The Complex Economic System of Supply Chain Financing

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Abstract. Supply Chain Financing (SCF) refers to a series of innovative and complicated financial services based on supply chain. The SCF set-up is a complex system, where the supply chain management and Small and Medium Enterprises (SMEs) financing services interpenetrate systematically. This paper establishes the organization structure of SCF System, and presents two financing models respectively, with or without the participation of the third-party logistic provider (3PL). Using Information Economics and Game Theory, the interrelationship among diverse economic sectors is analyzed, and the economic mechanism of development and existent for SCF system is demonstrated. New thoughts and approaches to solve SMEs financing problem are given.

Keywords: supply chain financing, small and medium enterprises financing, information economics, optimization.

1 Introduction

Around the world, the source of external financing for small and medium enterprises (SMEs) is an interesting topic to academics, and it's also an issue of great importance to policy makers. The practice of supply chain financing has expanded greatly in recent years, which brought new fields of study on the solutions to SMEs financing and financial innovation in the Banking Industry.

As a new topic, limited systematic research results of SCF have been revealed. Some of the extant literature just put forward the idea or perception of SCF, described its consequence or worth [1-4]; others mostly focused on logistics to analyze the conception, members, operational process etc of SCF models [5-8]. They have paid scant attentions to quantitative, systematic, and intensive study on SCF.

In this paper, the economic organization of SCF is regard as a complex system composed of many interest parties. After establishing the organization structure of SCF System, we analyze the basic financing models of SCF systematically, and demonstrate the economic mechanism of its development and existence by game theory. Then the advantage, properties and financing mechanism come out clearly.

2   SCF's Properties and Financing Models

As a new concept, there has not a vulgate definition for SCF. In this paper, the SCF system is defined as a complex financial system, which means a bank measures the quality of company's supply chain, and then provides finance to one or several suppliers and distributors (especially the SMEs) to ensure the integrated chain running stably and smoothly. The commercial bank, the big enterprises and SMEs on the chain, the 3LP, the government and other institutions co-exist in a mutualism environment. The organization structure of SCF system is given in Figure 1.
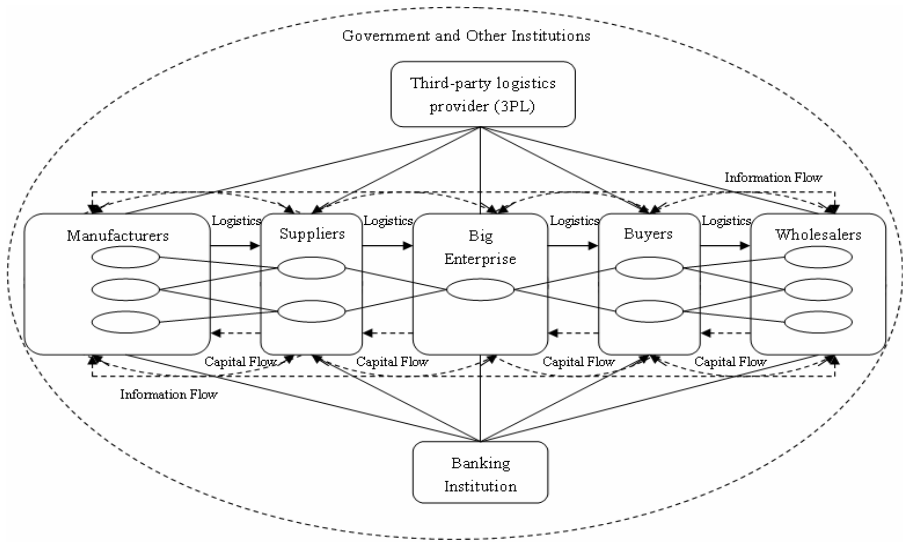

Fig. 1. The organization structure of SCF system

2.1   SCF's Conception and Properties

According to the definition above, we can get three properties of the SCF models as follows.

(1) An organ system. The SCF system is composed of series of interdependent subsystems with specific functions. It consists of three units, inputting, processing and outputting. Its ultimate aim is to expand the supply chain value and upgrade the overall competitiveness.

(2) Collective rationality. In SCF system, the enterprises' (including the banking institution) decisions react directly with other's, which means chain parties' present interests and long-term interests should be considered in decision making. And the collective rationality comes to effect because of the good competitive and cooperative relation and enhanced visibility among the subsystems.

