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Manufacture's Optimal Pricing Policy and Retailer's Optimal Ordering Policy Under Different Carbon Emission Policies

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Abstract: The implementation of carbon reduction policy is an important method for the firms to reduce carbon emissions. So it is of great significance to research on the firms's trategies under different carbon reduction policies. In this paper, we study the manufacturer's wholesale price strategy and the retailer's ordering strategy, as well as carbon emissions policy's impact on the production and profit, under mandatory carbon emissions capacity policy, carbon emissions tax policy and cap-and-trade policy respectively. In addition, the government's decision-making about carbon emissions policy parameters is also discussed. The conclusion builds a microeconomic foundation for the carbon emissions policy's design and development, and also verified the policy's effectiveness and scientificity, at last achieved the "win-win" ofthe government and enterprises.

Key word: Pricing; Ordering; Carbon emission policies

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1. INTRODUCTION

Greenhouse effect caused by carbon dioxide emissions has become the focus of global attention. As the development of low-carbon economy, reducing global carbon emissions is an important strategy to prevent climate from warming. Today, carbon emission has become a major survival and development threat to global enterprise that can not be ignored. At present, the world has entered a critical period of energy saving and emission reduction: The chinese govermment has solemnly promised to the international organization that carbon dioxide emissions brought by per unit of GDP will be reduced by 40%-45% in 2020 than in 2005.

Different carbon emission policies, including mandatory carbon emissions capacity, carbon emissions tax and cap-and-trade have become the key factors in effecting manufacture's pricing and retailer's Ordering. In 2009, Wal-Mart proposed the "low carbon supermarket" in the "World Low Carbon and ecological economy Conference." Wal-Mart has developed a variety of methods, such as energy saving and green products, reducing waste, and improving supply chain's efficiency.

2. LITERATURE REVIEW

In recent years, as serious global environmental problems are increasing, many scholars have researched on carbon emissions issues. Most of the present researches focused on the macroscopic level. Benjaafar, Li and Daskin (2013) study aboutlow-carbon supply chain under mandatory carbon emissions capacity policy, cap-and-trade and carbon offsets, the vendor deciding the production and when to replenish in multiple cycles. (Du, Ma, Fu, Zhu, & Zhang, 2011) When considering emissions trading, constructs a supplier and rely on non-profit organization of green environmental protection as a carbon emissions rights of enterprises to form a new type of supply chain, based on the newsboy model research on Stackberg of the game process. (Lin, Anderson, & Cruz, 2012) Production and sales of environmentally friendly products the important benefit from an increase in demand from the consumer environmental awareness, environmental protection manufacturers marketing methods should be taken to guide the consumer to increase environmental protection meaning, motivate the green consumers into a green consumer. (Vipul & Sridhar, 2000) Considering the risk factors, we use the newsvendor model under uncertain demand to get the optimal purchase quantity and price decision, in order to achieve maximum expected utility. Song and Leng (2012) found the firm's optimal production and corresponding expected profit under different carbon emissions policies.

3. MODEL DESCRIPTIONS AND ASSUMPTION

This paper considers a two-stage supply chain which is composed of a manufacturer and a retailer, manufacturer dominating. In this supply chain, we study how the manufacturer prices the products and how much the retailer orders goods. We assumes that the manufacturer is independent ofthe retailer, and their information is symmetrical, their risks are neutral. The cost of each product is C_S, the retailer faces with a stochastic market demand x, and the priceis an exogenous variable. If the production Q exceeds the demand, the remaining products P will be sold at a price of V. On the contrary, if the demand exceeds the production, the manufacturer will pay C_μ as "shortage cost", $P > C_S > V > C_\mu$.

Under Policy 1-mandatory carbon emissions capacity (a mandatory capacity on the amount of carbon emitted by each firm), the carbon quotais A, each product produces e unit carbon emissions, Q_0means the mandatory capacity of the production that results incarbon emissions, Q_0=A/e. Under Policy 2-carbon emissions tax (tax imposed to each firm on the amount of carbon emissions), the carbon emissions tax foreach product is t. Under Policy 3-cap-and-trade policy, the trading price of unit carbon emissionis i.

This paper analyzes and discusses the influence of different carbon policy on manufacturer's pricing and retailer's ordering.

