



Endogenous default risk in supply chain and non-linear pricing

Zhihui Gu^{a,*}, Shiyun Zhang^b

^a Business School of Nankai University, Weijin Road No. 94, Tianjin 300071, China

^b School of Economics and Management, Chongqing University of Posts and Telecommunications, Chongqing 400065, China

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ABSTRACT

Based on incomplete contract theories, we studied the strategic behaviors of up-stream and down-stream manufacturers by option game model and obtain some conclusions. First, the down-stream's pay-off function is a concave function of its investment in fixed assets, so there is an optimal investment, which ensures the down-stream's maximal pay-off and prevents it from being holdup. Second, in presence of endogenous default risks, the up-stream can improve its pay-off level through non-linear pricing. Last, increasing business risks of the down-stream may lead to an increased price fluctuation of the up-stream, while the down-stream's technological advancement can make such fluctuation less.

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1. Introduction

From 2007 to the recent financial crisis, as down-stream manufacturers can hardly pay off goods payment or go bankrupt, numerous suppliers have been faced with financial distress or on the edge of bankruptcy, and some have claimed for bankruptcy liquidation. For example, as General Motors went bankrupt, auto parts suppliers in China, Japan, and Korea are faced financial distress. The dissemination of such crisis attracts concerns from auto parts suppliers and relative financial institutions. On the other hand, rankings of Takata, Yorozu, and Akebono Brake Industry have been lowered due to bankruptcy of General Motors. Of course, statesmen of different countries also show increased concerns for such crisis. The Chinese government formulated plans to revitalize the auto industry, and Toshihiro Nikai, minister of Economy, Trade and Industry of Japan, openly announced that the Japanese government would assist Japanese companies, which have been influenced by the bankruptcy of General Motors. The occurrence of such events forces us to rethink about endogenous default risks of supply chain contract as well as manufacturers' corresponding strategies.

In recent years, supply chain risk management has received concerns from the academics. On the part of buyers, supply chain risks mainly include supply management, production management, information management, and demand management (Tang, 2006). From the perspective of the supply chain structure, suppliers are closely connected with down-stream manufacturers in risk. If the

supplier is risky to be bankrupt, the supply price in contract may change due to the effect of bankruptcy (Babich et al., 2007). Likely, demand fluctuation of the down-stream manufacturer may convey to up-stream manufacturer (Lee et al., 1997). From the perspective of financial risk, if the down-stream manufacturer is faced with liquidity risks, the supplier can reduce the down-stream manufacturer's risk level through contract design, and the contracted price is determined by the down-stream manufacturer's market risks and decision making behaviors (Agrawal and Seshadri, 2000; Chen and Seshadri, 2006; Wang and Webster, 2007). In addition, the supply chain may be broken by bankruptcy of the supplier or the down-stream manufacturer, leading to inefficient investment and moral hazard (Bakshi and Kleindorfer, 2009). On the other hand, according to fundamentals of accounting, a supplier's goods payment is expressed as the manufacturer's debt. Once the manufacturer cannot pay off its debt, it will go bankrupt, causing losses to suppliers. However, such risk factor was neglected in Christopher's framework. It follows from the recent financial crisis that such risk factor has brought fatal dangers to suppliers, one of the future difficulties the supply chain restructuring has to overcome. For this reason, we attempt to study this issue from the perspective of endogenous default risk in the supply chain contract. Endogenous default risk means that once a supply chain contract is signed, the supplier becomes a debtor of the manufacturer, who may select a bankruptcy value level endogenous in the supply chain contract under some circumstance, meaning that it will choose to go bankrupt rather than pay off goods payment once its assets add up to the selected value level. Such perspective helps to understand the manufacturer's bankruptcy behaviors as well as the ensuing restructuring.

Whenever a supply-demand contract is mentioned, the problem of incomplete contract and holdup (Grossman and Hart, 1986;

* Corresponding author. Tel.: +86 22 23498759; fax: +86 22 23501314.

E-mail addresses: philipsnankai@126.com (Z. Gu), nankai1919.zsy@163.com (S. Zhang).

Hart and Moore, 1990) is always involved. Hart and Moore (1988) analyzed reasons for holdup. Suppose a supplier signs a supply chain contract with a down-stream manufacturer and the investment level is determined by the down-stream manufacturer after the contract is signed, then the down-stream manufacturer's investment level would maximize its own pay-off rather than maximize both parties' pay-offs. The reason is that the up-stream manufacturer's default will result in sunk costs if its investment is up to such a level that both parties' pay-offs can be maximized. This example shows that there are problems of insufficient investment and holdup in a supply chain, a phenomenon studied by Böckem and Schiller (2008) with option contract. If we analyze the behaviors of up-stream and down-stream manufacturers in a supply chain contract from the perspective of incomplete contract, their pay-off function may be defined as a call option (Maskin and Tirole, 1999). This provides a basis on which to study the supply chain contract with a real option model.

