Supply Chain Carbon Finance with Bank and Trade Credits

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Abstract. How to get loan from the bank is one of the biggest problem for the small and medium enterprises (SMEs). Fortunately, the cap and trade system may give the SMEs more capital to pledge. In this paper, we considered a newsvendor model in which the retailer has capital constraints. Three situations has been discussed: (i) the retailer takes a bank loan by traditional pattern (ii) the retailer takes a bank loan by carbon finance pattern (iii) the retailer applies to the manufacturers for trade credit. We used Stackelberg game model and found that the carbon finance pattern can help SMEs to expand their operation scale and reduce the carbon emission. Our conclusion may help the SMEs to realize the advantages of cap and trade system. It is benefit for its applications and generalizations.

Introduction

Most of us can agree that reducing greenhouse gas emissions is an urgent thing in the face of the rapid warming of the planet. But just how to do it best is another question entirely. The two leading market strategies are a carbon tax, whereby polluters are simply taxed for the carbon dioxide and other greenhouse gases they spew, and “cap-and-trade”, whereby government sets an overall cap on the amount of greenhouse gases that each industry or sector can emit without penalty and issues permits or allowances accordingly that companies can buy and sell to each other based on their own business and sustainability priorities.

Cap-and-trade allows affected businesses to choose how much pollution reduction they can tolerate and then leverage market forces to buy or sell allowances accordingly. Such systems effectively penalize polluters who exceed allowable limits (those who therefore must “buy” credits) while rewarding those who don’t just meet emissions target levels but get down below them (the difference being what they can then “sell”). Cap-and-trade markets are designed to encourage flexibility in allowing companies to decide how they want to meet emissions reduction targets. And now it has been carried out in many countries, such as America, European Union and China.

As every coin has two sides, cap and trade are beneficial to promoting carbon emission reduction, but it may raise the cost of enterprises. So the generalization of cap and trade is still limited. But in this paper, we try to understand the essence of carbon emission rights from another perspective. Taking cap and trade means that we treat carbon-permit as the asset of value. And as we know, many SMEs can’t get the loan because of lacking of the collateral. To some extent, carbon-permit can be the collateral.

Carbon finance is a series of derivative financial activities based on the carbon emissions trading, including direct investment financing, green loans, CERs trading, carbon options, carbon futures and other financial instruments [1]. The cost of carbon emission has a correlation with prevention costs, cost control, carbon content, industrial added value, carbon finance index and so on. And this will affect the operation decision of the supply chain, so that governments and enterprises should take some measures such as perfecting carbon finance system and promoting the carbon finance pattern to reduce the cost of carbon emissions and protect our environment [2].

Cost is the problem SMEs always care about. There has some research show that trade credit complements the formal finance of SMEs at the local level [3]. But some researchers think trade credit pattern needs more social trust than the traditional finance pattern [4]. Most of them think low
carbon economy can bring opportunities for SMEs. But they usually discuss the effect of Clean Development Mechanism (CDM) projects [5], rarely of them has concerned the problem that what if the cap and trade policy will bring to the capital constraint problem of SMEs.

A expand newsvendor model with capital constraint can help us to explore this problem. There are many people has used newsvendor model to do similar research, such as Kouvelis and Zhao. They obtain the Stackelberg equilibrium in the strategic interaction between the supplier (leader) and capital constrained “newsvendor” and compare supplier and bank financing from the supplier’s, retailer’s and overall supply chain’s perspectives [6]. Hu, Zhang and Zhou discuss distributor's financing and ordering decisions under stochastic inventory financing needs, then establishes profit maximization model and profit margin maximization model based on the newsvendor model [7].

In this paper, we will consider how a small retailer with capital constraints to resolve his financial matter. The remainder of this paper is organized as follows. In section 2 we begin with the assumption and notation of the model, then we modeling three different conditions to analyze the decision of retailer. Section 3 conducts numerical experiments to provide more insights. Finally, we offer concluding remarks in section 4. For proofs, the reader can contact authors.

