A Supply Chain System with Capital Constraints Considering Various Salvage Values

Song-Man Wu
Industrial and System Engineering Department
The Hong Kong Polytechnic University
Hung Hum, Hong Kong
songmanwu@foxmail.com

Felix T.S. Chan
Industrial and System Engineering Department
The Hong Kong Polytechnic University
Hung Hum, Hong Kong
f.chan@polyu.edu.hk

S.H. Chung
Industrial and System Engineering Department
The Hong Kong Polytechnic University
Hung Hum, Hong Kong
nick.sh.chung@polyu.edu.hk

Abstract

This paper examines the effects of positive or negative residual values on the supply chain participants' decisions. The supply chain consists of a cash-strapped manufacturer, a reputable retailer, and a financial institution. Two financing tools are considered to address the manufacturer's financial difficulties. It is found that, firstly, positive and negative residual values affect the optimal order quantity. Secondly, residual values have an impact on the profits of each supply chain member. The threshold value of the retailer's internal asset level is related to the residual value under the condition of single financing equilibrium. Finally, the results are verified by some numerical experiments.

Keywords

Supply chain management, Capital constraints, Supply chain finance, Residual values.

1. Introduction

Supply chain parties often face working capital constraints in ordering and production decisions, especially for small and medium-sized enterprises (SMEs) (Vandenberg 2003), and they may not be able to get loans from financial institutions (Kouvelis and Zhao 2012). To solve this problem, supply chain finance (SCF) emerged to help the enterprises obtain funds. In the past few years, SCF services have been widely adopted worldwide, especially in developing countries. When liquidity is tight, companies

need short-term financing to operate their business. Therefore, how to build effective financing channels and solve the problem of capital constraints of SMEs has become a major problem in today's society. Hence, this study focuses on advance payment discounted (APD) and buyer-backed purchase order financing (BPOF) to reduce the capital constraints of the manufacturer.

Further, perishable goods (such as clothing, consumer electronics, laptops, toys, cosmetics, and fragrances) have a volatile market (Tsay 2001). The retailer is likely to face overstock, and it is common for retailers to clear stock through residual value (Wang and Webster 2009). In many literatures of SCF (Yan et al. 2018), many researchers assume that the sign of residual value makes no difference and ignore the residual value in financing; thus, the residual value of unsold products is set to zero in their studies. Therefore, our research explores how to manage the corporate financial risks with finance instruments (APD and BPOF) with both positive and negative residual values in supply chains. The manufacturer and the retailer are risk-neutral profit maximizers. Our main contributions are in three aspects: 1) the positive and negative residual values affect the order quantity; 2) different residual values affect the parties' profits; 3) for the financing equilibrium, various residual values affect the threshold of the retailer's asset level.

The rest of this research begins with the literature review in Section 2. Two models with APD and BPOF are built in Section 3. Section 4 analyzes the financing equilibrium. Numerical experiments are carried out in Section 5 and Section 6 concludes the paper.

2. Literature Review

Two literature streams are relevant to the research: SCF and the study on the residual value of perishable goods.Firstly, the closest thing to our work is SCF research. For a long time, operating management and corporate finance research respectively in a different direction. The studies of operating management have tended to ignore the corporate usability problem, and the corporate finance research often neglects the operational problems of the enterprise. Few scholars take operations management and financing at the same time into consideration. Joint operational and financial strategies could be used to deal with the enterprise's budget constraints. Recently, there has been a growing emphasis on various financing strategies. According to Petersen and Rajan (1997), trade credit is the most popular short-term financing for American companies. Trade credit is also widely used in economies with underdeveloped financial markets or weak bank-enterprise relationships (Biais and Gollier, 1997). Cai et al. (2014) investigated both trade credit and bank financing and found the relationship. Yang and Birge (2013) theoretically and empirically showed that even when bank and supplier financing could be jointly used, manufacturer financing was still preferred to bank financing. Alan and Gaur (2018) explored the role of inventory in bank financing and trade credit. Lekkakos et al. (2016) studied the reverse factoring and traditional factoring in a stochastic multi-period environment. Khan et al. (2019) presented the impact of early-payment financing on supply decisions for perishable goods and showed the demand depended on price and inventory. Qin et al. (2019) presented the study of advance payment financing on environmental problems. Most SCF studies focus on retailers' capital constraints, with little discussion of upstream enterprises' capital constraints (Tang et al. 2018; Tunca and Zhu 2018; Yan, et al. 2020). In this paper, we use two less studied financial instruments, APD and BPOF (Zhao and Huchzermeier 2019).

