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The Value of Supply Chain Finance

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1. Introduction

In traditional study of supply chain management, people mainly consider the decisions from perspective of the operations management, such as, capacity, inventory, ordering level, pricing, etc., and often ignore to consider the impact of financial flow within the supply chain. However, the key function of supply chain management is concerned with the coordination of material flows, information flows, and funds flow (Figure 1). Therefore, the operation decisions of a firm is affected by its own initial capital status. For instance, with the globalization and international competition intensified, many companies have experienced a shortage of capital. The constrained capital of a company could affect the funds flow in the supply chain, and the performance of the entire supply chain as well.

In global supply chain, and especially in the post-financial-crisis era, capital constraints are strengthened by common cash-management practices that promote collecting account receivable as quickly as possible while postponing payments to providers and suppliers. This "war for cash" (Milne, 2009) is squeezing small companies harder—these cash-strapped companies find themselves faced with increasing chances of going out of business. Also, the fact that large buyers are forcing suppliers from less developed countries to move to open account has further contributed to the problem of cash flow (UPS Capital, 2007). Consequently, a company with capital constraints who cannot raise funds from bank credit channel or other's channel could hurt its own profit as well as that of the entire supply chain.

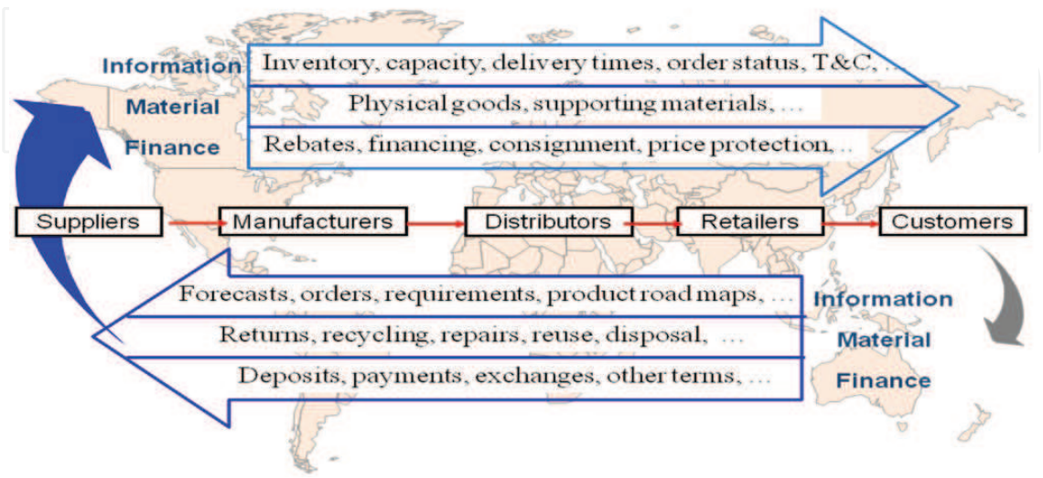

Fig. 1. Three types of flows in the supply chain

How to solve this grave problem of capital constraints in the supply chain in developing or developed economics? To answer this question, this chapter sheds some light on how Supply Chain Finance (SCF) impacts agents' operational and financial decisions under the symmetric/asymmetric information and how SCF can create value for supply chain with capital constraints. In this chapter, we define SCF as the jointly operations/logistics and financing service, offered by a 3PL firm (Control Role), or an alliance of 3PL firm (Delegation Role) and financial institution (i.e., bank), etc. On one hand, SCF is a financing service which can relax the capital constraints in the supply chain; on the other hand, SCF is combined with a logistics service or trade transaction service.

Different from traditional commercial loans which rely on fixed assets as the securities, SCF commonly depends on the liquid asset, such as inventories, accounting receivables or others, as the collateral. Since the bank does not have the resources to track or monitor the status of liquid assets, the bank could refuse to offer financing service with liquid assets as the collateral. Instead, the bank prefers to offer the fixed asset based financing. Unfortunately, the small-medium size firms are often of limited fixed asset, and could not raise funds from the bank by fixed-asset-based-financing. Even the development of Globalization and Outsourcing has resulted in fewer assets for the firms in the supply chain, making it more difficult for firms to borrow funds secured by fixed-based-financing. Then, SCF, as an innovative financing solution, bridges the bank and capital-constrained firms in the supply chain, reduces the mismatch risk of supply and demand in the financial flow, and creates value for supply chain with capital constraints.

Based on the definition of SCF, the 3PL firm plays an important role in SCF, since it is able to have access to various information generating from supply chain's activities, and then marry this information with the material flow. Consequently, the coupling of information and material flows enable lenders (i.e., banks) to mitigate financial risk within the supply chain, and then reduce the credit risks of financing service. The mitigation of financing risk allows the capital-constrained firm in the supply chain more capital to be raised, capital to be accessed sooner or capital to be raised at lower rates[1].

Before characterizing the value of SCF in the supply chain with capital constraints, we further illustrate the meanings of SCF by the following three examples in real business operations (Caldentey and Chen 2010, Chen and Wan 2011, Chen and Cai 2011).

Chinese Material Shortage Transportation Group (CMST) is one of the largest logistics enterprises in China. Many small and medium size paper manufacturers in mainland China purchase materials from international suppliers. It is not uncommon that the financial system is unable to provide adequate services to support these manufacturers though they are short of capital. As a result, most of these small manufacturers find themselves making suboptimal procurement decisions. CMST viewed this gap as a business opportunity and, since 2002, started financing these small paper manufacturers to buy paper materials from international suppliers while simultaneously providing the logistics services required in these transactions. Under this credit contract, the paper manufacturer pays a fraction of the wholesale price charged by the supplier as a deposit and CMST covers the difference. After the sale season, the manufacturer repays CMST the remaining fraction of the wholesale price. With this supply chain financing service, CMST has become one of the leading

[1] We refer the reader to read UPS Captal Global Supply Chain Finance in 2007.

logistics-financing service providers in China. In 2006, CMST financing supply chain business was about 1.1 billion dollars, up from 750 million dollars in 2005. Currently, this operation is one of most popular modes of financing for small-and-medium companies in China. As the CMST example unveils, bringing financing services into supply chain management has the potential to improve the operational efficiency and the profits of the entire supply chain.

In an example of a mobile-phone supply chain in China, a manufacturer sells mobile-phones to end-users via retailers. Although demand for the mobile phones is high, many retailers can order only a limited number of mobile phones from the manufacturer because of limited cash. Hence, the capital constraints of retailers strongly influence both the retailers' and manufacturer's revenue, as well as the performance of the entire supply chain. With the above situation taken into consideration, the manufacturer built an alliance with a local bank to motivate the bank to offer commercial loans to those capital-constrained retailers. This practice achieved great success and the manufacturer attained its largest market share in 2002. Since then, many mobile-phone manufacturers in China have started to cooperate with banks to help capital-constrained retailers make loans from banks to increase their revenue. As discussed above, capital constraints may influence the operational decisions in a supply chain while financing may relax the constraints with additional costs (usually in form of interest). Therefore, it is important to know how financing influences the operational decisions and performance of individual firms in a capital-constrained supply chain, and how a retailer jointly makes operational and financial decisions under capital constraints.

Financing support from banks could facilitate capital-constrained companies greatly. A professional aluminum ingots trading company grew from less than 5 million Yuan to over 600 million Yuan in one year, with the aid of a goods-ownership mortgage loan (50 million Yuan) from Shenzhen Development Bank. However, not all companies could get as lucky as the one in this case. Banks might not be willing to provide financing service for it's difficult for them to monitor the transactions of the products. Thus, without accurate real-time information about the transactions, banks would have to figure out some way to keep the capital-constrained companies from diverting the loan to other riskier projects. Here comes the *integrating logistics and financing service (ILFS)*, through third party logistics (3PL) firms that ally with financial institutions and provide cooperative logistics and financial solutions to capital-constrained retailers. The benefits of ILFS are absolutely worth discussing.

These examples show that SCF plays an important role in the real business. However, the research on SCF is very limited in the literature. The motivation of this chapter is to make a first step on the research about this field.

The rest of this chapter is organized as follows. We review the literature in Section 2. Under the symmetric information, we inspect the value of financing service to the supply chain with capital constraints, and examine the jointly operations and financing decisions for the agents, in Section 3. We then model to highlight the value of 3PL firm in SCF under asymmetric information, and analyze how SCF could create more value for supply chain in Section 4 and 5. We conclude in Section 6.

2. Literature review

Our work is relative to the interface research of operations and financial management. In this section, we firstly review the related work in the economic and financial area;

secondly, we further review the current research of operations/finance track; finally, we analyse the related work in which 3PL firm plays a role in supply chain's financing service.

Economics research has shown that a buyer's budget constraints may influence the optimal mechanism of supply/procurement contract. In this vein, Levaggi (1999) develops a principal-agent model in which the principal (a buyer) faces a binding budget constraint, and argues the budget constraint does not guarantee that the principal is always better off if an incentive compatible contract is used. Hence the likely outcome is either a pooling or a bargaining solution. Che and Gale (2000) argues that a buyer's budget constraint may make it optimal for the seller to use non-linear pricing, to commit to a declining price sequence, to require the buyer to disclose her budget, or to offer financing. Simchi-Levi and Thomas (2002) study the non-linear pricing problem when a budget constraint limits the magnitude of monetary transfer. The literature examines only the operational decisions, and does not consider the interaction between operational decisions and financial decisions. In this chapter, we study the supply chain management problem in which the retailer is capital-constrained, thus involving both financial decisions and operational decisions simultaneously.