The Model

Preliminaries

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>$i$</td>
<td>$i= M$ for manufacturer, $i=R$ for retailer, $i=B$ for bank</td>
</tr>
<tr>
<td>$e$</td>
<td>Initial carbon emission of unit product</td>
</tr>
<tr>
<td>$p$</td>
<td>Retail price, we assume $p^-$</td>
</tr>
<tr>
<td>$w$</td>
<td>Wholesale price</td>
</tr>
<tr>
<td>$c$</td>
<td>The unit production cost of the manufacturer</td>
</tr>
<tr>
<td>$Q$</td>
<td>Order quantity</td>
</tr>
<tr>
<td>$\Gamma$</td>
<td>The reduction rate of CO2</td>
</tr>
<tr>
<td>$r$</td>
<td>Interest rate</td>
</tr>
<tr>
<td>$C(\Gamma)$</td>
<td>Cost of reduction, $C(\Gamma)=m\Gamma$, $m$ represent the technical level</td>
</tr>
<tr>
<td>$E(Q)$</td>
<td>the general emission, $E(Q)=eQ$</td>
</tr>
<tr>
<td>$T$</td>
<td>Volume of emission trade, $T &gt; 0$, sell permits; otherwise, buy permits</td>
</tr>
<tr>
<td>$G$</td>
<td>Carbon-permit</td>
</tr>
<tr>
<td>$p_c$</td>
<td>Carbon price on the carbon trading market, external variable</td>
</tr>
<tr>
<td>$B$</td>
<td>The initial capital of the retailer</td>
</tr>
<tr>
<td>$L$</td>
<td>Loan amounts of retailer</td>
</tr>
<tr>
<td>$F(D)$</td>
<td>The cumulative distribution function of demand</td>
</tr>
<tr>
<td>$f(D)$</td>
<td>The probability density function of demand</td>
</tr>
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</table>

Table 1 introduces all notation used in the paper. This paper focuses on a expand newsvendor model with one manufacturer, one retailer and one bank. The retailer buys one kind of commodity from manufacturer and faces the random consumer demand. Unlike the traditional newsvendor model, the retailer has limited initial capital here. The retailer can figure out the capital constraints by external financing, whereby the retailer loans from bank, or internal financing, whereby the retailer applies to the manufacturers of trade credit. There are two pattern of external financing: one is traditional pattern which the bank is not considering the value of carbon-permit of retailer, the other is carbon finance pattern which the bank will treat the carbon-permit as part of the retailer’s assets. Without loss of generality, we assume the retailer is a limited liability company.

The government implements cap and trade. So both two enterprises are facing the carbon emission cap and they can sell or buy credits at liberty on the carbon trade market. We assume that
the manufacturer is a monopoly and has abundant carbon credit. The retailer is just one trader of
manufacturer, so we don’t consider the carbon emission reduction of the manufacturer in this paper.
The government will severely punish the companies that emit excess of carbon. And for the rule
utility maximization, the enterprises will sell the redundant credits on the carbon market. Therefore,
the trading credits of the retailer are equal to the difference between the carbon-permit and the real
carbon emission.

At the beginning of the period, the retailer orders a number of commodities from the
manufacturer. The quantity of commodity is relying on the initial capital and interest rate. The
product has no salvage value at the end of period. Its retail price and wholesale price remain
unchanged in the same period. For convenience, we assume the retail price is one Yuan, and the
risk-free return of the retail price should low than the retail price whereby \( w(1+r) < p \). Otherwise, the
retailer will not order any product.

The retailer must borrow a sum of money to purchase the product and invest the emission control
devices. At the end of period, if the retailer can’t repay the loan, he will declare bankruptcy. In this
situation, the lender will get all the capital of retailer. This study looks at how the carbon finance
pattern affects the quantity and CO2 reduction rate of retailer.

We take Stackelberg model to describe the supply chain decision-making process. The lender
(the bank or the manufacturer) will be the leader and decide interest rate first. After observed the
interest rate, the follower which means the retailer will decide the order quantity and invest in
reducing emissions. We use backward induction to solve the game. In the following, we star with
external financing.

**External Financing**

In this situation, the manufacturer just the supplier of product and has no effect on the decision of
the supply chain. Thus, we only consider the profit function of the retailer and the bank. Before the
period of sales, the bank decides the interest rate by the information of retailer, such as initial
capital and cost function of emission reduction to maximize his profit. Then the retail decides the
order quantity and carbon reduction rate according to the interest rate and other market information.
When the sales period ends, the retailer sold \( \min\{Q,D\} \) pieces of products.