Secondly, the residual value is an important factor in supply chain management. For instance, Mauer and Ott (1995) interpreted residual value and depreciation as functions of stochastic operating costs, reducing the dimension to 1, while Dobbs (2004) embedded residual values in the single-factor model. Cachon and Kök (2007) proposed a clearance pricing model of the surplus market. The analytic real option solution of the optimal after-tax allocation time boundary was established by Adkins and Paxson (2017) for the alternative assets with a stochastic deterioration of operating cost and residual value. In summary, most previous research on perishable goods with positive residual value. Few studies incorporated a negative residual value into the model (e.g., Keren and Pliskin (2006)).

3. Model description

There are three key participants in our approach: an SME manufacturer (seller), a retailer (buyer), and a financial institution, all of whom are risk neutral. The buyer purchases goods from the seller. Then, the buyer deliveries the goods to clients. These parties collaborate to deal with the SME manufacturer's financial stress. Firstly, the BPOF strategy means that the manufacturer obtains funds from a financial institution. Secondly, by using APD, the retailer can finance financially troubled manufacturers by pre-paying for products before delivery. In other words, the manufacturer obtains early payment from the retailer for production. Figure. 1 displays a sequence of events about two financing tools (Zhao and Huchzermeier 2019). For convenience, the notations are summarized in Table 1.

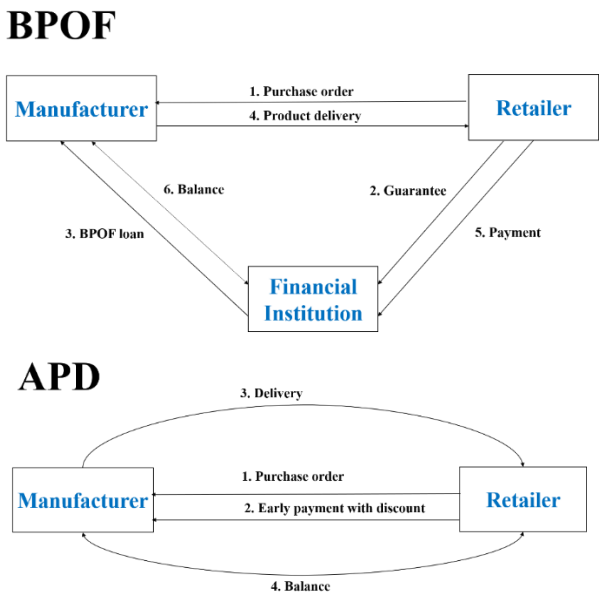

Figure 1. The sequence of events of two financing instruments

Table 1. Summary of notations

Notation	Description
π	Expected profit
A	Asset level
L	Short-term debt
p	Selling price
α	Proportional distress cost
γ	Proportional liquidation cost
δ	A portion of financial institution's loss
c_p	Production cost
c_k	Capacity cost
i	Interest rate
r	Residual value
K	Capacity level
q	Order quantity
w	Wholesale price
d	Discount rate
λ	A portion of purchase order value

Furthermore, D, $F(D)$, $f(D)$, $\bar{F}(D)$ $h(D)$

$\bar{F}(D) = 1 - F(D)$ and $h(D) = f(D) / \bar{F}(D)$. Let $H(D) = Dh(D)$ represent generalized failure rate, and the generalized failure rate is $h(D) = Df(D) / (1 - F(D))$. After the sales season ends, *r* and can be positive, negative, or even zero. The capital market in our study is imperfect. That is, when a firm fails to pay its debts, it can either be liquidated or negotiated with creditors in an expensive restructuring process (Gamba & Triantis, 2014).