In finance literature, researchers mostly study a firm's integrated investment decision which influences its capacity sizes and debt decisions, and implicitly study a firm's integrated operational and financial decisions. For example, Dotan and Ravid (1985) show that the investment and optimal financial decisions have to be made simultaneously and that a negative relationship exists between capacity expansion and the financial leverage. Dammon and Senbet (1998) analyse how the corporate and personal taxes influence a firm's optimal investment and financial decisions under uncertainty. They show that, when investment (equity investment) is allowed to adjust optimally, the existing prediction about the relationship between investment-related and debt-related tax shields must be modified. Mello and Parsons (1992) compare the operational decisions of a mine under all-equity financing policy with those mines of partial financing to maximise leveraged equity value. Mauer and Triantis (1994) analyse the case where the firm has the flexibility to shut down or reopen its production facility in response to price fluctuations. In contrast to the literature in economics and finance, this chapter incorporates the financial decisions into operational decisions more directly and analyses the interactions between financial and operational decisions.

In the literature on supply chain management, researchers are mostly concerned with the material flow and often ignore the impact of the financial flow. For instance, in Graves and Ton (2003) and Simchi-Levi et al. (2004), the mostly studied problems include production planning/inventory control, capacity expansion and performance of supply chains. However, financial flows are important in real-world supply chain management. Caldentey and Haugh (2005) argue that budget constraints are quite common in practice due to many reasons.

Recently, more and more studies in operations management have started to look at the interface between operations and financial management. Chen and Wan (2011) reveal how supply chain could benefit from financing services, compared to the situation without financing services. However, most literature is concerned with the integrated operational and financial decisions based on retailer's behaviour/strategy in a supply chain under symmetric information. For instance, most literature focuses on discussion of the budget-constrained firm's production/inventory or capacity decisions and debt decisions, and seeks to demonstrate that it is important to incorporate financial decisions into operational

decisions. Buzacott and Zhang show the importance of joint production and financial decisions in a start-up setting, where the firm's growth capability is mainly constrained by its limited capital and depends on bank loans. They use a single period newsvendor model to explain the motivation for asset-based financing by analysing the decision-making at a bank and a set of retailers with different budgets. Hu and Sobel (2005) use a dynamic newsvendor model with a criterion of maximising the expected present value of dividends to analyse the interdependence of a firm's capital structure and its short-term operational decisions involving inventory, dividends and liquidity. Chao et al. (2008) use multi-period inventory models to provide insights into the interaction between financial and operational decisions, and shows that it is essential for the retailers to take financial considerations into their operational decisions, especially for the retailers who are short of capitals. Boyabatli and Toktay (2006) analyse the impact of capital market imperfection on a firm's operational and financial decisions in a capacity investment setting, where the firm's limited budget, depending partly on a tradable asset, can be increased by borrowing from external market (commercial loan collateralised by physical asset), and its distribution can be altered with financial risk management (using forward contract to reduce the financial risk of tradable asset). However, all literature except for Buzacott and Zhang (2004) assume the interest rate of a loan is exogenous, ignoring the impact of competition of financial market or borrowing level on the interest rate of loan. Buzacott and Zhang (2004) consider the bank's decision on the interest rate but their optimal interest rate is independent of the competition in a financial market.

Although currently an increasing number of literature considers the jointly operations and financial decisions in the supply chain management area, limited literature characterises the value of SCF or the role of 3PL firm in the supply chain with capital constraints. Hofman (2005) introduces some conceptual insights of supply chain finance, and help the executives to look behind the SCF approach. To the best of our knowledge, among the first to examine the value of 3PL firm's integrated logistics and financing service is the paper by Chen and Xie (2009). They use the model to show that if 3PL firm offers the conventional logistics service, the budget-constrained retailer may not apply for loans successfully because of the asymmetric information, and also show that a monopolistic or competitive financing market can create value for budget-constrained supply chain. Lu et al. (2009) inspect the incentive of logistics service provider (LSP) for a 3PL firm to provide financial support to the retailer/supplier and to establish the backup inventory. Chen and Cai (2010) investigates an extended supply chain model with a supplier, a budget-constrained retailer, a bank, and a 3PL firm, in which the retailer has insufficient initial budget and may borrow or obtain trade credit from either a bank (traditional role) or a 3PL firm (control role). Their analysis indicates that the control role model yields higher profits not only for the 3PL firm but also for the supplier, the retailer, and the entire supply chain.

In order to inspect the value of supply chain finance, in this current chapter we would mostly summarize some of the results and highlights from Chen and Wan (2011), Chen and Xie (2009), and Chen and Cai (2011). This chapter emphasizes on understanding of SCF and 3PL firm's value in the capital-constrained supply chain.

3. Model description and assumptions

We consider a simple supply chain with a supplier and a retailer. The supplier produces a single product which retailer sells to customers. Demand D is a nonnegative random

variable with a cumulative distribution function $F(D)$. We define the Hazard Function $h(D) = f(D)/\bar{F}(D)$ and the Generalized Failure Rate (GFR) $H(D) = Dh(D)$, where $\bar{F}(D) = 1 - F(D)$ is the tail distribution of F(D). We also impose the following assumption to guarantee the existence and uniqueness of the equilibrium of our model.

Assumption A1: The demand distribution function F(D) has the following properties:

i. It is absolutely continuous with density $f(D) > 0$ in (a, b), for $0 \leq a \leq b \leq \infty$.
ii. It has a finite mean $\bar{D}$.
iii. The generalized failure rate H(D) is increasing in $D \geq 0$ (IGFR).

We discuss the situation with symmetric information (i.e., all information is common knowledge to both the supplier and the retailer) first (and asymmetric information will be mentioned later). In particular, we assume the supplier and the bank know the retailer's initial capital B, the demand probability distribution F(D), and the retail price p. We use superscripts, B, R and S to denote the bank, the retailer, and the supplier, respectively, and use subscripts F or NF to denote the case the retailer does or does not have the chance to raise funds from a competitive financial market, respectively.

A feature of our model is the introduction of an initial capital constraint on the retailer, which may limit her order levels. We assume the retailer has an initial capital B for ordering products from the supplier while the supplier has no capital constraints (i.e., he has sufficient working capital to pay for the manufacturing costs). Furthermore, we assume that all parties (the supplier, the retailer, and banks) are risk-neutral. Based on the financial "pecking order" theory, we also assume the retailer uses up all her capital before considering making a loan from a bank. Let the risk-free interest rate of the financial market be r_f . The banks are always willing to finance the retailer for purchasing products with an interest rate r_F (B), and act competitively such that the expected return on a loan is equal to the expected return with the risk-free interest r_f . Here, r_f can be regarded as the average return on investment in the competitive financial market. Therefore, r_f can be used to measure competition of services in the financial market. The lower the risk-free interest rate r_f, the stronger the competition in the financial market. For example, the financial market has the strongest competition when $r_f = 0$. Intuitively, many banks competing sufficiently in the financial market could lead to the result that the average return on investment for the financial market be reduced to (normalized) zero.

Due to the popularity of the wholesale price contract in both academics and practice, we consider a capital-constrained supply chain with financing service under such a contract. In our model, we assume the following sequence: At the beginning of the period ($t = 0$), the supplier offers a wholesale price contract (w), an exogenous variable, to the retailer, then the retailer decides to accept or reject the contract; If the retailer accepts the contract and chooses ordering quantity $Q_F(w)$, she may also make a commercial loan from the bank; Learning $Q_F(w)$, the bank announces the interest rate $r_F(B)$ for the loan that amounts to $(wQ_F(w) - B)^+$, where $(x)^+ = \max\{x, 0\}$; The retailer borrows loan $(wQ_F(w) - B)^+$ from the bank and pays the amount $wQ_F(w)$ to the supplier for her order; The supplier produces and deliveries to the retailer before the selling season. At the end of the period ($t = T$), demand is realized. The revenue is equal to $p \min\{D, Q_F(w)\}$, where p is a fixed retailer price, and finally a payment $((wQ_F(w) - B)^+(1 + r_F(B)))$ is made by the retailer to the bank. Certainly, if the retailer rejects the contract, the game ends and each firm earns a default payoff. Neither a salvage value nor a return policy for unsold units is assumed in our model.

Before we inspect the 3PL firm's role, we model the game between the bank and the retailer in this current section.

3.1 The bank

Assume banks in the financial market have enough cash for loans. At time $t = 0$ (i.e., beginning of selling season), the retailer makes an order quantity $Q_F(w)$ in response to the wholesale price contract w chosen by the supplier, and a bank may announce a loan contract ($r_F(B)$) to the retailer, whose initial capital is B, for loan size $(wQ_F(w) - B)^+$. With the support of a loan from the bank, the retailer is able to make the full payment to the supplier. At time $t = T$ (i.e., the end of the selling season), the loan generates a random payoff $\mathcal{L} = p\min\{D, Q_F(w)\}$ for the retailer, and revenue for the bank is equal to $\min\{\mathcal{L}, L(B)(1 + r_F(B))\}$, where $L(B) = (wQ_F(w) - B)^+$. If revenue $\mathcal{L}$ falls below the sum of the principle and the interest of a loan (i. e., $L(B)(1 + r_F(B))$), then the retailer may declare a bankruptcy, and the bank suffers a loss from the loan. Otherwise, the bank makes an expected profit $L(B)r_F(B)$ as a return on the loan.