4. MODEL FORMULATIONS

4.1 Retailer' Sorderingstrategy

The retailer faces a stochastic market demand, the quantity of order is made according to the wholesale price W. For the retailer, no matter which policy the government adopts, the ordering decision is based on the wholesale price. Without carbon policy, let the optimal wholesale prices W^*, the optimal order quantity is Q^*_r. Under different policy, the optimal wholesale price is W^*_c, W^*_t, W^*_{rc}, and the optimal order quantity is Q^*_c, Q^*_t, Q^*_{rc}, respectively.

Under the stochastic demand, the manufacturer's profit is as Equation (1):

$$\pi_r = \begin{cases} Px + (Q-x)V - QW, & x \le Q \\ PQ - QW - (x-Q)C_\mu, & x > Q \end{cases} \tag{1}$$

Then we can get the retailer's profit as Equation (2):

$$E(\pi_r) = \left(P - W + C_\mu\right) - \left(P - V + C_\mu\right)\int_0^Q F(x)\mathrm{d}x - \mu C_\mu. \tag{2}$$

Due to the manufacturer dominates, the retailer's decision is the optimal order quantity Q^*_r according to the manufacturer's wholesale price. According to Equation (2), we can get that $\frac{\partial^2 E(\pi_r)}{(\partial Q)^2} < 0$, so $E(\pi_r)$ is a strictly concave function. If we set $\frac{\partial E(\pi_r)}{\partial Q} = 0$, we can get the optimal order quantity Q^*_r as Equation (3):

$$Q_r^* = F^{-1}\left(\frac{P - W + C_\mu}{P - V + C_\mu}\right). \tag{3}$$

The tailer's wholesale price varies according to the type of carbon policy, so under different carbon policies, the retailer's order quantity varies, too.

4.2 Manufacturer's Wholesale Price Strategy

4.2.1 Manufacturer's Wholesale Price Strategy Without Carbon Policy

The information of the manufacturer and the retailer is symmetrical, as the dominant party, the manufacturer can predict the retailer's ordering strategy to determine the optimal wholesale price, so the profit of the manufacturer is as Equation (4):

$$\pi_m (Q^*_r) = (W - C_s)\, Q^*_r\ . \tag{4}$$

According to Equation (3) and (4), we can get the manufacturer's expected profit as Equation (5):

$$E(\pi_m) = (W - C_s)F^{-1}\left(\frac{P - W + C_\mu}{P - V + C_\mu}\right). \tag{5}$$

And the optimal wholesale price W^* meet Equation (6):

$$W^* = Q^*_r(P-V+C_\mu)f(F(Q^*_r))+C_s\ . \tag{6}$$

According to Equation (3) and (4), we can get the retailer's optimal order quantity as Equation (7):

$$Q_r^* = F^{-1}\left(\frac{P - W^* + C_\mu}{P - V + C_\mu}\right). \tag{7}$$

4.2.2 *Manufacturer's Wholesale Price Strategy Under Carbon Policy*

Under different carbon policies, the manufacturer's wholesale price strategies differ from each other. Now let us discuss manufacturer's wholesale price strategy under each carbon policy respectively.

4.2.3 *Manufacturer's Wholesale Price Strategy Under Policy 1- Mandatory Carbon Emissions Capacity*

Under Policy 1- mandatory carbon emissions capacity, the profit of the manufacturer is as Equation (8):

$$E(\pi_m)_c=(W_c-C_s)Q^*_c\ . \tag{8}$$

According to Equations (3) and (8), the profit of the retailer is as Equation (9):

$$\begin{aligned} E(\pi_m)_c &= (W_c - C_s)F^{-1}\left(\frac{P - W_c + C_\mu}{P - V + C_\mu}\right) \\ s.\text{t.}\quad Q_c^* &= F^{-1}\left(\frac{P - W_c + C_\mu}{P - V + C_\mu}\right) \le Q_0 \end{aligned} \ . \tag{9}$$

According to Equation (9), we can get the following conclusion:

1) If $<Q^*_c$, $W_{c1}>W_{c2}$, the optimal wholesale price is $W_{c1}=P+C_\mu-F(Q_0)(P-V+C_\mu)$.

2) If the optimal wholesale price meet the equation.

Proposition 1: Under mandatory carbon emissions capacity, when the manufacturer's carbon emissions less than the carbon quota A, the policy has nothing to do with the optimal wholesale price and profit of the manufacturer. On the contrary, the manufacturer's optimal wholesale price will be increased and the manufacturer's profit will decrease. The retailers' profit is a monotone increasing function of the order quantity, it will decrease with the decrease of order quantity.