(3) Complexity. The SCF system's participants are excessive, where include capital flow, logistics flow and information flow. They are all complicated and uncertain.

2.2 SCF's Financing Models

The cash gap [9] is the number of days between a business's payment of cash for goods and services bought and the receipt of cash from its customers for goods or services sold. As defined above, the cash gap model is made up of three parts: receivables, payables and inventory. Correspondingly, the models of SCF consist of three ones which are reflected in table 1. In details, the financial models can be divided into two main types, one is debt financing model without the participation of 3PL, the other is personalty financing model with the participation of 3PL.

Table 1. The types of SCF models

	Financial Model	3PL	Stage	Hypothecation	Position on the Supply Chain
Debt Financing Model	Receivables	Non-participation	Inventory Shipped to Cash Received	Creditor Right	Supplier
Personalty Financing Model	Payables	Participation	Inventory Arrives to Cash paid	Real Right (Goods will be bought)	Distributor
	Inventory	Participation	All times with stable inventory	Real Right (Inventory)	Any Enterprises

3 Game Theory Analysis of Debt Financing without the Participation of 3PL

First, let's analyze the debt financing model without the participation of 3PL, whose fundamental idea is: a SME, the creditor of a big enterprise, can apply for loan to bank through the creditor right. The availability of financing for a SME increases while the bank credit risk decreases.

3.1 Repeated Game with Complete Information between Bank and Enterprise

We assume that a SME needs loan L for an investment project, whose success probability is α ($0 < \alpha < 1$). Let β be the rate of investment if successfully, then the SME's expected revenue from the project loan is $\alpha\beta L$. To the bank, let R be interest income and C be monitoring costs, then the return to the bank can be written as

$$\alpha\beta L - R \left(\alpha\beta L - R > 0, 0 < C < R \right) \ .$$

For simplicity, we shall assume that the interest rate is fully liberalized on the market and transaction cost between the bank and SME is zero. Their discount rate is $\delta \left(0 < \delta < 1 \right)$.

With the information presented above, it is possible to specify the pay-off matrix of the game in Table 2. [10]

Table 2. Pay-off matrix of repeated game with complete information between bank and enterprise

		SME Strategies	
		Repay	Don't repay
Commercial bank Strategies	Loan	$\dfrac{R-C}{1-\delta}, \dfrac{\alpha\beta L-R}{1-\delta}$	$-L-C, \alpha\beta L+L$
	Don't loan	0,0	0,0

Whether he bank provide the loan or not is given on the success probability of the project α.

Then

$$\frac{\alpha\beta L-R}{1-\delta} > \alpha\beta L+L \ ,$$

that is

$$\alpha \geq \frac{R+L-\delta L}{\delta\beta L} \ ,$$

the Nash Equilibrium in perfect information games sets. As a matter of fact, it cannot attain in practical because of "information asymmetry" and "credit grudging". Then SCF emerges and provides new thoughts and approaches to solve the problem.

3.2 Signalling Game between Bank and Enterprise in SCF System

We assume that there are two types of SMEs. One is good SME whose success probability is

$$\alpha_1 \geq \frac{R+L-\delta L}{\delta\beta L} \ .$$

It will repay the loan under complete information to keep good terms with the bank. The other one is bad SME whose success probability is lower,

$$\alpha_2 < \frac{R+L-\delta L}{\delta\beta L} \ .$$

It will not repay the loan without restrained mechanism.

Suppose the SME has two strategies to select.

The first one is to "be in" SCF system, that is, the SME has real and stable trade contacts with the big enterprise. If the SME fails to repay, the big enterprise will also make up for the lost of bank. To SME, we resume the reverse guarantee costs provided by big enterprise are S (As debtor-creditor relationship between SME and big enterprise exists originally, the costs S is too small and can be neglected.) and default costs are F. In SCF system, the information set the bank can observe is f.

The second one is to "be out of" SCF system, which information set is i. With the information presented above it is possible to specify the extensive game in Figure 2.

According to the strategy set of the SME, four aspects can be discussed. First of all, we analyze the situation (Be in, Be in).

