Effort Levels of Capital-constrained Retailer under Bank Financing

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Abstract In a supply chain with a retailer confronted with financial constraints, impacts on profits of the supply chain can be alleviated by increasing the retailer's efforts and market demand through external financing (bank). If the cost of bank lending is not very high, the capital-constrained retailer can borrow money and make efforts. The reduction of bank interest rates, however, increases the retailer's efforts. We prove that there is a unique equilibrium point between the retailers. We find out the optimal interest rate of the bank and the optimal efforts by the retailer through numerical analysis and verify validity of the results.

Key words Bank financing, Capital constraints, Effort levels, Interest rates

1 Introduction

Faced with uncertain market demands, one of the effective inventory management strategies is to purchase sufficient goods as a buffer against the unexpected demands. Oftentimes, decision makers can have financial liquidity constraints, especially when a new company starts to run its business. The Wall Street Journal recently reported a detailed story of a start-up company called Pen Again. The company produced one type of hand tool which has the advantage of relieving pressure of writers and reducing risks of repetitive strain injuries when writing. However, due to improper estimation of the US market demand, many operation problems occurred, including inventory backlog, lack of working capital and financial difficulties. Finally the company filed for bankruptcy protection and got local debt financing to solve the problems. Therefore, the shortage of funds has become one of the biggest barriers to the development of companies and even economies. Our research focuses on capital-constrained retailers' choices in the selling season, regarding retailers' increasing efforts to increase market demand or reducing efforts to use their own funds without a bank. The Stackelberg model is used in this research, and the game process is: the retailer orders goods at wholesale prices and sells out in selling periods. In other words, the retailer has to decide the purchasing amount under a given interest rate from the bank. The market demand is uncertain and changes as effort level of the retailer changes. When sales are not high in the selling season, the retailer cannot pay off the loan in full amount. Therefore, the bank must determine the interest rate considering the possibility of default.

2 Literature review

As documented in research, lack of funds can be solved with external financing, but other problems may occur, such as the difficulty in determining a reasonable interest rate by the external financing bank and determining the appropriate amount of loan that one can get from the bank. Archibald, Thomas, Betts & Johnston pointed out that new companies should be more cautious than mature companies when processing procurement of components, and there can be multiple sources for the purchase funds. Through building models, Xu & Birge found that enterprises' production decisions were highly impacted by capital constraints. Dada & Xu studied a capital-constrained newsboy model and found that companies would choose to ask for a loan from a bank and make purchases as long as the interest rate is not too high. Xu & Zhang studied that under certain conditions, banks providing loans and goods for capital-constrained retailers can facilitate smooth operation of the entire supply chain. Buzacott & Zhang discussed the relationship between operation of companies with capital constraints and their financing under uncertain market demands. Cadentey & Haugh found that there were significant differences regarding the performances of supply chain contracts with arbitrage vs. without arbitrage when the retailer was capital-constrained. Cadentey & Haugh, Xu & Birge studied optimal production decisions with both financial constraints and management incentives. Chen & Ying analyzed financial services and decision-making of banks in a medical supply chain. Chen, Zhu & Ying studied operational decisions and financial decision-making in a supply chain with a single supplier and a single retailer. Yu & Luo studied a reverse auction mechanism under capital constraints. All of the literature mentioned above considered possible capital constraints in the supply chain system, especially for new companies. However, in practice, retailers' effort levels can affect market demand of products, for instance, effectively increasing investments in advertising of one product can possibly expand its market demand. Wang & Gerchak studied the supply chain cooperation with commodity shelf space as a proxy variable for effort levels. Taylor proved that coordination of a supply chain system cannot be achieved under simple return policies when the funding was sufficient. Krishnan, Krishnan, & Butz found that retailers would be misled regarding their effort levels of sales promotion when they cannot observe the actual market demand signals. Working on the

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supply chain with sale efforts and sufficient funds, Qu & Guo found that improved revenue-sharing contracts could enhance coordination of the supply chain. Ma, Xue, & Wang found supply chain coordination could be achieved with the help of repurchase contracts under retailers' sale efforts and sufficient capital. With the consideration of impacts of effort levels on product market demand, the above literature has assumed that retailers' capital is not constrained. Based on the study by Dada & Hu, this paper tries to consider effects of effort levels of one retailer and identify optimal decisions by the bank and the retailer when both capital constraints and efforts levels exist. More specifically, our research stands out regarding three points: first, we apply the theory of budget-constrained supply chain on retailer issues; second, we consider effort factors in a capital-constrained supply chain and analyze how these factors influence the supply chain operating decisions and performance; third, we include the bank into the supply chain system and analyze how financial services influence the supply chain operating decisions.