Proof:

1) When the carbon emissions emit from the manufacturer's optimal production less than the carbon quota A, $Q_0 \geq Q^*_r$, then$Q^*_c=Q^*_r$, and the optimal wholesale is

$$W_{c2}= Q^*_r\,(P-V+C_\mu)f(F(Q^*_r))+C_s=W^*,\ E(\pi_m)_c=E(\pi_m).$$

2) When the carbon emissions emit from the manufacturer's optimal production more than the carbon quota A, $W_{c1}=P+C_\mu-F(Q_0)(P-V+C_\mu)$. What is more, $F(Q_0)$ is a monotone increasing function of Q_0, $Q_0<Q^*_r$, so $F(Q_0)<F(Q^*_r)$, $W_{c1}=P+C_\mu-F(Q_0)(P-V+C_\mu)>P+C_\mu-F(Q^*_r)(P-V+C_\mu)$. That is, the optimal wholesale price will increase.

The unconditional maximum value must be greater than or equal to the maximum value under certain conditions, so when the carbon quota less than the carbon emissions produced by the optimal production, the manufacturer's profit will decrease. From the Equation (2) we can know that $\frac{\mathrm{d}(E(\pi_r))}{\mathrm{d}Q} > 0$, so the retailer's profit $E(\pi_r)$is a monotone increasing function of the order quantity Q. It will decrease with the decrease of order quantity.

4.2.4 Manufacturer's Wholesale Price Strategy Under Policy 2- Carbonemissions Tax Policy

Under carbon emissions tax policy, the manufacturer's profit is as Equation (10):

$$\pi_m (Q^*_t)=(W_t-C_s-t)\, Q^*_t\, . \tag{10}$$

From Equation (3) and (10), we can get:

$$_n(Q_t^*) = (W_t - C_s - t)F^{-1}\left(\frac{P - \mathrm{W}_t + C_\mu}{P - V + C_\mu}\right). \tag{11}$$

From Equation (11), we can know that the manufacturer can make out the optimal wholesale price W^*_t, and it meet the Equation (12):

$$W^*_t=Q^*_t(P-V+C_\mu)f(F(Q^*_t))+C_s+t. \tag{12}$$

According to Equation (11) and (12), the optimal order quantity can be concluded as Equation (13) :

$$Q_t^* = F^{-1}\left(\frac{P - {W_t}^* + C_\mu}{P - V + C_\mu}\right). \tag{13}$$

Proposition 2: Under carbon emissions tax policy, the wholesale price will increase, the order quantity will decrease, the profit of the manufacturer and the retailer will decrease.

Proof: Under carbon emissions tax policy, the existence of carbon tax is equivalent to the addition of the cost of production, so the retailer's optimal order quantity will drop, which means $Q^*_t < Q^*_r$. According to Equation (12), the optimal wholesale price W^*_t is aninverse function of the order quantity, so W^*_t>W*.Comparing the manufacturer's profit under carbon emissions tax policy with that without carbon policy, we can find:

$\pi_m(Q^*_t\ )-E(\pi_m)=(P-C_s+C_\mu)(Q^*_t-Q^*_r\ )-tQ^*_t-(P-V+C_\mu)[F(Q^*_t)Q^*_t-F(Q^*_r)Q^*_r]$,where$(P-C_s+C_\mu)>0$, $Q^*_t<Q^*_r$, $F(Q^*_t)<F(Q^*_r)$.

Then it can be easily found that $\pi_m(Q^*_t\ )-E(\pi_m)<0$, which means the manufacturer's profit will drop down under carbon emissions tax.

As proposition 1, the retailers' profit is a monotone increasing function of the order quantity, so under carbon emissions tax policy, $Q^*_t<Q^*_r$, the retailer's profit also drops.

4.2.5 Manufacturer's Wholesale Price Strategy Under Policy 3- Cap-and-Trade

Under cap-and-trade policy, if the carbon quota is equal or greater than Q^*_r, the policy will have nothing to do with the carbon emissions. So the necessary condition that the policy works is $Q_0 = \frac{A}{e} < Q_r^*$.