Although the bank can't judge a SME whether a good enterprise or not just by the signal sent by SME, the probability of a SME to be considered as a good one, $p(0.5 < p < 1)$, is high provided that the SME has closer economic partnership with the big enterprise.
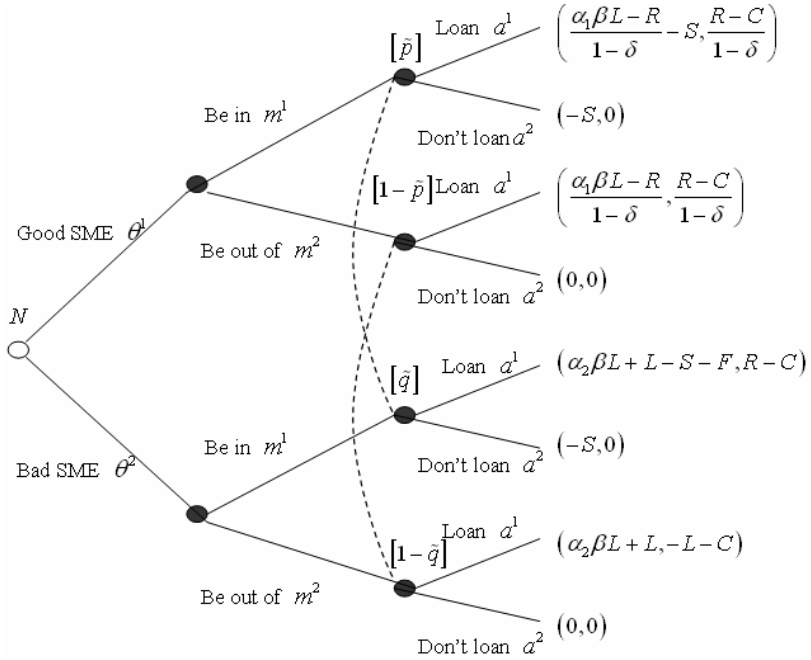

Fig. 2. Signaling game between the bank and enterprise

Within the information set f, the return to the bank if it selects "loan" is

$$\Pi_{B_1}^f = p\frac{R-C}{1-\delta} + (1-p)(R-C) , \tag{1}$$

and the return to the bank if it select "don't loan" is

$$\Pi_{B_2}^f = 0 . \tag{2}$$

It was patently obvious that $\Pi_{B_1}^f > \Pi_{B_2}^f$, and the bank will select "loan".

Within the information set i, the return to the bank if it select "loan" is

$$\Pi_{B_1}^i = q\frac{R-C}{1-\delta} + (1-q)(-L-C) , \tag{3}$$

and the return to the bank if it select "Don't loan" is

$$\Pi_{B_2}^i = 0 . \tag{4}$$

If

$$\Pi^i_{B_1} > \Pi^i_{B_2} \ ,$$

then

$$q > \frac{L+C-\delta L-\delta C}{R+L-\delta L-\delta C} \ ,$$

the bank will select "loan".

Given the selection of the bank, the good SME will select to establish stable business relations with the big enterprise on the supply chain. Given that

$$\alpha_2 \beta L + L - S - F > 0 \ ,$$

that is

$$F < \alpha_2 \beta L + L - S \ ,$$

the bad SME will also choose to lean on the big enterprise. Then a pooling equilibrium can be gotten.

We summarize the analytical result of signaling game between bank and enterprise in Table 3.

Table 3. Analytical result of signalling game between bank and enterprise

	$S(SME)$	$S(Bank)$	$\left[\tilde{p}\left(\theta^1\middle|m^1\right),\tilde{p}\left(\theta^2\middle|m^1\right)\right]$	$\left[\tilde{p}\left(\theta^1\middle|m^2\right),\tilde{p}\left(\theta^2\middle|m^2\right)\right]$
Pooling Equilibrium $F<\alpha_2\beta L+L-S$	(Be in, Be in)	(Loan, Loan)	$\left(0.5<p<1,0<1-p<0.5\right)$	$\left(q>\dfrac{L+C-\delta L-\delta C}{R+L-\delta L-\delta C},1-q<\dfrac{R-C}{R+L-\delta L-\delta C}\right)$
Out-of Equilibrium	(Be out of, Be out of)	/	/	/
Separating Equilibrium $F>\alpha_2\beta L+L-S$	(Be in, Be out of)	(Loan, Don't loan)	$(1,0)$	$(0,1)$
Out-of Equilibrium	(Be out of, Be in)	/	/	/