**Traditional Model.** Under this situation, the retailer with capital constraints will loan from bank,
the loan amount is equal to the different between operation cost and the initial capital whereby
\( L = wQ + \frac{1}{2} mf^2 - B \). Thus, the profit function of retailer under the traditional pattern is

\[
\Pi_r^T = \max E \left[ \min\{D,Q\} - L(1+r) + TP_r \right] - B
\]

\[
= \max \left\{ \int_{1+r}^{\infty} \left[ 1 - F(D) \right] dD - B \right\}
\]

For bank, when the operation revenue of retailer is greater than the payment, the bank can get the
profit \( L(1+r) \). The bank will not consider the carbon-permit and its earning under the traditional
pattern. Hence the expect operation revenue of the retailer is \( E[\min\{Q,D\}] \). When \( Q < L(1+r) \), no matter
how much the consumer demand is, the retailer will go broke and the bank can get the revenue
of \( L(1+r) \). In order to reduce unnecessary computation, we assume that \( Q \geq L(1+r) \). At this time, the
profit function of the bank is

\[
\Pi_f^T = \int_{1+r}^{\infty} (D - L)f(D)dD + \int_{1+r}^{\infty} Lf(D)dD + \int_{1+r}^{\infty} Lf(D)dD
\]

\[
= \int_{1+r}^{\infty} (D - L)f(D)dD + \int_{1+r}^{\infty} Lf(D)dD
\]

**Carbon Finance Model.** In the carbon finance model, the profit function of the retailer is
unchanged. But for the bank, since the carbon-permit will be taken into account, the expect
operation revenue of the retailer is \( E[\min\{Q,D\} + TP_r] \). By the same token, we assume that \( Q \geq L(1+r) - TP_r \).
Therefore, the profit function of the retailer and the bank are
Actually, we can find that the profit functions of retailer are the same in different situation. Different financing patterns changed the lender’s view of carbon-permit. Thus there are several kinds of lender’s profit functions.

**Internal Financing**

In this situation, the manufacturer is not only a product supplier, but also the capital lender. Now, we should consider the profit of retailer and manufacturer. Similar to external financing, the bank decides the interest rate by the information of retailer, such as initial capital and cost function of emission reduction to maximize his profit before the period of sales. Then the retail decides the order quantity and carbon reduction rate according to the interest rate and other market information. When the sales period ends, the retailer sold \( \min [Q, D] \) pieces of products.

The profit function of retailer is similar to (1). Consist of the operation revenue, carbon emission revenue (loss) and financing cost.

\[
\Pi_r = \max E \left[ \min \left[ D, Q \right] - L(1 + r) + TP \right] - B
\]
\[
= \max \left[ \int_0^D \left( 1 - F(D) \right) dD - B \right]
\]

But for the manufacture, he will take loan interest revenue and sales revenue into account. And we assume he will regard the carbon-permit as asset. So under the assumption of \( Q \geq L(1 + r) - TP \), the profit function of the manufacturer is

\[
\Pi_u = \int_0^L (D - L)f(D)dD + \int_0^\infty \left[ Lr(D)dD + \int_0^\infty Lf(D)dD \right]
\]

Through the three model, we can get to know that the decision making process of retailer is invariable. Different financing patterns have changed the subject for lending or the perspective of carbon-permit.

**Numerically Analysis**

Numerical experiments are conducted in this section to gain some managerial insights. Because we cannot derive explicit solutions for the optimal supply chain profit, we turn to numerical examples to illustrate the impact of key factors on these reduction rates and order quantity. Let \( p = 1, e = 1, w = 0.5, \epsilon = 0.3, \mu = 1, G = 100, m = 100 \) and \( B = 0 \). We assume that the demand function subjects to uniformly distribution from 0 to 100. Note that our following observation is robust in other distribution function, such as exponential distribution. We first analyze order decision of retailer in Table 2.

To investigate how the interest rate affects the order decision of the retailer, Table 2 shows the curves of order quantity as function of interest rate on three financing pattern. We can see that when the interest rate increases, the retailer must increase the order quantity simultaneously to make sure he can earn the maximum profit. More interesting, we can see that the curve of carbon finance pattern is almost overlapped with the curve of internal financing pattern. But if we use the order quantity in internal financing pattern to minus the quantity in the carbon finance pattern, the result is always positive. Thus, the order quantity of retailer is larger in the internal financing pattern. The profit function of manufacturer includes the sales revenue. So at the same condition, the manufacturer may will to sacrifice part of the interest revenue for more sales revenue.
Table 2. The retailer’s order quantity under external financing and internal financing.