The manufacturer's profit can be expressed as Equation (14):

$$\pi_m(Q_i)=(W_{rc}-C_s)Q_i-i(Q_i-Q_0). \tag{14}$$

According to Equation (3) and (14), it can be found that

$$_n(Q_i) = (W_{rc} - C_s - i)F^{-1}\left(\frac{P - W_{rc} + C_\mu}{P - V + C_\mu}\right) + iQ_0.$$

Then the optimal wholesale price W_{rc}^* can be concluded as Equation (15):

$$W_{rc}^*=Q^*_i(P-V+C_\mu)f(F(Q^*_i))+C_s+i. \tag{15}$$

From Equation (3) and (15), the optimal order quantity is as Equation (16):

$$Q_i = F^{-1}\left(\frac{P - W_i^* + C_\mu}{P - V + C_\mu}\right). \tag{16}$$

Proposition 3: Under cap-and-trade policy, the wholesale price will rise, the production and order quantity will decrease, and the retailer's profit will decrease too.

Proof: Under cap-and-trade policy, the manufacturer will buy more carbon emissions permits from carbon emissions market. That is equivalent to the increase of each commodity's cost. So the optimal order quantity and the production will decrease.

According to Equation (15), the wholesale price is an inverse function of the order quantity, so the wholesale price will rise.

As proposition 1, retailer's profit is a monotone increasing function of the order quantity, and $Q_i<Q^*_r$, so under cap-and-trade policy, the retailer's profit will decrease as well.

Proposition 4: Under cap-and-trade policy, the manufacturer's profit is decided by the carbon quota A. Let $A_0 = \frac{e(W^* - C_s)Q_r^* - e(W_{rc}^* - C_s)Q_i}{i} + eQ_i$, if $A>A_0$, the manufacturer's profit will increase, if $A<A_0$, the manufacturer's profit will decrease, and the manufacturer's profit will remain the same as that without carbon policy when $A=A_0$.

Proof: According to Equation (4) and (14), $\pi_m(Q_i) = (W_{rc}^* - C_s)Q_i - i\left(Q_i - \frac{A}{e}\right)$

$\pi_m(Q^*_r)=(W-C_s)\,Q^*_r$. When $\pi_m(Q_i)=\pi_m(Q^*_r)$, $A = \frac{e(W^* - C_s)Q_r^* - e(W_{rc} - C_s)Q_i}{i}+eQ_i$.

So if $A>A_0$, $\pi_m(Q_i)>\pi_m(Q^*_r)$, the manufacturer's profit will increase, if $A<A_0\pi_m(Q_i)<\pi_m(Q^*_r)$, the manufacturer's profit will decrease, and if $A=A_0$, $\pi_m(Q_i)=\pi_m(Q^*_r)$the manufacturer's profit will remain the same as that without carbon policy.

5. CONCLUSIONS AND FUTURE RESEARCH

In this paper, we studied the manufacturer's pricing strategy and retailer's ordering strategy when considering mandatory carbon emissions capacity policy, carbon emissions tax policy and cap-and-trade policy respectively, based on the classic newsvendor mode, with the two-stage supply chain of one manufacturer and one retailer (manufacturer dominates) as the object. Comparing with the situation without carbon emissions policy, it could be concluded as follows: (1) Under mandatory carbon emissions capacity policy, when the limit production (the production according to the carbon quota) is more than the optimal production, the manufacturer's wholesale price, the retailer's ordering quantity and their profits will not be affected. The retailer's ordering quantity depends on the wholesale price. On the contrary, when the limit production is less than the optimal production, the manufacturer's wholesale price will be increased, the retailer's ordering quantity will be decreased, and each member's profit will decline. The manufacturer's wholesale and profit depend on the carbon quota. (2) Under carbon emissions tax policy, the manufacturer's wholesale price will be increased, the retailer's ordering quantity will be decreased, and their profits will decline, the retailer's ordering quantity depends son the carbon emissions tax. (3) Under cap-and-trade policy, the retailer's ordering quantity and profit will be decreased, and the manufacturer's wholesale price will be increased. The manufacturer's profit depends on the carbon quota and the carbon emission's price. The retailer's ordering quantity depends on the sale price of carbon emissions.

Under three different carbon emissions policies, the manufacturer's pricing strategy and the retailer's ordering strategy are different. From the perspective of supply chain, the research on the strategies of each node company of the supply chain under different carbon emissions policies built a micro-foundation for the design and formulation of carbon emissions policies. By studding the companies' strategies, carbon policies's scientificity and effectiveness was validated, and achieved "win-win". In the future, it will be of greate significance to study from the perspective of multiple retailers and multiple manufacturers.

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