3 Retailer's optimal decisions

The fund owned by a single retailer in a supply chain is η. The sales effort level of the retailer is e, and $h(e)$ indicates the cost of the retailer when the effort level is , with $h(e) \leqslant \eta$. Let $h(0) = 0$, $h'(e) > 0, h''(e) > 0$, and effort level affects the market demand, and further affects the retailer' upstream order quantity. In sales season, the retailer orders Q units of goods at a wholesale price. Let the market price be p and the market demand x a random variable. $f(x|e)$ represents the probability density function of the demand with effort level e; $F(x|e))$ represents probability distribution function of the demand with effort level e; and $F^{-1}(x|e)$ indicates the inverse function of the market demand distribution function. Define $\bar{F}(x) = 1 - F(x)$, without considering inventory and residual value losses. The optimal order quantity of classical newsboy model is Q_0, satisfying $\bar{F}(Q_0) = w/p$. However, when the retailer is under capital constraints, his own funds are not sufficient to order any more goods. Then the retailer can order Q units of goods by borrowing money B from external risk-neutral financial institutions (such as a bank) at the interest rate of r, and B meets the following condition:

$$B = wQ - [\eta - h(e)] \tag{1}$$

When the market demand achieves and the retailer sells out the products, he can repay bank loans $B(1+r)$ with part of the revenue.

Let $S(Q,e)$ represent the expected sales volume given the order quantity and effort level, which indicates that $S(Q,e) = E\min(Q,x)$. Specifically, we have:

$$S(Q,e) = \int_{\frac{B(1+r)}{p}}^{Q} x f(x|e)\,dx + \int_{Q}^{+\infty} Q f(x|e)\,dx \tag{2}$$

In order to simplify the optimization model, following Wang, we assume that demand satisfies the multiplication form $x = z(e)\xi$, in which, $z(e)$ is a continuous, non-negative, second-order differentiable and increasing function of effort level e, and it is also concave, i. e. , $z'(e) > 0, z''(e) \leqslant 0$. ξ is a random variable, which is independent of e, and the probability density function ξ of is represented by $f(\xi)$. $F(\xi)$ is the probability distribution function of ξ. At this point, we can also introduce the assumptions made by Hu&Wang's. According to properties of conditional probability, we can get the probability density function and distribution function of the market demand x :

$$f(x|e) = \frac{1}{z(e)} f\left[\frac{x}{z(e)}\right] \tag{3}$$

$$F(x|e) = F\left[\frac{x}{z(e)}\right] \tag{4}$$

Substitute the above equations (3) and (4) in equation (2), then the retailer's expected sales volume is:

$$S(Q,e) = Q - \frac{B(1+r)}{p} F\left[\frac{B(1+r)}{pz(e)}\right] - z(e)\int_{\frac{B(1+r)}{pz(e)}}^{\frac{Q}{z(e)}} F(x)\,dx \tag{5}$$

The retailer uses his own funds to order goods firstly, and the minimum order quantity is $Q_d = \eta - h(e)/w$. Further, in order to get higher income while paying off the loan, the order quantity Q must be far greater than Q_d, which will cause the capital-constrained retailer to ask for external financing from the bank. Therefore, to ensure that retailer can get benefits and repay the loan, we can get a minimum order quantity that the retailer needs to purchase. Thus the retailer's profits can be expressed as:

$$\begin{aligned}\max_{Q \geqslant \eta - h(e)/w} \pi_R &= pS(Q,e) - \eta - B(1+r) \\ &= pQ - B(1+r) F\left[\frac{B(1+r)}{pz(e)}\right] - pz(e)\int_{\frac{B(1+r)}{pz(e)}}^{\frac{Q}{z(e)}} F(\xi)\,d\xi \\ &\quad - \eta - B(1+r)\end{aligned} \tag{6}$$

$$m = \frac{pz(e)}{1+r}, y = \frac{[wQ - \eta + h(e)](1+r)}{z(e)p} = \frac{B}{m} \tag{7}$$

where m represents the discounted income per unit of sales; y represents loan repayment B only if the retailer sells the minimum quantity of goods. Therefore, the retailer' default probability is $F(y)$.