From previous assumption, the bank is risk-neutral and operates in a competitive financial market, it will set an interest rate $r_F(B)$ that yields the expected profit. The profit is equal to the one generated by a risk-free interest rate r_f in the competitive financial market. Intuitively, under the risk-neutral assumption, banks are indifferent to risks, and the payoff of risk- free capital and the return of financing service are identical. Hence, the interest rate on a loan is determined by the following equation:

$$L(B)(1 + r_f) = E\left[min\{\mathcal{L}, L(B)(1 + r_F(B))\}\right] \quad (1)$$

Here, the bank evaluates the credit risk of loans based on the retailer's initial capital. The assumption of competitive financing is also found in the previous literature in economics, finance, and operations field, such as, Brenna et al. (1988), Dotan and Ravid (1985), Xu and Birge (2004), etc..

3.2 The retailer

The impact of the retailer's limited initial capital on the execution of the wholesale price contract is twofold. First, the order quantity placed at $t = 0$ could satisfy the capital constraint $B \leq wQ_F(w)$. Second, if demand D is too low, then the retailer is unable to pay the bank the full amount $(wQ_F(w) - B)^+(1 + r_F(B))$ that is due at time T. In this case (occurring if $p\min\{D, Q_F(w)\} < (wQ_F(w) - B)^+(1 + r_F(B))$), the retailer declares bankruptcy and the bank collects only $p\min\{D, Q_F(w)\}$ instead of $(wQ_F(w) - B)^+(1 + r_F(B))$. In this case we say the retailer has limited liability.

For a given wholesale price contract (w), the capital-constrained retailer with an initial capital B chooses order quantity $Q_F(w)$, and may raise funds $(wQ_F(w) - B)^+$ from the bank under the interest rate $r_F(B)$. Then, the retailer's net expected payoff is a function of $Q_F(w)$ and defined as:

$$\pi_F^R(Q_F(w)) = E\left[\left(p\min\{D, Q_F(w)\} - (wQ_F(w) - B)^+(1 + r_F(B))\right)^+ - B\right],$$

where $E[\cdot]$ denotes the expectation with respect to F(D). Note that in the definition of $\pi_F^R(Q_F(w))$ the initial capital B is subtracted from the retailer's profits. Hence, $\pi_F^R(Q_F(w))$

measures the net profit the retailer obtains by operating in this supply chain. For example, if the retailer chooses Q_F (w) = 0 then her net payoff is zero, reflecting the fact that she gains nothing from her business. The retailer's optimal net expected payoff is obtained by solving the following program:

$$\begin{aligned}\Pi_F^{R*}(B) &= \max_{Q_F(w)\geq 0} \pi_F^R\left(Q_F(w)\right) \\ &= \max_{Q_F(w)\geq 0} E\left[\left(p\,min\{D, Q_F(w)\} + B - wQ_F(w) - L(B)r_F(B)\right)^+ - B\right]\end{aligned} \tag{2}$$

subject to:

$$L(B) = (wQ_F(w) - B)^+ \tag{3}$$

It is worth noting that the positive part in the definition of Π_F^{R*}(B) captures the retailer's limited liability in the case of bankruptcy. Here we implicitly assume the retailer has no other investment opportunity except her retailing business. This is to clearly show the financing service (represented here by banking loans) is a value generating activity.

Notice that when the retailer cannot have the access to the financial market, the optimization problem for her is then given by:

$$\Pi_{NF}^{R*}(B) = \max_{Q_{NF}(w)\geq 0} E\left[p\,min\{D, Q_F(w)\} - wQ_{NF}(w)\right] \tag{4}$$

subject to:

$$0 \leq wQ_{NF}(w) \leq B \tag{5}$$

If the retailer does not have capital constraints, the capital constraint (5) is redundant and has no impact on the retailer's order decisions. Hence, (4) becomes a standard newsvendor problem and the optimal order level is given by $Q^N(w) = \bar{F}^{-1}\left(\frac{w}{p}\right)$. However, if the initial capital is not sufficient to support optimal ordering (i.e., $\frac{B}{w} < Q^N(w)$), the capital constraint (5) is active and the retailer cannot achieve her optimal order level. (4)-(5) indicate the retailer's capital constraints may influence her order level. Depending on the tightness of the constraints, the effects can be significant. Therefore, when the retailer has no access to the financial market, the optimal order policy for the retailer with capital constraints is $Q_{NF}^*(w) = \min\{\frac{B}{w}, Q^N(w)\}$.

In the following section, we should analyse how the financing service has the impacts on the performance of supply chain with capital constraints under symmetric information.

4. Financing service and supply chain's performance

Based on the assumptions in Section 3, under the case where the retailer has access to a financial market, and then chooses order quantity $Q_F(w_F)$ for an exogenous wholesale price w_F from the supplier. Noting that when the retailer orders $Q_F(w_F)$, the bank immediately announces an interest rate r_F (B).

We proceed backwards to derive the equilibrium in the competitive finance market and the supply chain. Firstly, we determine the interest rate r_F^* (B) by solving Eq. (1); Secondly, we

compute the retailer's best response as a function of a strategy chosen by the supplier by solving the retailer's optimization problem in (2)-(3) to find $Q_F^*(w_F, r_F^*(B))$ for a fixed wholesale price (w_F) and a given $r_F^*(B)(B)$.

4.1 Supply chain performance without financing service

In the following discussion we assume the retailer has no access to financial markets as a benchmark for comparison, to address the motivation of financing services from a competitive financial market.

Recall that the optimal order problem without the financing service for a retailer who has capital constraints in (4)-(5) is:

$$Q_{NF}^*(w_{NF}) = min\left\{\frac{B}{w_{NF}}, \bar{F}^{-1}\left(\frac{w_{NF}}{p}\right)\right\}$$

In the setting in which retailers cannot have access to the financial market, the optimal ordering level for the retailers Q_{NF} is $Q_{NF}^*(w) = min\left\{\frac{B}{w}, \bar{F}^{-1}\left(\frac{w}{p}\right)\right\}$. When $B \le w\bar{F}^{-1}\left(\frac{w}{p}\right)$, $Q_{NF}^*(w) = \frac{B}{w}$; When $B > w\bar{F}^{-1}\left(\frac{w}{p}\right)$, $Q_{NF}^*(w)$ is the constant value of $\bar{F}^{-1}\left(\frac{w}{p}\right)$. Obviously, without the support of financing service from financing market, the capital-constrained retailer is not able to make an optimal ordering level in the traditional newsvendor model, $Q^N(w) = \bar{F}^{-1}\left(\frac{w}{p}\right)$, and leads to the loss to the supply chain performance.

4.2 Supply chain performance with financing service

Different to the previous subsection, we consider that the capital-constrained retailer has access to a competitive financing market during the operations of supply chain. We should show how the financing service affects the supply chain performance.

The decisions of bank

Recall the assumption of financing market in Section 3, by (1), the bank may determine the optimal interest rate $r_F^*(B)$ as follows:

$$(w_F Q_F(w_F) - B)^+(1 + r_f) = E\left[min\left\{\mathcal{L}, (w_F Q_F(w_F) - B)^+\left(1 + r_F^*(B)\right)\right\}\right] \quad (6)$$

We can show the existence and uniqueness of $r_F^*(B)$ by the following reason, for any $r_f \ge 0$, any scalar $y \ge 0$, and any random variable $\mathcal{L} \ge 0$, there exists a unique $r \ge r_f$ such that $y(1 + r_f) = E[\min\{\mathcal{L}, y(1 + r)\}]$ if and only if $E[\mathcal{L}] \ge y(1 + r_f)$. (Refer to Chen and Wan 2011).

Consequently, , let y be the loan size $L(B) = (w_F Q_F(w_F) - B)^+$, $r = r_F^*(B)$, and let L be the retailer's random revenue $p\min\{D, Q_F(w_F)\}$, then if the condition $E[\mathcal{L}] \ge (w_F Q_F(w_F) - B)^+(1 + r_f)$ holds, we can obtain a unique interest rate $r_F^*(B) > r_f$ by solving the equation $(w_F Q_F(w_F) - B)^+(1 + r_f) = E\left[\min\left\{\mathcal{L}, (w_F Q_F(w_F) - B)^+\left(1 + r_F^*(B)\right)\right\}\right]$. Furthermore, we can derive the optimal interest rate for a bank as follows.

For a given order level $Q_F(w_F) \ge 0$ and $c \le w_F \le p$, the retailer with an initial capital B may make a loan $(w_F Q_F(w_F) - B)^+$ from a bank in the competitive financial market, with a risk-free interest rate $r_f \ge 0$. If the capital-constrained retailer has limited liability, then:

i. there exists a unique interest rate $r_F^*(B)$ charged by the bank satisfying the following equation: $(w_F Q_F(w_F) - B)^+(1 + r_f) = E\left[\min\left\{\mathcal{L}, (w_F Q_F(w_F) - B)^+\left(1 + r_F^*(B)\right)\right\}\right]$;

ii. $r_F^*(B)$ is monotonically increasing when retailer's initial capital B decreases;
iii. for a fixed initial capital B, $r_F^*(B)$ increases with the risk-free interest rate r_f .
The above characteristics of $r_F^*(B)$ can be illustrated by Figure 2.