4. Models

4.1 APD model

By adopting APD, the retailer determines the ordered quantity and pays the manufacturer before product delivery. If any quantity ordered is not completed, the retailer will receive the fund after delivery. The manufacturer's profit and capacity in APD is

$$\pi_m^{apd} = \begin{cases} [w(1-d) - c_p]N - c_k K & \text{Continuation} \\ [w(1-d) - c_p]N - c_k K - (1-\alpha)(L_s - A_s + c_k K - w(1-d)q) & \text{Reorganization} \\ 0 & \text{Liquidation} \end{cases} \quad (4.1)$$

Here $N = \min(q, K)$.

The retailer's expected profit is:

$$\pi_r^{apd} = p\mathrm{E}\min[D, N] - w(1-d)N + r[N-D]^+ - (1-\alpha)[L_r - A_r + w(1-d)q]^+ \quad (4.2)$$

Under APD, q^{apd*} satisfies $(p-r)\bar{F}(q^{apd*}) + r = w(1-d)$ in continuation and in the reorganization the optimal order quantity satisfies $(p-r)\bar{F}(q^{apd*}) + r = w(1-d)(2-\alpha)$.

Proposition 1 Under APD, the higher the residual value of the product is, the buyer will order more products, which will bring higher profits, and the financial risk is low, i.e., $q^{apd*}(r<0) < q^{apd*}(r=0) < q^{apd*}(r>0)$.

Proposition 1 indicates that products with positive high residual value are more attractive to the retailer so that he can order more products to earn more money. Conversely, goods with a negative low residual value are ordered in fewer quantities.

4.2 BPOF model

In this case, the retailer decides to use only BPOF and offers a loan guarantee to the financial institution. Then the manufacturer determines the borrowing level according to the capital level and the orders, and finally receives the loan from the financial institution. The manufacturer's profit is

$$\pi_m^{bpof} = \begin{cases} (w - c_p)N - c_k K - \lambda wqi & \text{Continuation} \\ (w - c_p)N - c_k K - (1-\alpha)(L_s - A_s - \lambda wq + c_k K) - \lambda wqi & \text{Reorganization} \\ 0 & \text{Liquidation} \end{cases} \quad (4.3)$$

The buyer's expected profit function is:

$$\pi_r^{bpof} = p\mathrm{E}\min[D, N] - wN + r[N-D]^+ - \int_{\underline{A_S}}^{\%} \delta \left\{ \lambda wq - \gamma \begin{bmatrix} (w - c_p)N - c_k K \\ -\lambda wqi + A_s - L_s \end{bmatrix} \right\} \phi(A_s) dA_s \quad (4.4)$$

And the optimal order quantity is $q^{bpof*} = F^{-1}\left(\frac{p - w - (\delta\lambda w - \delta\gamma w + \delta\gamma c_p + \delta\gamma\lambda wi)[\Phi(\%) - \Phi(\underline{A_S})]}{p - r}\right)$.

Proposition 2 In BPOF, both π_r^{bpof} and q^{bpof*} increase with the residual value. That is, $q^{bpof*}(r<0) < q^{bpof*}(r=0) < q^{bpof*}(r>0)$.

Proposition 2 suggests that if the order quantity exceeds the market demand, that is, there is surplus inventory. Items with high residual value will encourage the retailer to order more products because high residual value can help reduce losses and maximize profits.

5. Financing equilibrium with a residual value

If either of the two financing instruments can satisfy the upstream manufacturer's financial requirements, the downstream buyer will select one of them. Here, if the buyer is unfamiliar with both, we assume that the buyer selects APD over BPOF.

