74766	65420	56075

Table 6: The influence on the agricultural products LSSC's expected profit π^{SC} with the changes in the purchase price r and penalty cost g

	r							
g/π^{sc}	24	26	28	30	32	34	36	38
35	187176	187176	187176	187176	187176	187176	187176	187176
45	187115	187115	187115	187115	187115	187115	187115	187115
55	187056	187056	187056	187056	187056	187056	187056	187056
65	187000	187000	187000	187000	187000	187000	187000	187000
75	186946	186946	186946	186946	186946	186946	186946	186946
85	186894	186894	186894	186894	186894	186894	186894	186894

CONCLUSION

Based on revenue-sharing contract, the study researches capability coordination of two-stage agricultural products LSSC comprised of one agricultural products logistics services integrator and one functional logistics service provider. After analyzing the structure of agricultural products LSSC, the study builds models about revenue-sharing contract and no contract. We get the conditions of the LSSC achieving an optimal coordination. By comparative analysis, we find that the revenue-sharing contract in this study is superior to the traditional model. It can reasonably distribute the profit between agricultural products logistics services integrator and functional logistics service provider.

There are some deficiencies in this study. For example, we just consider single cycle LSSC in model. It can be extended to more cycles, multistage agricultural products LSSC. In addition, the demand may be related to price, time and service satisfaction in the process of actual operation. This is our further research direction.

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