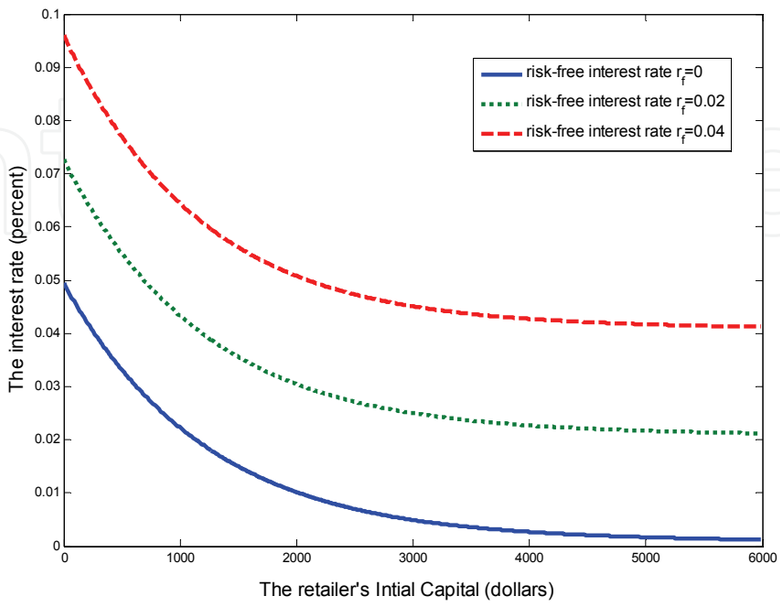

Fig. 2. The relationship between interest rate $r_F^*(B)$ and B, r_f

The decisions of retailer

If the wholesale price contract is w_F, then the retailer may make a loan of $L(B) = (w_F Q_F(w_F) - B)^+$ with an interest rate $r_F^*(B)$ from a bank in the financial market. By the decisions of the bank, we can show that the sufficient and necessary condition for the existence of a loan is $pE[\min\{D, Q_F(w_F)\}] \geq (w_F Q_F(w_F) - B)^+(1 + r_f)$. Therefore, the retailer's optimization problem with financing service (2)-(3) can be formulated as:

$$\Pi_F^{R*}(B) = \max_{Q_F(w_F)\geq 0} E\left[\left(p\min\{D, Q_F(w_F)\} + B - w_F Q_F(w_F) - L(B)r_F^*(B)\right)^+ - B\right]$$

subject to :

$$\begin{aligned} L(B) &= (w_F Q_F(w_F) - B)^+ \\ pE[\min\{D, Q_F(w_F)\}] &\geq (w_F Q_F(w_F) - B)^+(1 + r_f) \\ L(B)(1 + r_f) &= E\min[p\min\{D, Q_F(w_F)\}, L(B)(1 + r_F^*(B))] \end{aligned} \tag{7}$$

We can rewrite the constraint in Eq. (7) as follows

$$E[\min\{p\min\{D, Q_F(w_F)\} - L(B)(1 + r_f), L(B)(r_F^*(B) - r_f)\}] = 0$$

Then, by virtue of the constraint in (7), the retailer's optimization reduces to the following equation.

$$\Pi_F^R(B) = \max_{Q_F(w_F)\geq 0} E[p\min\{D, Q_F(w_F)\} - L(B)(1 + r_f)] - B$$

subject to:

$$\mathrm{E}[\min\{\mathrm{p}\ \min\{\mathrm{D}, \mathrm{Q}_{\mathrm{F}}(\mathrm{w}_{\mathrm{F}})\} - \mathrm{L}(\mathrm{B})(1 + \mathrm{r}_{\mathrm{f}}), \mathrm{L}(\mathrm{B})(\mathrm{r}_{\mathrm{F}}^{*}(\mathrm{B}) - \mathrm{r}_{\mathrm{f}})\}] = 0$$

Solving problem (7) we get: $\mathrm{Q}_{F}^{*}(\mathrm{w}_{F}) = \bar{F}^{-1}\left(\frac{w_F(1+r_F)}{p} \wedge 1\right)$, where $\mathrm{x} \wedge \mathrm{y} = \min[\mathrm{x}, \mathrm{y}]$. To ensure the operability of the supply chain, the market price must exceed the purchasing cost, that is, $\mathrm{w}_{F}(1 + \mathrm{r}_{\mathrm{f}}) \leq \mathrm{p}$. And we can rewrite $\mathrm{Q}_{F}^{*}(\mathrm{B}) = \bar{F}^{-1}\left(\frac{w_F(1+r_f)}{p}\right)$.

Recall that, in the traditional newsvendor model with no capital constraint (Hadley and Whitin (1963)), for a given w_F, the retailer's optimal solution $\mathrm{Q}^{N}(w_F)$ solves the equation $\mathrm{p}\bar{\mathrm{F}}\left(\mathrm{Q}^{N}(w_F)\right) = w_F$. This is the first-order optimality condition where the marginal revenue of an extra unit, $\mathrm{p}\bar{\mathrm{F}}\left(\mathrm{Q}^{N}(w_F)\right)$, is equal to the cost of the extra unit, w_F. Here, the first-order optimality condition is $\mathrm{p}\bar{\mathrm{F}}\left(Q_{F}^{*}(w_F)\right) = w_F(1 + \mathrm{r}_{\mathrm{f}})$. Since $w_F(1 + \mathrm{r}_{\mathrm{f}}) \geq w_F$, it follows that a retailer with financing service and limited liability has higher marginal costs and $\mathrm{Q}_{F}^{*}(\mathrm{w}_{F}) \leq \mathrm{Q}^{N}(w_F)$.

In the case where retailers can have access to a competitive financial market, the optimal ordering level for the retailers can be described by the following. When the retailer has a capital small to medium in size (i.e., $\mathrm{B} \leq \mathrm{w}\,\bar{F}^{-1}\left(\frac{w(1+r)}{p}\right)$), the optimal order level for the retailer with limited liability is a constant $\bar{F}^{-1}\left(\frac{w(1+r_f)}{p}\right)$, and $Q_{F}^{*}(w) \geq Q_{NF}^{*}(w)$; When the retailer has a medium capital (i.e., $\mathrm{w}\bar{F}^{-1}\left(\frac{w(1+r)}{p}\right) < B \leq w\bar{F}^{-1}\left(\frac{w}{p}\right)$), the retailer does not make any loan but simply uses up her initial capital to order $Q_{F}^{*}(w) = \frac{B}{w}$, and $Q_{F}^{*}(w) = Q_{NF}^{*}(w)$. In fact, the marginal revenue from a loan is not enough to offset the financial cost; hence, the retailer does not make any loan from banks; When the retailer has a large capital (i.e., $\mathrm{B} > w\bar{F}^{-1}\left(\frac{w}{p}\right)$), the optimal order level is $Q_{F}^{*}(w) = Q_{NF}^{*}(w) = Q^{N}(w)$, and it is actually the optimal order level in a traditional newsvendor problem. Therefore, we can characterize the optimal operational and financial decisions of the retailer as functions of her initial capital as follows.

These conclusions are shown in Table 1. We show that the risk-free interest rate r_f of the competitive financial market may influence the retailer's optimal order level and loan size.

In Figure 3, we plot the optimal order level as a function of the retailer's initial capital. Note that the initial capital is B, demand follows a normal distribution N(500, 200), the risk-free interest rate is set to 0, 0.02, and 0.04, respectively, and p = 10, w = 8. As seen in Figure 2, all observations are consistent with what we discussed in this section.

Fascinatingly, results in our model are related to the Modigliani-Miller Theory. If the capital markets are perfect, Modigliani and Miller (1958) prove that managers may consider financial decisions independently from the firm's other decisions (e.g., capacity investment). In Section 4.2, a retailer with a small to medium capital and limited liability can raise funds from banks in a competitive financial market. Thus, we can instead hold that the retailer has access to an unlimited capital account with interest rate r_f, which is similar to the perfect capital market in Modigliani-Miller Theory. Interestingly, the results show the retailer's financial decisions on loan size can be separated from the order decisions. Therefore, we can conclude that a competitive financial market decouples the financial decisions and operational decisions.

Initial capital	Loan	$Q_F^*(w)$
$B \leq w\bar{F}^{-1}\left(\frac{w(1+r_f)}{p}\right)$	Yes	$\bar{F}^{-1}\left(\frac{w(1+r_f)}{p}\right)$
$w\bar{F}^{-1}\left(\frac{w(1+r_f)}{p}\right) < B \leq w\bar{F}^{-1}\left(\frac{w}{p}\right)$	None	$\frac{B}{w}$
$B > w\bar{F}^{-1}\left(\frac{w}{p}\right)$	None	$\bar{F}^{-1}\left(\frac{w}{p}\right)$

Table 1. The optimal operational and financial strategy of the retailer. (Refer to Chen and Cai, 2011)

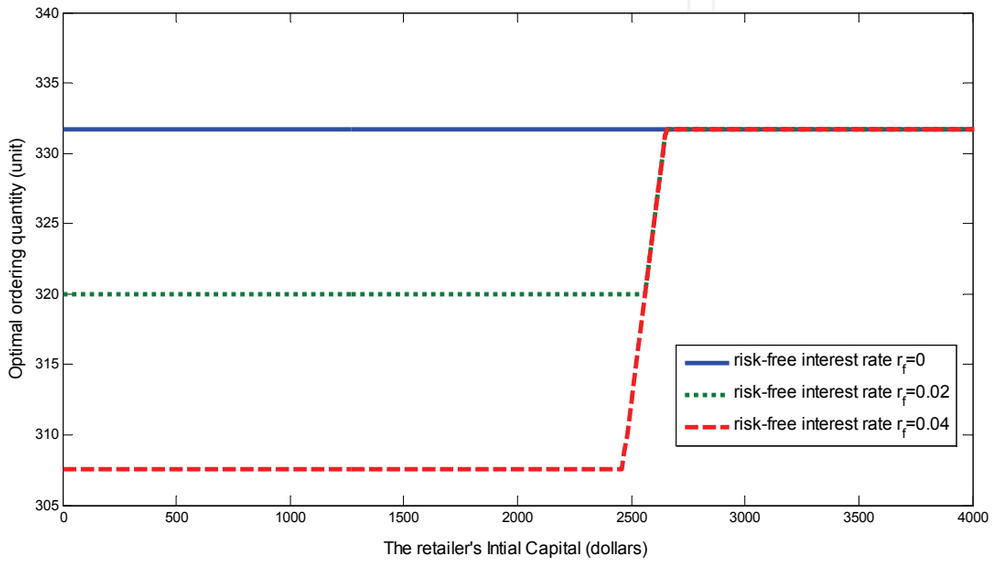

Fig. 3. The optimal order level Q_F^* as a function of the initial capital B. (Refer to Chen and Cai, 2011)

5. The role of 3PL firm in supply chain financing

Following the above discussion about simple supply chain with a supplier and a retailer, we then introduce how the third party logistics (3PL) firm plays an important role in adding value to all parties and supply chain as a whole.