Theorem 1 There is a unique threshold of the retailer's internal asset level ω_r exists, which makes the buyer preferred to choose BPOF iff if $A_r < \omega_r$. Otherwise, APD is chosen. Besides, the value ω_r is in direct proportion to s. That is, $\omega_r(r > 0) > \omega_r(r = 0) > \omega_r(r < 0)$.

Theorem 1 reveals that the threshold of asset level of the retailer with positive residual value is higher than the threshold of asset level of the retailer with no residual value and negative residual value. The reason is that goods with high positive residual value will make the retailer order more, and at the same time, the increase of the order quantity will increase the inventory risks of the retailer, making the inventory in the backlog state. Therefore, if the retailer buys goods with a positive high residual value, the buyer's asset level should be higher.

6. Numerical analysis

The effects of different residual values on the retailer's performance are investigated through some computational experiments. p = \$600, α=0.85, ck=cp=\$100, and the demand is N(1000,100). Further, in our paper, r is set to vary between -10 and 25.

We show the effect of residual value on the retailer's expected profit in Figure.2. As can be seen from Figure.2, as the residual value increasing, the retailer's profit increases. That is to say, when the order quantity of the retailer exceeds the market demand, if the residual value of these remaining items is high, the retailer will reduce more losses during the clearance period. Compared with the items with low residual value, the retailer can obtain more benefits and reduce the risk. On the contrary, orders with negative residual values will increase losses, resulting in lower profits.

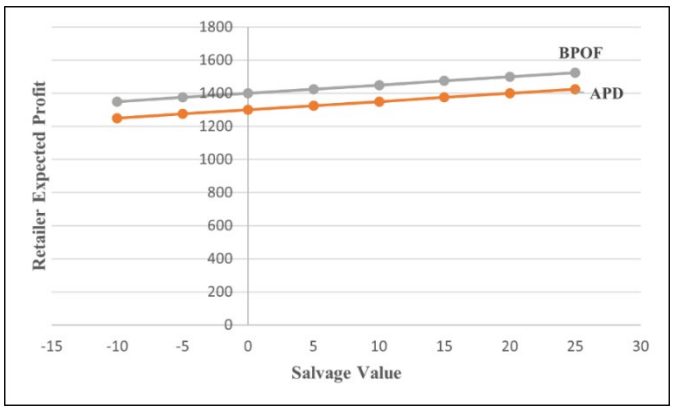

Figure 2. Impact of residual value on retailer's expected profit

From Figure.3, when the residual value of the item increases, q increases in both conditions. Disposal of products with high positive residual values during the clearance period can avoid excessive losses on the part of the retailer, so the retailer is encouraged to buy more from the manufacturer to meet demand.

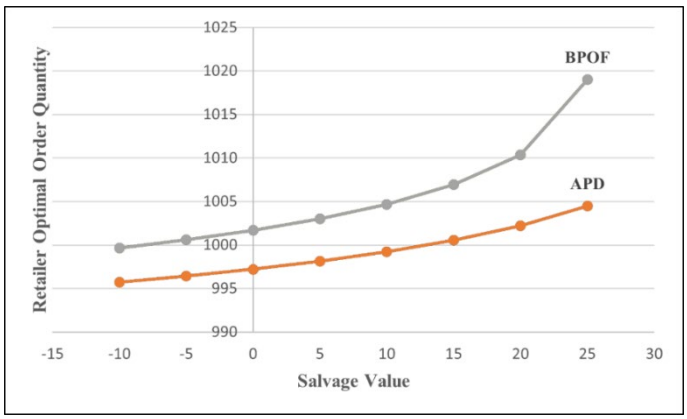

Figure 3. Impact of residual value on order quantity

7. Conclusion

We study a supply chain system with a cash-strapped manufacturer and analyze the supply chain participants' optimal decisions and financing strategies with considering positive and negative residual values. To solve the manufacturer's financial difficulties, the manufacturer can use BPOF and APD. Our research yielded some important results. In the clearance period, considering different residual values, the retailer's optimal order quantity is different. Specifically, compared with orders with no residual value, an order with a positive residual value can reduce the loss of the retailer, which will make the buyer gain more profits. On the contrary, orders with negative residual values increase losses, resulting in lower profits. Therefore, in the SCF system, the retailer is more likely to order products with high positive residual values from the manufacturer. Moreover, when residual values are high, the retailer should have higher asset levels to ensure that there is sufficient capital to provide financing to the manufacturer.