3.3 Research Revelation of Debt Financing Model

The above discussion thus shows that a pooling equilibrium can be gotten, if

$$\Pi^f_{C_2} > \Pi^i_{C_2} \ ,$$

that is

$$F < \alpha_2 \beta L + L - S \approx \alpha_2 \beta L + L \ .$$

In such a case, the return of "be in" is greater than that of "be out of", and so both the SMEs, good or bad, will choose to apply to the bank for a loan under the SCF

system. Under this model, the bank cannot discriminate good SEM from bad, it will provide the loan to the "Be out of" SME given its prior belief

$$\tilde{p}\left(\theta^2 \left| m^2 \right.\right) < \frac{R-C}{R+L-\delta L-\delta C} \ .$$

Then the bank can transfers the credit risk of the loan to the suppliers' high-quality buyers as a joint-liability guarantor and will provide the loan to both good and bad SMEs, which is bound to cause loss to the bad SME's counterpart. The big enterprise will "raise the threshold" accordingly to avoid this pooling equilibrium.

On the other hand, a separating equilibrium can be gotten,

if

$$\Pi_{C_2}^f < \Pi_{C_2}^i \ ,$$

that is

$$F > \alpha_2 \beta L + L - S \approx \alpha_2 \beta L + L \ .$$

In such a case, the good SME chooses to "be in" and bad one chooses to "be out of". Consequently, the good one can secure the loan and the bad not. Then a "virtuous cycle" is starting between the bank and SME. Furthermore, the whole industrial chain can develop more stably and coordinately.

4   Optimal Analysis of Personalty Financing with the Participation of 3PL

"Payables" and "Inventory" belong to "Personalty Financing" model with the participation of 3PL, whose fundamental idea is: The bank B holds the eminent domain of finance; the logistics provider L holds supervision and control right over the inventory. They make an alliance A to provide financing services to SME. In such a case, the bank and logistics provider are principal, and the SME is agent. [11]

4.1   Optimal Decision Analysis of Personalty Financing Model

We assume that ultimate demand for products depends on the price, i.e., $q = \alpha - \beta p$ (α, β is nonnegative parameter). Supervision cost per unit product of the bank and logistics provider is c_B and c_L respectively. Product unit revenue defines as u_i, $i = B, L, A$. The SME's production profit gained by demand can be measured by the bank's profit simply, if the production cost is standardized to 0 and the interest is left out of account.

Let a random variable X_i be the posterior belief of $c_i (i = B, L)$, its cumulative distribution function is $\psi_i(x)$ and density function is $\varphi_i(x)$. Meanwhile let a random variable $\hat{X}_i$ signs the indirect information, its cumulative distribution function is $\hat{\psi}_i(x)$ and density function is $\hat{\varphi}_i(x)$. All the distribution functions are assumed strictly positive and have increasing failure rate.

For further analyses, let's give a useful property. [12]

Property 1. Suppose a random variable X_i is a log-concave function, whose cumulative distribution function is $F_i(x)$ and density function is $f_i(x), i = 1, 2$. Then,

(1) The increasing failure rate $\dfrac{F_i(x)}{f_i(x)}$ is monotone decreasing.

(2) If $t(x)$ is twice differentiable and strictly log-concave, $\dfrac{F_i(x)}{f_i(x)}$ is a log-concave function.

(3) Integral equation $F(x) = \int_0^x G_1(x - x_2) G_2(x_2)$ is a log-concave function.

When $u_A \geq c_B + c_L$, the alliance will accept agreement offered by SME. The supervision cost of the alliance observed by SME can be denoted by $\hat{X}_B + X_L$, so that the probability of signing the contract agreement at the first stage is given by

$$P\{\hat{X}_B + X_L \leq u_A\} = \int_0^{u_A} \psi_L(u_A - x_B) d\hat{\psi}_B(x_B) . \tag{5}$$

The SME wishes to maximize its expected profit at the first stage

$$\max \Pi(p, u_A) = (p - u_A)(\alpha - \beta p) \int_0^{u_A} \psi_L(u_A - x_B) d\hat{\psi}_B(x_B) . \tag{6}$$

Since $\Pi(p, u_A)$, u_A is concave function with respect to p, find the critical numbers of p, then have

$$\begin{cases} p = \dfrac{\alpha + \beta u_A}{2\beta} \\ q = \dfrac{\alpha - \beta u_A}{2} \end{cases} . \tag{7}$$