<table>
<thead>
<tr>
<th>Interest Rate</th>
<th>Traditional finance pattern</th>
<th>Carbon finance pattern</th>
<th>Internal financing pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>50.43</td>
<td>61.96</td>
<td>64.14</td>
</tr>
<tr>
<td>0.1</td>
<td>55.29</td>
<td>68.00</td>
<td>70.19</td>
</tr>
<tr>
<td>0.2</td>
<td>60.16</td>
<td>74.04</td>
<td>76.23</td>
</tr>
<tr>
<td>0.3</td>
<td>65.01</td>
<td>80.08</td>
<td>82.28</td>
</tr>
<tr>
<td>0.4</td>
<td>69.87</td>
<td>86.12</td>
<td>88.32</td>
</tr>
<tr>
<td>0.5</td>
<td>74.72</td>
<td>92.15</td>
<td>94.36</td>
</tr>
<tr>
<td>0.6</td>
<td>79.56</td>
<td>98.18</td>
<td>100.39</td>
</tr>
</tbody>
</table>

And the order quantity of both two patterns is larger than the order quantity of traditional pattern. This shows us a revelation that if a SME wants to grab more market share, taking the carbon finance pattern or internal financing pattern may be a good attempt. Especially the carbon finance pattern, because the internal financing pattern requires the SMEs to have certain strength. In fact, internal financing pattern has no more effect than carbon finance pattern. However, gain the qualification of carbon finance pattern is relatively easy for SMEs.

We examine how the carbon reduction rate of retailer is influenced by the interest rate. Table 3 shows that the carbon reduction rates in three situations are always increasing and then decreasing with the increasing of interest rate. From Table 2 we know that when the interest rate is large, the order quantity will be large. Thus the total carbon emission will be greatly increasing. The retailer must enhance the carbon reduction rate to avoid the punishment from government.

Table 3. The retailer’s carbon reduction rate under external financing and internal financing.

<table>
<thead>
<tr>
<th>Interest Rate</th>
<th>Traditional finance pattern</th>
<th>Carbon finance pattern</th>
<th>Internal financing pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>99.02%</td>
<td>99.04%</td>
<td>98.94%</td>
</tr>
<tr>
<td>0.10</td>
<td>97.66%</td>
<td>97.71%</td>
<td>97.61%</td>
</tr>
<tr>
<td>0.15</td>
<td>96.53%</td>
<td>96.61%</td>
<td>96.50%</td>
</tr>
<tr>
<td>0.20</td>
<td>95.65%</td>
<td>95.77%</td>
<td>95.65%</td>
</tr>
<tr>
<td>0.25</td>
<td>95.09%</td>
<td>95.26%</td>
<td>95.13%</td>
</tr>
<tr>
<td>0.30</td>
<td>94.99%</td>
<td>95.22%</td>
<td>95.08%</td>
</tr>
<tr>
<td>0.35</td>
<td>95.66%</td>
<td>96.01%</td>
<td>95.84%</td>
</tr>
</tbody>
</table>

When the interest rate is low, the carbon reduction rate in internal financing pattern and the rate in the traditional finance pattern are very close. With the increasing of interest rate, the difference between those is larger and larger. And the reduction rate in the internal financing pattern is first close to and then larger than the one in the traditional finance pattern. The advantage of internal financing pattern can’t be unfolded in the low level of interest rate. The internal financing pattern is usually considered to be a better solution when the financing cost is large.

However, we can find that the carbon reduction rate in the carbon finance pattern is largest among the three. This may prove that promoting the carbon finance pattern is a solution can benefit everyone. The carbon finance pattern is relatively simple way to get the loan compared to the traditional finance pattern. But it can obtain the similar effect with internal financing pattern for SMEs. For the society, promoting the carbon finance pattern can reduce the emission rate of retailer and improve the provision of product especially in the low interest rate situation.

Conclusions

Financing difficulty has been the one of the biggest problems in SMEs operation. The strict cap and trade policy may compound this problem. But on the other hand, there also has a favorable turn for SMEs to solve both two problems.
In this paper, we study the impact of cap and trade policy on the operation decision of SMEs. We view cap and trade from another perspective and try to find the benefit for SMEs to resolve their financial matters. An expanded news-vendor model with capital constraint has been explored. After modeling and analyzing three patterns of finance, i.e., traditional finance pattern which the bank is not considering the value of carbon-permit, carbon finance pattern where the bank treats carbon-permit as assets and internal financing pattern where the manufacturer acts as a lender. Our findings demonstrate that the order quantity and carbon reduction rate have improved in the carbon finance pattern compared to the traditional finance pattern. Compared to the internal finance pattern, the situation must be discussed more carefully.

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