Future research directions mainly include the following aspects: 1) Future research can explore supply chain coordination with other contracts; 2) Risk preferences of supply chain participants can be considered in future models; 3) In real life, information asymmetry exists among supply chain participants, which needs to be further solved.

References

Adkins, R., and Paxson, D., Replacement decisions with multiple stochastic values and depreciation. *European Journal of Operational Research,* vol. 257, pp. 174-184, 2017.

Alan, Y., and Gaur, V., Operational investment and capital structure under asset-based lending. *Manufacturing and Service Operations Management,* vol. 20, pp. 637-654, 2018.

Biais, B., and Gollier, C., Trade credit and credit rationing. *The Review of Financial Studies,* vol.10, pp. 903-937, 1997.

Cachon, G. P., and Kök, A. G., Implementation of the newsvendor model with clearance pricing: How to (and how not to) estimate a salvage value. *Manufacturing and Service Operations Management,* vol. 9, pp. 276-290, 2007.

Cai, G. G., Chen, X., and Xiao, Z., The Roles of Bank and Trade Credits: Theoretical Analysis and

Empirical Evidence. *Production and Operations Management,* vol. 23, pp. 583-598, 2014.

Dobbs, I. M., Replacement Investment: Optimal Economic Life Under Uncertainty. vol. 31, pp. 729-757, 2004.

Gamba, A., and Triantis, A. J., Corporate risk management: Integrating liquidity, hedging, and operating policies. *Management Science,* vol. 60, pp. 246-264, 2014.

Keren, B., and Pliskin, J. S., A benchmark solution for the risk-averse newsvendor problem. *European Journal of Operational Research,* vol. 174, pp. 1643-1650, 2006.

Khan, M. A. A., Shaikh, A. A., Panda, G. C., Konstantaras, I., and Cárdenas-Barrón, L. E., The effect of advance payment with discount facility on supply decisions of deteriorating products whose demand is both price and stock dependent. *International Transactions in Operational Research,* vol. 27, pp. 1343-1367, 2019.

Kouvelis, P., and Zhao, W., Financing the Newsvendor: Manufacturer vs. Bank, and the Structure of Optimal Trade Credit Contracts. *Operations Research,* vol. 60, pp. 566-580, 2012.

Lekkakos, S. D., Hofmann, Mark Johnson, E., and Serrano, A., Supply chain finance for small and medium sized enterprises: the case of reverse factoring. *International Journal of Physical Distribution and Logistics Management,* vol. 46, pp. 367-392, 2016.

Mauer, D. C., and Ott, S. H., Investment under Uncertainty: The Case of Replacement Investment Decisions. *Journal of Financial and Quantitative Analysis,* vol. 30, pp. 581-605, 1995.

Petersen, M. A., and Rajan, R. G., Trade credit: theories and evidence. *The Review of Financial Studies,* vol. 10, pp. 661-691, 1997.

Qin, J., Han, Y., Wei, G., and Xia, L., The value of advance payment financing to carbon emission reduction and production in a supply chain with game theory analysis. *International Journal of Production Research*, pp. 1-20, 2019.

Tang, C. S., Yang, S. A., and Wu, J., Sourcing from manufacturers with financial constraints and performance risk. *Manufacturing and Service Operations Management,* vol. 20, pp. 70-84, 2018.

Tsay, A. A. J., Managing retail channel overstock: Markdown money and return policies. *Journal of retailing,* vol. 77, pp. 457-492, 2001.

Tunca, T. I., and Zhu, W., Buyer intermediation in manufacturer finance. *Management Science,* vol. 64, pp. 5631-5650, 2018.

Vandenberg, P., Adapting to the financial landscape: Evidence from small firms in Nairobi. *World Development,* vol. 31, pp. 1829-1843, 2003.