By (6) and (7) we may consider the optimization problem of solving the following equation

$$\max \Pi = \frac{(\alpha - \beta u_A)^2}{4\beta} \int_0^{u_A} \psi_L(u_A - x_B) d\hat{\psi}_B(x_B) . \tag{8}$$

Calculate the first derivative and get

$$\frac{\alpha - \beta u_A}{2\beta} = \frac{\int_0^{u_A} \psi_L(u_A - x_B) d\hat{\psi}_B(x_B)}{\int_0^{u_A} \varphi_L(u_A - x_B) d\hat{\psi}_B(x_B)} . \tag{9}$$

Since $\int_0^{u_A} \psi_L(u_A - x_B) d\hat{\psi}_B(x_B)$ is the integral of ψ_L and $\hat{\psi}_B$, it is also a log-concave function according to Property 1. The right side of (9) is the increasing function of u_A, while the left side of (9) is decreasing function of u_A. Hence, we get the

unique optimal solution u_L^* of (9), which means we attain the unique optimal solution $\left(p^*, u_A^* \right)$ of (6).

4.2 Research Revelation of Personalty Financing Model

Based on the optimism analysis above, we can state that the three participants, namely, the bank, 3PL and SME, can achieve the optimum and realize multi-win in the personalty financing model. Firstly, for banking institution, SCF represents an opportunity to generate new revenues, deepen relationships with regular clients, and reduce credit risk. Secondly, for logistics provider, SCF helps 3PL to upgrade service quality standards and enhance the value-added groups in marketing integration. Thirdly, for SME, SCF allows SME to increase its cash stock, strengthen its financial profile, and take advantage of its raw materials or finished goods on market as pledge, all of which contribute greatly to develop a more stable supply chain.

5 Conclusion

As an efficient and multi-win complex financial system, all participants in Supply Chain Financing system seek to maximize their profits by playing various roles respectively, inter-coordinating and sharing the risks or profits together. In this paper, by using information economics and game theory, we try to analyze the two SCF models with and without the participation of third-party logistic providers respectively. Then, by proving the existence of unique optimum solution, this paper explains the economic mechanism why the SCF model can solve the problem of SMEs financing.

References

1. Berger, A.N., Udell, G.F.: A More Complete Conceptual Framework for SME Finance. Journal of Banking and Finance 30, 2945–2966 (2006)
2. Yang, S.H.: Research on Supply Chain Financing Service. Logistics Technology 10, 179–182 (2005) (in Chinese)
3. Gonzalo, G., Badell, M., Puigjaner, L.: A Holistic Framework for Short-term Supply Chain Management Integrating Production and Corporate Financial Planning. International Journal of Production Economics 106, 288–306 (2007)
4. Feng, Y.: Supply Chain Financing: Financial Innovation Services to Realize Muilt-win. New Finance 2, 60–63 (2008) (in Chinese)
5. Richard, G.: Longer Chains, Lower Costs: to Create A Seamless Supply Chain, Every Link Must Feel Like It's Winning. Treasury and Risk Management 14, 40–46 (2004)
6. Klapper, L.F.: The Roal of Factoring for Financing Small and Medium Enterprises. Journal of Banking and Finance 30, 3111–3130 (2006)

7. Tang, S.Y.: Study of interflow of commodities service in finance. Inner Mongolia Coal Economics 05, 13–16 (2005) (in Chinese)
8. Yan, J.H., Xu, X.Q.: SME Financing model based on Supply Chain Financing. Shanghai Finance 2, 14–16 (2007) (in Chinese)
9. Boer, G.: Managing the Cash Gap. Journal of Accountancy 10, 27–32 (1999)
10. Chen, Q.A., Chen, L.: Study on Debt Financing Game Model of SMEs based on Credit Guarantee. On Economic Problems 7, 21–24 (2008) (in Chinese)
11. Li, J., Xu, Y., Feng, G.Z., Li, Y.X.: Research on Decision of Bank's Outsourcing in Warehouse Financing. Operations Research and Management Science 2, 84–87 (2007) (in Chinese)
12. Bergstrom, T., Bagnoli, M.: Log-concave Probability and Its Applications. Economic Theory 26, 445–469 (2005)