Currently, the real option method has been used in studying the supply chain contract. Burnetas and Ritchken (2005) argue that introduction of the option contract into the supply chain contract results in an increase in wholesale price and a decline in retail price fluctuation. Wang and Tsao (2006) provide a purchaser's optimal strategy, and Li et al. (2009) expound the role of the option contract under the condition of asymmetric information. Enlightened by such studies, we will consider optimal strategies of the contracting parties with the game theory method during our study of the supply chain contract. Based on Maskin and Tirole (1999), we suppose the up-stream manufacturer holds a call option concerned with the supply contract. Then, using the method of Black and Cox (1976), we will obtain the call option price, i.e., the pay-off function of the up-stream manufacturer. Finally, based on findings of Leland (1994, 1998), we will calculate the pay-off function of the down-stream manufacturer under the condition of bankruptcy. After we draw the pay-off functions of the up-stream and down-stream manufacturers, we will obtain the solution to the optimal investment strategy of the down-stream manufacturer, suggesting that the down-stream manufacturer invests insufficiently to avoid being holdup. According to Maskin and Tirole (1999), vertical integration can help to reduce the loss of welfare under this condition, but our conclusion means that market pricing mechanism can achieve a similar effect. In accordance with the terms of economics, we obtain the conclusion means that we introduced the mechanism design into the supply chain (Chen et al., 2005) and use non-linear pricing mechanism (Wilson, 1995; Kuhn, 1997) to decrease the supply chain risk. And then, we study the non-linear pricing how to influence assets investment and technological of upstream manufacturer, the conclusion means that the up-stream manufacturer's pricing is correlated positively to the down-stream manufacturer's assets value but negatively to its technological level, which suggests that technological advancement helps to reduce price fluctuation while an increase in business risks may make price fluctuation fiercer. On the other hand, our model is similar to a zero-sum game option model, which is different from the Smit–Trigeorgis framework (Smit and Trigeorgis, 2004). In our model, down-stream manufacturer can choose optimal level of investment assets, when he go bankrupt the up-stream manufacturer will obtain all the assets, which is endogenous in our model. And when the up-stream manufacturer anticipates the down-stream manufacturer's investment behaviors, it will make pricing decisions according to the order quantity from the down-stream manufacturer, which is non-linear pricing mechanism. From the point of Game Theory, endogenous default risk and non-linear pricing is rational choice of two players.

The rest of this paper is arranged as follows. Section 2 proposes a real option model of the supply contract, Section 3 focuses on

nonlinear pricing, Section 4 conducts a numeric simulation of the main conclusions, and the last section is the conclusion of our paper.

2. The real option model of supply contracts

Suppose up-stream manufacturer U signs a long-term supply contract $C(p, q)$ with down-stream manufacturer D at time point 0, which requires paying for goods after they have been received. The contract specifies the quantity q and price p of the supplied raw materials. As the contract is a long-term supply contract, under the assumption of sustained operation, we suppose the contract will continue to be executed within time period T ($T = [0, +\infty)$). Under the normal operation condition, at any time point $t \in T$, U will supply raw materials of q to D at a price of p , while D will provide q units of end products to customers. Then, we suppose at some time point t_0 ($0 < t_0 \ll +\infty$), manufacturer D will continuously pay off goods payment pq to manufacturer U, and this supply contract is expressed in balance sheet as D's debt. If we further suppose the risk-free rate is r , and the contract is valued to be pq/r for U under the assumption of continuing operation, i.e., the present value of D's debt is pq/r . For the sake of analysis, we suppose D has not borrowed money from any financial institution or other firms, and its raw materials come exclusively from U. After the supply chain contract is signed, suppose manufacturer D will determine its fixed assets investment level V_B and the investment is irreversible. In such contract, manufacturer D faces two uncertainties. First, if it can pay off goods payment timely, it will continue to operate. In contrast, if it has working capitals insufficient to pay off debt, it will go bankrupt, and suppose its exogenous bankruptcy cost is αV_B . It follows that the pay-off function of manufacturer D can be described some call option based on the finding of Maskin and Tirole (1999). Now, we will make further analysis.

In order to facilitate analysis, we assume D satisfy the following conditions: (i) there exists a risk-free rate of return known as r ; (ii) companies must promptly disclose information according to the rules; (iii) there do not exist arbitrage opportunity in the financial market in which rational investors can calculate value of D by information; (iv) there are no taxes and agency cost between shareholders and management of D; (v) the asset value of D follows the geometric Brown motion. Then we can describe assets value of D as following.

$$dV = rVdt + \sigma Vdz \quad (1)$$

where r stands for the risk-free rate, and σ for the standard deviation, including uncertainties of customer demand and other risk factors faced by D and following the conventional hypothesis $2r > \sigma^2$ for option pricing. Manufacturer D will go bankrupt due to the working debt if it cannot pay off debt, and U's pay-off is $(1-\alpha)V_B$. Hence, as for U, the expectation value of the supply chain contract $C(p, q)$ can be expressed as

$$V_U = \text{Min}\left(\frac{pq}{r}, (1-\alpha)V_B\right) \quad (2)$$

Likely, in the light of Merton (1974) and Leland (1994) and neglecting the firm's income tax, the expectation value of the supply chain contract $C(p, q)$ for D can be expressed as

$$V_D = V - V_U - BC(V_B) \quad (3)$$

where $BC(V_B)$ stands for the expected bankruptcy cost, which can be calculated from information disclosed by D. It follows from Eqs. (2) and (3) that due to the bankruptcy risks, the contract implies that the fixed assets investment level V_B will influence both parties' returns though manufacturers U and D have contracted on the supply of raw materials concerned. As for U, if it has a positive correlation to its pay-off function, it will probably

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