Wang, C. X., and Webster, S., Markdown money contracts for perishable goods with clearance pricing. *European Journal of Operational Research,* vol. 196, pp. 1113-1122, 2009.

Yan, N., Liu, Y., Xu, X., and He, X., Strategic dual-channel pricing games with e-retailer finance. *European Journal of Operational Research,* vol. 283, pp. 138-151, 2020.

Yan, Y., Zhao, R., and Liu, Z., Strategic introduction of the marketplace channel under spillovers from online to offline sales. *European Journal of Operational Research,* vol. 267, pp. 65-77, 2018.

Yang, S. A., and Birge, J. R., How inventory is (should be) financed: Trade credit in supply chains with demand uncertainty and costs of financial distress. *Available at SSRN 1734682*, 2013.

Zhao, L., and Huchzermeier.A., Managing supplier financial distress with advance payment discount and purchase order financing*, Omega,* vol. 88, pp. 77-90, 2019.

Biographies

Song-Man Wu received the M.S. degree in management science and engineering from Shanghai University, Shanghai, China, in 2018. She is currently working toward a Ph.D. degree with the Department of Industrial and Systems Engineering, Hong Kong Polytechnic University, Hong Kong. Her research interests include operations management, supply chain management, supply chain finance, quality management, and decision-making theory and application, etc. She has published 6 international journal papers, including the International Journal of Production Research, International Transactions in Operational Research, IEEE Transactions on Engineering Management, Total Quality Management & Business Excellence, International Journal of Computational Intelligence Systems, etc.

Professor Felix T. S. Chan received his BSc Degree in Mechanical Engineering from Brighton University, UK, and obtained his MSc and Ph.D. in Manufacturing Engineering from the Imperial College of Science and Technology, University of London, UK. Prior joining PolyU, Prof. Chan has many years of working experience in other universities including University of Hong Kong; University of South Australia; University of Strathclyde. His current research interests are Logistics and Supply Chain Management, Operations Research, Production and Operations Management, Distribution Coordination, Smart Manufacturing, AI Optimization. To date, Prof. Chan has published over 16 book chapters, over 370 SCI refereed international journal papers and 310 peer reviewed international conference papers. His total number of citations (without self-citations) > 10700, h Index= 52. (based on Web of Science, search by "Chan F. T. S."). Prof. Chan is a chartered member of the Chartered Institute of Logistics and Transport in Hong Kong. Based on the recent compilation (2020) from a research group of Stanford about the impact of scientists (top 2% listed). Prof. Felix Chan is categorized in the field of Operations Research, ranked 10 out of 23,455 scientists worldwide, i.e., Top 0.04% worldwide. At PolyU, only 5 staff ranked top 10 in his own field, and Prof. Felix Chan is one of them.

S.H. Chung graduated with a BEng (Hon) in Industrial, Manufacturing and Systems Engineering from The University of Hong Kong in 2001. He obtained his MPhil and Ph.D. from there in 2004 and 2007 respectively. He joined the Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, as a Lecturer in 2007 and was gradually promoted to Associate Professor in 2019. He joined as the Associate Director of the Integrated Graduate Development Scheme Unit since 2018. His research interests include logistics and supply chain management, supply chain collaboration, supply chain finance, production scheduling, distribution network, vehicle routing, container terminal operations, airline crew scheduling, aircraft maintenance routing, flight fuel consumption estimation, etc. Dr. Chung has been the principal investigator of about 10 research projects and published over 80 international journal papers, including IEEE Transactions on Industrial Electronics, IEEE Transactions on Systems, Man, and Cybernetics, IEEE Transactions on Systems Journal, OMEGA, Decision Support Systems, Decision Sciences, International Journal of Production Economics, International Journal of Production Research, Computers & Operations Research, Robotics and Computer Integrated Manufacturing, Resources, Conservation & Recycling, Transportation Research Part E, Transportation Research Part B, Risk Analysis, etc.