In this section, we investigate three different roles of a 3PL firm in an extended supply chain with a supplier, a retailer, a 3PL firm, and a bank. The retailer is capital-constrained and may borrow capital from either the bank or the 3PL firm. The first role is called the Traditional Role (TR), where the 3PL firm provides only the traditional logistics services in the supply chain when the retailer borrows capital from the bank. The second role is regarded as the Delegation Role (DL), in which the 3PL firm aligning with the bank provides capital-constrained retailer with the integrated logistics and financing service. The third role is referred to as the Control Role (CR), where the 3PL firm provides both logistics services and trade credit financing to the capital-constrained retailer. Note that in supply chain finance, 3PL plays as either DR or CR.

The retailer is of limited liability and procures a single product from the supplier with a wholesale price w_p, and then sells to a random market by a fixed retail price p normalised to

be one. More specially, the 3PL firm offering TR or DR to the capital-constrained retailer is also involved in the supply chain. Without loss of generality, this paper assumes that the 3PL firm would charge the retailer w_l for per unit product under TR or DR with cost c_l per unit in its business operations.

To make the operations of supply chain feasible, we offer the following assumption.

Assumption A2: $w_l > c_l$, $w_p > c_p$ *and* $(1+r)(w_p + w_l) = (1+r)w < 1$

5.1 3PL firm with TR in SCF

With TR, we consider 3PL firms offering traditional logistics service to the supply chain, and then analyse the capital availability to the capital-constrained retailer. The roles of suppliers and 3PL firms are passive, and their payoffs depend on retailer's ordering quantity only. Suppose that the retailer borrows funds from a bank in a monopolistic financial market and pays the supplier in full payment for the stock of goods purchased, we may then focus on studying the interplay between the retailer and the bank.

We first discuss the game between the bank and the retailer under symmetric information and show that the retailer cannot separate operations and financial decisions in a monopolistic financial market. Then, we show that under asymmetric information on retailer's initial capital, the bank may refuse to provide commercial loans for capital-constrained retailers.

Decisions of retailer and bank under symmetric information

Before characterizing the bank's decisions of interest rate, we start with examining capital-constrained retailer's optimal strategies.

The retailer's optimal strategies

Based on Eq (2), for a given $r_M(B)$ (the interest rate on a loan in the monopolistic finance market), we rewrite the retailer problem as follows:

$$\Pi_M^R = \max_{Q_M(B)} E\left\{\left(min\{D, Q_M(B)\} - (wQ_M(B) - B)\left(1 + r_M(B)\right)\right)^+ - B\right\} \tag{8}$$

The characteristics for the retailer's optimal ordering strategy and its basic properties can be written by the following: Suppose Assumptions A1 and A2. Under symmetric information, regardless the 3PL firm playing TR or CR, at a given interest rate on a loan $r_M(B)$ in a monopolistic financial market (1) the optimal ordering quantity of the retailer, Q^* , is given by $\bar{F}(Q_M) = w(1 + r_M(B))\bar{F}\left[(wQ_M(B) - B)(1 + r_M(B))\right]$; (2) the capital-constrained retailer should get a loan with size $(wQ^* - B)$. (Refer to Chen and Cai, 2011).

As the retail price is normalised to 1, $\bar{F}(Q_M^*)$ represents the retailer's expected marginal revenue from ordering an additional unit, while the expected marginal cost of ordering an additional unit is $w(1 + r_M)\bar{F}\left[(wQ_M(B) - B)(1 + r_M(B))\right]$. The volume of marginal cost depends on the interest rate $r_M(B)$, and might be greater or less than the marginal cost in traditional newsvendor model.

Here, we show that in the capital-constrained supply chain, the retailer's operational decision (e.g. ordering quantity) and financial decisions (e.g. loan size) cannot be separated. Consequently, under perfect information, the Modigliani-Miller Theory cannot hold water in this setting. If the capital markets are perfect, Modigliani and Miller (1958) hold that the managers may consider financial decisions independent of the firm's operational decisions.

In contrast, we show that the capital-constrained retailer has to integrate the operations and financial decisions to optimize her payoff.

The interest rate of the bank

There is Stacklberg-Nash game between the retailer and the bank. The optimal problem for the bank in a monopolistic financial market would be addressed by the following:

$$\Pi_M^B = \max_{r(B)} E\{min\{min\{D, Q\}, (wQ - B)\big(1 + r(B)\big)\} - (wQ - B)\} \tag{9}$$

Combing Eqs. (2) and (9), we can describe the bank's decision problem in the following.

$$\Pi_M^B = \max_{r_M} E\{min\{min\{D, Q_M^*\}, (wQ_M^* - B)(1 + r_M)\} - (wQ_M^* - B)^+\} \tag{10}$$

Let $\mathrm{L(r)} = (\mathrm{wQ}_M^* - B)^+\big(1 + \mathrm{r_M(B)}\big)$. We denote that $\mathrm{r(B)} = r_M^*(\mathrm{B})$ is the optimal solution for Eq. (10). We then present the characteristics of the interest rate in the monopolistic financial market by the following,

Suppose Assumption A1 and Assumption A2. Under symmetric information, the optimal interest rate $r_M^*(\mathrm{B})$ in a monopolistic bank is given by: $\bar{\mathrm{F}}(Q_M^*) = w\frac{1-L(\mathrm{r_M(B)})h[L(\mathrm{r_M(B)})]}{1-\frac{\mathrm{wQ}_M^*-B}{w}h(Q_M^*)}$; Q_M^* is always less than the optimal ordering level $\mathrm{Q^N}$. (refer to Chen and Cai, 2011).

We then show that $Q_M^*(\mathrm{B}) < \mathrm{Q^N}$. So the optimal ordering of retailer in monopolistic financial market $Q_M^*(\mathrm{B})$ is always less than traditional newsvendor optimal ordering quantity $\mathrm{Q^N}$.

Compared to 'deep pocket' assumption in the traditional newsvendor model, the capital-constrained retailers intuitively have to pay interest to the bank, and increase the marginal cost of operations.

The behaviour of the retailer and the bank under asymmetric information

Suppose the bank provides a loan contract (r(B)) with the borrower (the capital- constrained retailer) and evaluates the retailer's credit risk based on her initial capital. If there is no device to screen the information on the retailer's initial capital, the retailer can falsify her initial capital information and get a corresponding contract to increase her profit.

We then conclude that under the asymmetric information, given a commercial loan menu r(B) from a bank operating in a monopolistic finance market, the capital-constrained retailer with $\mathrm{B} < w\mathrm{Q^N}$ may overstate her initial capital to get a lower interest rate of loans (refer to Chen and Cai, 2011 in detail).

Accordingly, Chen and Cai (2011) show under asymmetric information of retailer's initial capital, the bank may incur a loss in lending funds to the capital-constrained retailer. And under asymmetric information of retailer's initial capital, the capital-constrained retailer has the incentive to falsify her real initial capital to get higher payoff. In turn, the bank would suffer a loss from loans due to asymmetric information. Naturally, the bank might refuse to extend loans to capital-constrained retailers. These insights can explain why the small-medium size companies are not able to borrow loans from the financial institutions during the operations in supply chain.

5.2 3PL with DR in SCF

The asymmetric information of initial capital may break the equilibrium under full information and move part of revenue from the bank to the retailer. Hence the bank cannot

get its expected return from a loan. As a consequence, some banks might leave the financial market because of credit risk, hurting individual firms in the capital-constrained supply chain.

However, the DR of 3PL firm can help the bank to track the liquid collateral of loan (inventory, etc.) and share the retailer's real information. In this case, the retailer would have no chance to overstate her initial capital to the bank. Also, if the bank offers loan contract menu (L(B),r(B)), the retailer would have no chance to lie about her initial capital either. But the retailer may divert funds in loans to a higher risk project without 3PL firms' monitoring, leaving the bank with a higher risk. It follows that the bank would be unwilling to offer loans to the capital-constrained retailer if the bank has no effective approach to monitor the retailer's real procurement behaviour.

Then we can conclude the motivation of 3PL firm's DR under asymmetric information with the following: Under asymmetric information of retailer's initial capital, 3PL firm's DR might force the retailer to declare her real information and help individual firms to achieve the equilibrium under symmetric information (Refer to Chen and Cai, 2011).

As is shown above, under asymmetric information, the bank may have no incentive to offer commercial loans to the capital-constrained retailer with TR, because the retailer may falsify her initial capital or divert capital loans. Without DR, the retailer's ordering level would be $\mathrm{Q}_{NF} = \min\left\{\frac{B}{w}, \mathrm{Q}^N\right\}$. But with DR, the bank would be encouraged to provide loans for the capital-constrained retailer. And the ordering level for the capital-constrained retailer $\mathrm{Q}_F^* = \min\{\mathrm{Q}_M^*, \mathrm{Q}^N\}$ is always no less than Q_{NF}.