Substitute equation (7) into equation (6), and the retailer's optimization problem becomes:

$$\pi_R = pz(e)\int_{y}^{\frac{Q}{z(e)}} \bar{F}(\xi)\,d\hat{s} - B(1+r)F(y) - \eta \tag{8}$$

Proposition 1 When $\eta - h(e) < wQ_0$ and $\dfrac{f(x)x}{1-F(x)}$ is an increasing function of x, i. e. , the demand distribution is IGFR (increasing generalized failure rate), then the retailer's optimal order quantity Q^* is:

$$Q^* = \begin{cases} \dfrac{\eta - h(e)}{w} & \dfrac{\eta - h(e)}{w} > \bar{F}^{-1}\left[\dfrac{w}{m}\right] \\ \hat{Q} & or \end{cases} \tag{9}$$

where $\hat{Q}$ satisfies:

$$p\bar{F}\left[\frac{\hat{Q}}{z(e)}\right] = w(1+r)[1 + yf(y)] \tag{10}$$

Proof When the bank interest rate is high, the retailers make full use of their own funds and do not get financing from the bank. Thus the expected revenue for the retailer is $\pi_R^H = p.\dfrac{\eta - h(e)}{w} - \eta$. The optimal decision for the retailer is to use all the available funds to order goods, and the optimal order quantity is $Q^* = \eta - h(e)/w$.

When the interest rate of bank loans is low, the retailer will spend his own funds and ask for a loan from the bank. Then the retailer's expected revenue is represented by equation (8). The retailer maximizes his expected profits. We can solve equation (8) to figure out the first-order and second-order derivatives of order quantity Q and the effort level e:

$$\frac{\partial \pi_R}{\partial Q} = p\bar{F}\left[\frac{Q}{z(e)}\right] - w(1+r) - w(1+r)yf(y) \tag{11}$$

$$\frac{\partial^2 \pi_R}{\partial Q^2} = -\frac{p}{z(e)}f\left[\frac{Q}{z(e)}\right] - \frac{w^2(1+r)}{m}[f(y) + yf'(y)] \tag{12}$$

$$\frac{\partial^2 \pi_R}{\partial Q \partial e} = pQf\left[\frac{Q}{z(e)}\right]\frac{z'(e)}{z^2(e)} + \frac{wf(y)}{m}[Bz'(e) - (1+r)h'(e)] + \frac{wy(1+r)f'(y)h'(e)}{m}\left[\frac{yz'(e)}{z(e)} - \frac{1}{m}\right] + \frac{wy^2(1+r)f'(y)z'(e)}{z(e)}\left[\frac{h'(e)}{m} - \frac{yz'(e)}{z(e)}\right] \tag{13}$$

$$\frac{\partial \pi_R}{\partial e} = pQF\left[\frac{Q}{z(e)}\right]\frac{z'(e)}{z(e)} - p'z(e)(y+A) - (1+r)h'(e)F(y) - [pz(e)\bar{F}(y) + B(1+r)f(y)]\frac{dy}{de} \tag{14}$$

$$\frac{\partial^2 \pi_R}{\partial e \partial q} = \left\{pQF\left[\frac{Q}{z(e)}\right] - w(1+r)yf(y)\right\}\frac{z'(e)}{z(e)} - \frac{2pw}{m}\bar{F}(y)z'(e) - (y+A) - \frac{w(1+r)}{m}f(y)h'(e) - w(1+r)yf'(y)\frac{dy}{de} \tag{15}$$

$$\frac{\partial^2 \pi_R}{\partial e^2} = pQf\left[\frac{Q}{z(e)}\right]\frac{z''(e)}{z(e)} - pQ^2 f\left[\frac{Q}{z(e)}\right]\frac{[z'(e)]^2}{z^3(e)} - pz''(e)(y+A) - h''(e)(1+r)F(y) - [2pz'(e)\bar{F}(y) + h'(e)(1+r)f(y)]\frac{dy}{de} - [pz(e)f(y) - B(1+r)f'(y)]\left(\frac{dy}{de}\right)^2 - [pz(e)\bar{F}(y) + B(1+r)f(y)]\frac{d^2y}{de^2} \tag{16}$$

Let $A = \int_y^{\frac{Q}{z(e)}} F(\xi)d\xi$, and we can get a Hessian matrix regarding the order quantity and effort level:

$$H = \begin{bmatrix} \frac{\partial^2 \pi_R}{\partial Q^2} & \frac{\partial^2 \pi_R}{\partial Q \partial e} \\ \frac{\partial^2 \pi_R}{\partial e \partial Q} & \frac{\partial^2 \pi_R}{\partial e^2} \end{bmatrix} \tag{17}$$