Since the payoffs of supplier, 3PL firm, and the supply chain involving the bank and 3PL firm are respectively, $\Pi^S = (\mathrm{w_p} - \mathrm{c_p})Q$, $\Pi^L = (\mathrm{w_l} - \mathrm{c_l})Q$, $\Pi^{SC} = \mathrm{E}[min[D, Q] - CQ]$, we can obtain the following results directly: The payoffs of individual firms in the capital-constrained supply chain with DR are greater than those with TR. (Refer to Chen and Cai, 2011).

As DR brings all entities to the table – 3PL firm, bank, buyer and supplier, it helps to bridge the information gap and understand the needs of each party. As we explained earlier in the introduction the role of 3PL firm's DR for capital optimization within a capital-constrained supply chain, the coupling of information and physical control benefits lenders in the supply chain as well. For instance, the mitigation of risk allows more capital to be raised, or more capital to be assessed sooner. So the supply chain would be more efficient with the innovation service, DR of 3PL firm.

We move on to show that DR would impact the performance of individual firms as well as the entire supply chain, create value in the capital-constrained supply chain, and that asymmetric information might account for the motivation of DR.

5.3 Competitive financial market and SCF

DR of 3PL firm might decrease the financial risk when financial institutions offer loans to capital- constrained retailers in the supply chain. And more and more financial institutions have got the incentive to join hands with third party firms in order to enhance their profits and competitive advantages, which raises competition in the finance market. For instance, the 3PL firm could ally with many banks to provide integrated logistics and financing service to its clients in the supply chain, and banks have to confront a more competitive market in offering loans to capital-constrained retailers. We next examine how competition in the finance market influences decisions of agents in the supply chain.

The interest rate of a loan

Since the bank is risk-neutral and operates in a competitive financial market, it will set an interest rate r(B) that yields the expected profit. The profit is equal to the one generated by risk-free interest rate r_f. In this chapter, we assume $r_f = 0$.
In Eq (4), the bank may determine the optimal interest rate $r_B^*(B)$ as follows:

$$(wQ_{CF} - B)^+ = E\left[min\{(wQ_{CF} - B)^+(1 + r(B)), \mathcal{L}\}\right] \quad (11)$$

We can derive the optimal interest rate for a bank in the following: For a given ordering level $Q_{CF} \geq 0$ and $C \leq w \leq 1$, where C denotes the production cost, the retailer with an initial capital B may borrow a loan $(wQ_{CF} - B)^+$ from a bank in the competitive finance market. If the capital-constrained retailer is of limited liability, there exists a unique interest rate r_B^* charged by the bank through solving (11), while r_B^* is monotonically decreasing in retailer's initial capital B.
As the finance market is highly competitive, the bank's equilibrium interest rate r_B^* equates the expected discounted return from the loan $(wQ_{CF} - B)^+$ subtracting its costs. We note that r_B^* depends on the retailer's initial capital B. As B increases over the internal $[0, wQ^N]$, the loan size decreases and so does the bank's risk associated with the retailer's limited liability. Therefore, the prevailing interest rate decreases.

The retailer's optimal strategy

Fascinatingly, the above problem corresponds to the standard newsvendor problem. By combining Eqs (2) and (6), we can immediately get the following results：Suppose Assumptions A1 and A2. In the competitive financial market with DR, the optimal ordering level for a capital-constrained retailer is $Q_{CF}^*(B) = Q^N$ (the standard newsvendor quantity) and is independent of her initial capital B. In addition, the capital-constrained retailer would borrow $(wQ^N - B)$ from the bank.
The above results are related to Modigliani-Miller Theory. In this chapter, we show that the retailer's financial decisions on loan size can be separated from ordering decisions, and the ordering decision is the constant value and corresponds to the optimal ordering level in traditional newsvendor model. We then conclude that the competitive financial market can decouple financial and operational decisions of the capital-constrained retailer. (Refer to Chen and Cai, 2011)
The competitive financial market motivates the capital-constrained retailer to order a quantity up to Q^N, which increases the value of all players in the supply chain. As a result, the competitive financial market creates value in the capital-constrained supply chain.

5.4 The value of 3PL firm with CR in SCF

In the traditional role model, the 3PL firm provides the transportation service only and does not provide any screening effect as suggested in adverse selection. Lu et al. (2009) mention the incentive of logistics service provider (LSP) to provide financial support to the retailer/supplier and to establish the backup inventory. We will inspect more deeply on 3Pl financing. If the 3PL firm forms an alliance with the bank, then the 3PL firm could monitor the transaction of products from the supplier to the retailer for the bank. Consequently, the retailer's false revelation of the initial capital would be discovered and prohibited.
In the control role model, the 3PL firm provides not only logistics services but also trade credit to the retailer. While the retailer has insufficient capital to order directly from the supplier, the 3PL firm procures the products from the supplier for the retailer through trade

credit financing and then transports them to the retailer. In addition, the 3PL firm can effectively track and monitor the transaction of products in addition to providing trade credit to the capital-constrained retailer.

In the first stage of the Stackelberg game, the 3PL firm offers a trade credit contract $(\mathrm{w}, \mathrm{r_{cl}}(B))$ and in the second stage, the retailer orders $\mathrm{Q}_{cl}^{*}(B)$ from the supplier through the 3PL firm. The retailer's decision process is the same as in the traditional role model. The 3PL firm's profit is given as follows.

$$\Pi_{cl}^{3PL}(B) = \max_{0 \le r_{cl}(B) \le \tilde{r}(B)} E\left\{(w - C_{cl})Q_{cl}^{*}(B) + (wQ_{cl}^{*}(B) - B)^{+} r_{cl}(B) - \left(min[D, Q_{cl}^{*}(\mathrm{B})] - (wQ_{cl}^{*}(\mathrm{B}) - B)\left(1 + \mathrm{r_{cl}}(B)\right)\right)^{-}\right\} \quad (12)$$

where $C_{cl} = \mathrm{w_p} + \mathrm{c_l}$ represents procurement and logistics operational costs incurred to the 3PL firm and $\mathrm{x}^{-} = \min\{\mathrm{x}, 0\}$. The above payoff consists of two components: the operational revenue $(\mathrm{w} - C_{cl})Q_{cl}^{*}(\mathrm{B})$ and the financial revenue $(\mathrm{w}Q_{cl}^{*}(\mathrm{B}) - B) - \left(min[D, Q_{cl}^{*}(\mathrm{B})] - (wQ_{cl}^{*}(\mathrm{B}) - B)\left(1 + \mathrm{r_{cl}}(\mathrm{B})\right)\right)^{-}$. It is straightforward that the operational profit is positive as long as $\mathrm{w} > C_{cl}$; however, the financial profit could end up with a negative value if demand uncertainty is too high; as a result the retailer could not repay the trade credit plus interest. Thus, a trade-off occurs: on the one hand, the 3PL would like to choose a small $\mathrm{r_{cl}}$ (B) to improve operational performance; on the other hand, the 3PL would like to choose a large $\mathrm{r_{cl}}$ (B) to satisfy his financial motive. The 3PL firm optimizes its trade credit contract while taking both motives into consideration.

We characterize the optimal interest rate in the following: In the control role model, the optimal interest rate $\mathrm{r}_{cl}^{*}(\mathrm{B})$ for the 3PL firm financing is

$$\mathrm{r}_{cl}^{*}(\mathrm{B}) = \begin{cases} \tilde{\mathrm{r}}(\mathrm{B}) & \text{if } \epsilon_{\mathrm{cl}}\left(\tilde{\mathrm{r}}(\mathrm{B})\right) \le 1, \\ 0 & \text{if } \epsilon_{\mathrm{cl}}(0) \ge 1, \\ \tilde{\mathrm{r}}_{\mathrm{cl}}(\mathrm{B}) & \text{if } \epsilon_{\mathrm{cl}}(0) < 1 \text{ and } \epsilon_{\mathrm{cl}}\left(\tilde{\mathrm{r}}(\mathrm{B})\right) > 1 \end{cases}$$

The unique $\tilde{r}_{cl}(B)$ satisfies $\epsilon_{cl}\left(r_{cl}(B)\right) = 1$, and $\epsilon_{cl}\left(r_{cl}(B)\right) = \frac{\bar{F}\left(Q_{cl}^{*}(\mathrm{B})\right)\left[1 - H\left(Q_{cl}^{*}(\mathrm{B})\right) + \frac{B}{w}h\left(Q_{cl}^{*}(\mathrm{B})\right)\right]}{C_{cl}\left[1 - H\left[(wQ_{cl}^{*}(\mathrm{B}) - B)(1 + \mathrm{r_{cl}}(\mathrm{B}))\right]\right]}$ and even $\epsilon_{cl}\left(r_{cl}(B)\right)$ increases in $r_{cl}(B) \in [0, \tilde{r}(B)]$ (Refer to Chen and Cai, 2011).

If the order quantity is inelastic to the interest rate change, where $\epsilon_{cl}\left(r_{cl}(B)\right) \le \epsilon_{cl}\left(\tilde{r}(B)\right) \le 1$ and hence $\frac{\mathrm{d}\Pi_{\mathrm{cl}}^{3\mathrm{PL}}(B)}{\mathrm{d}r_{cl}(B)} \ge 0$, the 3PL firm charges the interest rate at the highest level, $\tilde{r}(B)$, to optimize his profit. If the order quantity is very elastic to the interest rate, where $\epsilon_{cl}\left(r_{cl}(B)\right) \ge \epsilon_{cl}(0) \ge 1$ ad hence $\frac{\mathrm{d}\Pi_{\mathrm{cl}}^{3\mathrm{PL}}(B)}{\mathrm{d}r_{cl}(B)} \le 0$, the 3PL firm achieves its optimum by completely waiving the interest for the retailer. When interest-demand elasticity is in the medium range, the 3PL firm can find a unique optimal interest rate that balances the tradeoff between the financial and operational benefits. In reality, the benefit of a control role model can be even more significant because the 3PL firm can reduce logistics costs ($\mathrm{c_l}$) by taking advantage of the economy of scale by grouping many retailers together.

Comparison of the 3PL's Roles

Based on the analysis in Section 5.2, we find that the decisions of retailer and bank are the same in both TR and DR settings. In order to simplify the analysis, in this subsection, we let discussion of TR include that of DR.

It is not difficult to show that the optimal interest rate in the control role is no higher than that in the traditional/delegation role. The optimal order quantity in the control role is no less than that in the traditional /delegation role. The inequality holds when interest-demand elasticity is in the medium range. This result occurs because the 3PL firm shares a higher risk of demand uncertainty through the financing service and would like to reduce the interest rate to stimulate a higher order from the retailer. If interest-demand elasticity (ϵ) is either too large or too small for both traditional and control roles, the optimal interest rates are reached at the boundary; thus, the optimal interest rates and order quantities are the same in both cases.

$\epsilon_{\mathrm{cl}}(\mathrm{r_{cl}(B)})$	$\epsilon_{\mathrm{t}}(r_t(B))$	Elasticity (ϵ)	$r_{cl}^*(\mathrm{B})$	$r_t^*(B)$	$Q_{cl}^*(r_{cl}(B))\&Q_{\mathrm{t}}^*(r_t(B))$
$\epsilon_{\mathrm{cl}}(\tilde{\mathrm{r}}) \le 1$	$\epsilon_{\mathrm{t}}(\tilde{\mathrm{r}}) \le \epsilon_{cl}(\tilde{\mathrm{r}}) \le 1$	Low	$\tilde{\mathrm{r}}$	$\tilde{\mathrm{r}}$	Indifference
$\epsilon_{\mathrm{cl}}(0) \ge 1$	$\epsilon_{cl}(0) \ge \epsilon_{\mathrm{t}}(0) \ge 1$	High	0	0	
$\epsilon_{\mathrm{cl}}(0) \ge 1$	$\epsilon_t(\tilde{\mathrm{r}}) \le 1$	Medium	0	$\tilde{\mathrm{r}}$	$Q_{cl}^*(0) > Q_t^*(\tilde{\mathrm{r}})$
	$\epsilon_{\mathrm{t}}(0) < 1, \epsilon_t(\tilde{\mathrm{r}}) > 1$		0	$\tilde{\mathrm{r}}_t$	$Q_{cl}^*(0) > Q_t^*(\tilde{\mathrm{r}}_t)$
$\epsilon_{cl}(0) < 1,$	$\epsilon_t(\tilde{\mathrm{r}}) \le 1$		$\tilde{\mathrm{r}}_{cl}$	$\tilde{\mathrm{r}}$	$Q_{cl}^*(\tilde{\mathrm{r}}_{cl}) > Q_t^*(\tilde{\mathrm{r}})$
$\epsilon_{cl}(\tilde{\mathrm{r}}) > 1$	$\epsilon_{\mathrm{t}}(0) < 1, \epsilon_t(\tilde{\mathrm{r}}) > 1$		$\tilde{\mathrm{r}}_{cl}$	$\tilde{\mathrm{r}}_t$	$Q_{cl}^*(\tilde{\mathrm{r}}_{cl}) > Q_t^*(\tilde{\mathrm{r}}_t)$

Table 2. Optimal interest rates and ordering quantities in traditional and control roles

We can obtain additional technical details, as illustrated in Table 2 (Refer to Chen and Cai, 2011). The itemized results in Table 2 are determined by the interplay of interest-demand elasticity rates in both the control and traditional roles. For any given interest rate, interest-demand elasticity in the control role is no less than that in the traditional role. If both interest-demand elasticity rates are low, a low interest rate does not stimulate much demand; thus, the 3PL/bank will charge the interest rate at its highest level in both the control and traditional models. In contrast, if both interest-demand elasticity rates are high, the benefit from a higher demand will overweigh the benefit of a higher interest rate; in this case, the 3PL/bank will charge a zero interest rate in both the control and traditional role models. If interest-demand elasticity is in the medium range, the interest rates in both models will differ in the four sub-cases, as shown in Table 2. Nevertheless, the optimal interest rate in the control role is no more than that in the traditional role; while the optimal order quantity in the control role weakly dominates that in the traditional role.

Owing to a higher order quantity in the control role, we may expect that the entire supply chain will be more efficient in the control role. In the control role model, compared with the traditional role model, the 3PL firm more significantly shares the risk of demand uncertainty with the retailer when offering the trade credit and logistics services together. Thus, the retailer benefits from a lower interest rate, the supplier benefits from a larger order quantity, and the 3PL firm benefits from the integration of the financing and its traditional logistics services. This result provides theoretical support to the practice of 3PL firms integrating their logistics services with financing services, such as UPS and others.

Because of the capital constraint, one might expect that neither of our above models can outperform the classic newsvendor model (without capital constraint) in terms of overall supply chain profit. Note that supply chain profit includes the profits of the supplier, retailer, 3PL, and/or the bank and, hence, can be written as follows.

$$\Pi_{\mathrm{i}}^*(\mathrm{B}) = \mathrm{E}\{\min[\mathrm{D}, \mathrm{Q}_{\mathrm{i}}^*(\mathrm{B})] - (\mathrm{c_p} + \mathrm{c_l})\mathrm{Q}_{\mathrm{i}}^*(\mathrm{B})\}, \text{ where the subscript } \mathrm{i} = \mathrm{t}, \mathrm{c_l}, \mathrm{N}.$$

The following result delivers a somewhat counterintuitive message: Compare overall supply chain profits in the traditional role, control role, and classic newsvendor models, (1). The classic newsvendor model outperforms the traditional role model (i.e., $\Pi_{\mathrm{t}}^{*}(\mathrm{B}) \leq \Pi_{\mathrm{N}}^{*}(\mathrm{B})$; (2) The control role model outperforms the classic newsvendor model (i.e., $\Pi_{\mathrm{cl}}^{*}(\mathrm{B}) \geq \Pi_{\mathrm{N}}^{*}(\mathrm{B})$), as long as C_{cl} is sufficiently low (i.e., $\mathrm{C}_{cl} \leq \frac{w-(w\mathrm{Q}_{\mathrm{cl}}^{*}(\mathrm{B})-B)h\left(\mathrm{Q}_{\mathrm{t}}^{*}(\mathrm{B})\right)}{1-H\left[\left(w\mathrm{Q}_{\mathrm{cl}}^{*}(\mathrm{B})-B\right)\left(1+\mathrm{r}_{\mathrm{cl}}^{*}(\mathrm{B})\right)\right]}$), where $\mathrm{C}_{cl} = w_p + c_l$. (Refer to Chen and Cai, 2011).

The first statement above suggests the traditional role model cannot outperform the classic newsvendor in terms of entire supply chain efficiency, which is intuitive because the retailer bears additional financial risk plus the same demand uncertainty as in the classic newsvendor model. As for the control role model, the second statement indicates that overall supply chain profit in the control role model outweighs the classic newsvendor model. The rationale behind is that the 3PL firm shares the risk of demand uncertainty with the retailer by lowering the interest rate, such that the retailer orders a larger quantity that consequently yields a higher profit for the entire supply chain. Compared with the traditional role model, the 3PL in the control role model coordinates the supply chain by integrating the financial and logistics services. A lower combined value of product wholesale price and logistics operational cost (C_{cl}) enables the 3PL firm to charge a lower interest rate than in the traditional role model. This result conveys the message that an integrated service of financing and logistics can coordinate the capital constrained supply chain, and thus is a win-win-win solution to the retailer, the 3PL firm, and the supplier. However, if C_{cl} is too high, the burden of the capital constraint would outpace the benefit of 3PL coordination, such that the classic newsvender model would outperform the control role model in terms of overall supply chain efficiency.

6. Conclusion

We have studied the operational and financial decisions for a capital-constrained supply chain and the impact of financing on individual firms and the entire supply chain under wholesale price contract.

Our analysis indicates that financing can create value for a supply chain with small-medium capital retailer, and greater competition in a financial market leads to better performance improvement for the individual firms as well as the entire supply chain. Specifically, when the retailer has small-medium capital, she can make loans from a bank and place an order at a given level, depending on the market's risk-free interest rate, and the supplier should reduce his wholesale price to encourage the retailer to order more, thus increasing the transfer payment to the supplier. When the retailer has a medium capital, the retailer does not make loans and places an order at a level increasing with the size of her initial capital, and the supplier offers a suitable wholesale price, which is decreasing with the size of the retailer's initial capital to draw out all of the retailer's funds. When the retailer's capital is large, she never makes a loan from banks and sets an order level equal to the optimal order level in the traditional newsvendor model. We also show that interest rate on loans would decrease in the retailer's initial capital. We emphasize that when the retailer has small-medium capital, decisions on wholesale price and order level are independent of the initial capital.