Substitute equations (12), (13), (15) and (16) into (17). With further simplification of the Hessian matrix, we can get $|H| > 0$, which indicates that the retailer's profit is a joint concave function of the order quantity and effort level. There is an optimal order quantity to satisfy $\frac{\partial \pi_R}{\partial Q} = 0$, i.e., $p\bar{F}\left[\frac{\hat{Q}}{z(e)}\right] - w(1+r) - w(1+r)yf(y) = 0$. With equation (7), we can get the simplified form:

$$p\bar{F}\left[\frac{\hat{Q}}{z(e)}\right] = w(1+r)[1 + rf(y)] \tag{18}$$

Therefore, Proposition 1 is proved.

Equation (9) shows that the retailer will spend all of his own funds, without borrowing money from the bank. When the bank offers high lending interest rate, it may indicate that there is an interest rate cap charged by the bank for retailer's each personal fund η. It makes sense that the interest rate cap can reduce the retailer's net benefits. By contrast, if the lending interest rate is very low, in order to obtain higher returns, the retailer will spend his own funds and ask for external financing to be able to get higher order quantity $\hat{Q}$, which needs to satisfy equation (18).

Proposition 2 The optimal effect level of retailer e^* satisfies:

$$\left\{pQF\left[\frac{Q}{z(e^*)}\right] + B(1+r)yf(y)\right\}\frac{z'(e^*)}{z(e^*)} - [pyF(y) + pA]z'(e^*) = \left\{(1+r)[F(y) - yf(y)] - \frac{p\bar{F}(y)z(e^*)}{m}\right\}h'(e^*)$$

Proof Combining with equation (7), we can solve the first order condition of effect level e and easily get the following equation with simple manipulations:

$$\left\{pQF\left[\frac{Q}{z(e^*)}\right] + B(1+r)yf(y)\right\}\frac{z'(e^*)}{z(e^*)} - [pyF(y) + pA]z'(e^*) = \left\{(1+r)[F(y) - yf(y)] - \frac{p\bar{F}(y)z(e^*)}{m}\right\}h'(e^*)$$

Given that the interest rate is set up by the bank when the retailer's profits are maximum, we need to consider bank problem as well. As a leader, the retailer must consider the optimal effect level and a loan interest r or m that he can definitely choose. Hence we get the following theorem.

Theorem 1 Default possibility of the retailer is a decreasing function of the interest rate.

Proof According to derivation principles for implicit functions, we combine equation (1) and equation (7), and take derivative of both sides of equation (18) with respect to the discount income m:

$$-pf\left[\frac{my + \eta - h(e)}{z(e)}\right]\frac{y + m\frac{dy}{dm}}{z(e)} = w(1+r)\left[f(y)\frac{dy}{dm} + yf'(y)\frac{dy}{dm}\right] \tag{19}$$

Further simplify the above equation and we can get:

$$\frac{dy}{dm} = -\frac{pyf\left[\frac{my + \eta - h(e)}{z(e)}\right]}{w(1+r)[f(y) + y'f(y)]z(e) + pmf\left[\frac{my + \eta - h(e)}{z(e)}\right]} < 0 \tag{20}$$

According to equation (7), we know that the discount income m is a monotonic function of interest rates, and its value is correlated with each interest rate. Thus we can see that the retailer's default probability is a decreasing function of the interest rate. Theorem 1 demonstrates that when the loan interest rate is higher, the fund-constrained retailer will seriously consider whether to use external finance or not. The repayment ability will be weakened by the increased interest rate, and the worst result is that the retailer cannot pay any loan and goes bankrupt. In this case, it would be better if the retailer does not ask for any loan and reasonably utilizes his own funds to make rational invest-

ments. On the contrary, if the loan interest rate is lower, the retailer might not be very careful in operation, and perhaps he would make irrational investment or ignore market demands. If more loans are used to place orders, the markets can become saturated, and the inventory gets overstocked. If it's difficult to get the stock realized, the retailer is not able to pay off the loans even with lower interest rates and the company has to lose money and eventually goes bankrupt.

4 Numerical analysis

Assuming $w-5$, $p=10, \eta=100, F(x)=\frac{1}{2}x^2$, and $z(e)=e$.