Another important point is that with 3PL firm playing the traditional role in the monopolistic financial market, the retailers have to consider the integrated operations and

financial decisions to optimise her payoff, and the optimal ordering quantity is less than that of the traditional newsvendor model. However, under asymmetric information and without effective screening devices, the bank might refuse to offer financing service to the capital-constrained retailer. The main reasons lie in two factors: (1) the retailer has the incentive to overstate her initial capital; (2) the retailer could divert the loan to projects with higher risks. And interestingly, this chapter shows asymmetric information view might account for the motivation of 3PL firm's delegation role and control role, and both DR and CR could create value for the capital-constrained supply chain. As for 3PL firm's DR and CR, the retailer has to declare her private information of initial capital truly and might even have no chance to divert the capital loans.

We then further investigate the influence of the different roles of a 3PL firm in a supply chain with a capital-constrained retailer. The retailer can borrow capital from a bank or trade credit from a 3PL firm with financing services. We compare the traditional and control roles where the 3PL firm provides only logistics or logistics plus trade credit, respectively. Our analysis indicates the control role model yields higher profits not only for the 3PL firm, but also for the supplier and the retailer.

This chapter reveals the relation between financing services and supply chain management, and introduces how logistics firms could add value to all parties in supply chain. Supply Chain Finance is bringing not only more value, but also new trends of innovative financing services for supply chain management, which absolutely deserves further study.

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8. References

Barnett, W. (1997) 'What's in a name? A brief overview of asset-based lending', *Secured Lender*, Vol. 53, pp.80–81.

Boyabatli, O., L. B. Toktay. (2006), "Capacity investment in imperfect capital markets: the interaction of operational and financial decision", *Working Paper*, TM, INSEAD, Fontainebleau, France.

Brennan, M., V. Maksimovic, and J. Zechner (1988). Vendor financing. Journal of Finance 43(5), 1127-1141.

Burkart, M. and T. Ellingsen (2004). In-kind finance: A theory of trade credit. *The American Economic Review* 94 (3), 569–590.

Buzacott, J. A.and R. Q. Zhang. (2004), "Inventory management with asset-based financing", *Management Science*, Vol.50 No.9, pp. 1274-1292.

Caldentey, R. and M. B. Haugh. (2009), "Supply Contracts with Financial Hedging", *Operations Research*, Vol.57 No.1, pp.47-65.

Caldentey, R. and X. F. Chen. (2011), "The Role of financing service in procurement contracts", In Handbook of Integrated Risk Management in Global Supply Chains, co- edited by Panos Kouvelis, Onur Boyabatli, Lingxiu Dong, and Rong Li, John Wiley & Sons, Inc..

Chao, X., J. Chen and S. Wang. (2008), "Dynamic inventory management with financial constraints", *Naval Research Logistics*, Vol.55 No.8, pp.758-768.

Che, Y. K. and I. Gale. (2000), "The optimal mechanism for selling to a budget- constrained buyer", *Journal of Economic Theory*, Vol.92, pp.198-233.

Chen, J. and P. C. Bell (2009). The impact of customer returns on pricing and order decisions. *European Journal of Operational Research* 195(1), 280–295.

Chen, X. F. and G. Cai. (2011). Joint logistics and financial services by a 3PL firm, *European Journal of Operational Research,* doi:10.1016/i.ejor, 2011.05.010.

Chen, X. F. and G. Wan. (2011). The effect of financing on a budget-constrained supply chain under wholesale price contract, *Asia-Pacific Journal of Operational research*. Vol.28, No.4, pp.1-29

Chung, C.-S., J. Flynn, and J. Zhu (2009). The newsvendor problem with an in-season price adjustment. *European Journal of Operational Research* 198(1), 148–156.

Dada, M. and Q. Hu (2008). Financing newsvendor inventory. *Operations Research Letters* 36, 569–573.

Dammon, R. M. and L. W. Senbet. (1988), "The effect of taxes and depreciation on corporate investment and financial leverage", *Journal of Finance*, Vol.43, pp.357-374.

Dotan, A. and S. A. Ravid. (1985), "On the interaction of real and financial decisions of the firm under uncertainty", *Journal of Finance*, Vol.40, pp.501-517.

Gerchak, Y. and Y. Wang (2004). Revenue-sharing vs. wholesale-price contracts in assembly systems with random demand. *Production and Operations Management* 13(1), 23–33.

Graves, S. and Ton de Kok. (2003), *Handbooks in Operations Research and Management Science: Supply Chain Management*. North-Holland: Elsevier.

Groenevelt (2007). Impacts of financial collaboration in a three-party supply chain. The Simon School, University of Rochester, Working Paper.

Hadley, G. and T. Whitin. (1963), *Analysis of Inventory System*. NJ: Prentice-Hill. Hu, Q. and M. J. Sobel. (2005), "Capital Structure and inventory management", Working paper. Weather head School of Management, Case Western Reserve University, USA.

Haris, M. and Raviv, A. (1985) 'The theory of capital structure', *Journal of Finance*, Vol. 46, pp.297–355.

Hofmann Erik. (2005). "Supply Chain Finance- some conceptual insights", Logistik Management – Innovative Logistickonzepte, by Lasch, R./Janker, C.G.(Hrsg.), Wiesbaden 2005, S. 203-214.

Hu, Q. and Sobel, M.J. (2005) 'Capital structure and inventory management', *Working paper*, Weather head School of Management, Case Western Reserve University, USA.

Hu, Q., Y. Wei, and Y. Xia (2010). Revenue management for a supply chain with two streams of customers. *European Journal of Operational Research* 200(2), 582–598.

Jing, B., X. Chen, and G. Cai (2010). Equilibrium financing in a distribution channel with capital constraint. Working paper, Kansas State University.

Kouvelis, P. and W. Zhao (2008). Financing the newsvendor: Supplier vs. bank, optimal rates, and alterative schemes. Working paper, Olin Business School of Management, Washington University, St. Louis.

Lariviere, M. A. and E. L. Porteus. (2001), "Selling to the newsvendor: An analysis of price-only contracts", *Manufacturing and Service Operations Management*, Vol.3 No. 4, pp.293-305.

Lau, H.-S. and A. H.-L. Lau (1999). Manufacturer's pricing strategy and return policy for a single- period commodity. *European Journal of Operational Research* 116(2), 291–304.

Levaggi, R. (1999), "Optimal procurement contracts under a binding budget constraint", *Public Choice*, Vol.101, pp.23-37.

Lu, M., T. Wu, and H. Yan (2009). Inventory management in decentralized supply chains with logistics service provider. Working paper, The Chinese University of Hongkong.

Mauer, D. and A. J. Triantis. (1994), "Interactions of corporate financing and investment decisions: a dynamic framework", *Journal of Finance*, Vol.49, pp.1253-1277.

Mello, A. S. and J. E. Parsons. (1992), "Measuring the agency cost of debt", *Journal of Finance*, Vol.47, pp.1887-1904.

Modigliani, F. and M. H. Miller. (1958), "The cost of capital, corporation finance, and the theory of investment", *American Economic Review*, Vol.48 No.3, pp.261-297.

Parlar, M. and Z. K. Weng (2003). Balancing desirable but conflicting objectives in the newsvendor problem. *IIE Transactions* 35(2), 131–142.

Rajan, R. and L. Zingales (1995). What do we know about capital structure? Some evidence from international data. *The Journal of Finance* 53, 80–81.

Simchi-Levi, D, S. D. and Wu, Z. Shen. (2004), *Handbook of Quantitative Supply Chain Analysis: Modeling in the eBusiness Era*. NY: Kluwer Academic Publisher.

Spengler, J. (1950), "Vertical integration and antitrust policy", *Journal of Political Economy*, Vol.58, pp.347-352.

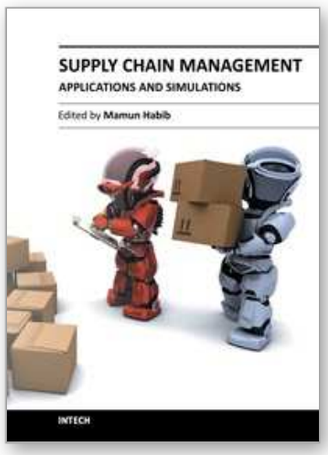
Thomas L. (2002), "Non-linear pricing with budget constraint", *Economic Letters*, Vol.75, pp. 257-263.

Xu, X. D. and J. R. Birge. (2004), "Join production and financing decisions: modeling and analysis", *Working Paper*, Graduate School of Business, University of Chicago, USA.

Xu, X. D. and J. R. Birge.(2006), "Equity valuation, production, and financial planning: A stochastic programming approach", *Naval Research Logistics*, Vol.53No.7, pp.641-655 .

Xu, X. D. and J. R. Birge. (2008), "Operational Decisions, Capital Structure, and Man- agerial Compensation: A News Vendor perspective", *Engineering Economist*, Vol.53 No. 3, pp.173-196.

Zhou, Y.-W. and S.-D. Wang (2009). Manufacturer-buyer coordination for newsvendor-type-products with two ordering opportunities and partial backorders. *European Journal of Operational Research* 198(3), 958–974.



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Supply Chain Management (SCM) has been widely researched in numerous application domains during the last decade. Despite the popularity of SCM research and applications, considerable confusion remains as to its meaning. There are several attempts made by researchers and practitioners to appropriately define SCM. Amidst fierce competition in all industries, SCM has gradually been embraced as a proven managerial approach to achieving sustainable profits and growth. This book "Supply Chain Management - Applications and Simulations" is comprised of twelve chapters and has been divided into four sections. Section I contains the introductory chapter that represents theory and evolution of Supply Chain Management. This chapter highlights chronological prospective of SCM in terms of time frame in different areas of manufacturing and service industries. Section II comprised five chapters those are related to strategic and tactical issues in SCM. Section III encompasses four chapters that are relevant to project and technology issues in Supply Chain. Section IV consists of two chapters which are pertinent to risk managements in supply chain.

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