According to the expression of effort level e in equation (1) and (10), we can get the relationship between effort levels of retailer and order quantities as well as the relationship between effort levels and the loan amount. In Fig. 1, we can see that the retailer's order quantity is in proportion to his own efforts, which means that the increasing of efforts increases the order quantity. Meanwhile, the loan amount from the bank is in direct proportion to the retailer's efforts, which indicates that with the increasing of efforts, the retailer has to borrow more money from the bank to make purchases. Thus, based on the Newsboy Model, the growth rate of the retailer's order quantity is less than that of the loan in the beginning, and then becomes greater later. Next, let's see how the bank interest rate influences the order quantity and the loan amount. Results from numeric analysis of the relationship between interest rates and order quantity as well as the relationship between interest rates and bank loan amount are shown in Fig. 2. From Fig. 2, we find out that the order quantity is inversely proportional to the interest rates, namely, the higher the interest rate, the lower the order quantity. With high interest rates, the retailer would like to use his own funds and avoid loaning from the bank. The high interest rates make the retailer worry about possibly large interest if large amount of loan he can get from the bank. The loan amount is first in direct proportion to the interest rate and later becomes inversely proportional. It clearly shows that the optimal interest rate is the one when the loan is maximum, so the optimal interest rate is 0.5.

5 Conclusions

The article studies the financing and operation decision-making of the supply chain when the retailer is faced with capital constraints, and focuses on the influence of the retailer's effort levels on market product demand. This research indicates that if the cost of loaning (interest rate) is not too high, the retailer constrained by capital will ask for loan from the bank and put more efforts, and the decreasing bank interest rates would increase the retailer's effort levels. Furthermore, we prove that there is a unique equilibrium point between the retailers, and we find out the optimal effort level of the retailer and optimal loan interest rate. The results indicate that interest rates determine companies' decision-making in a supply chain.

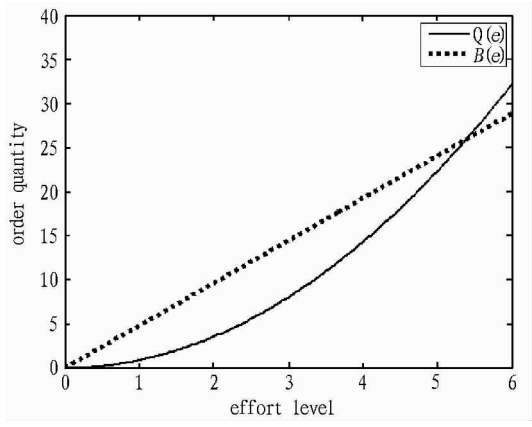

Fig. 1 The relationship between the retailer's order quantity $Q(e)$, loan amount $B(e)$ and effort level e

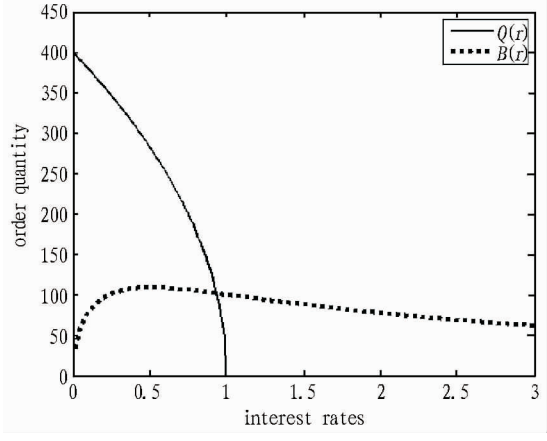

Fig. 2 The relationship between the interest rate and the retailer's order quantity and loan amount

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output, but Professor Kumar Vineet from Harvard University Business School published the papers with the highest number. Combining these situations, it can be known that the United States has powerful strength in marketing field. As to new trend of international cooperation, the cooperative network between the United States and other countries will be closer and exchange between institutions will be more frequent.

In addition, visual analysis of mapping knowledge domain indicates that hot spots of marketing are concentrated on high frequency key words, such as behavior, information, model, choice, performation, and competition. Also, through visual evolution analysis of research hot spots, it is able to clearly observe evolution path of hot spots, hot spots of certain period may change with deepening of researches, information to be explored is gradually reducing, thus scholars may turn to other unknown fields. During evolution, hot spots may experience mutation. Once there is mutation, it means there will be new discipline, and mutation words probably become direction of future research development. Apart from key words and mutation words, core papers play a decisive role in research history of Marketing Discipline. They lead the direction of Marketing Discipline and promote development of Marketing Discipline. Through analysis of core papers, we found that they can be divided into method model and marketing application as per research contents, and researches on method models take up a larger portion.

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