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Two-Echelon Supply Chain Decision Model with Price-and-Carbon-Emission Dependent Demand

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Abstract

As consumers' environmental awareness is growing, the impact of carbon emission on the demand is increasingly apparent. Based on price-and-carbon-emission dependent demand, we construct a two-echelon decision model consists of a manufacturer and a retailer. In this model, the manufacturer decides the wholesale price and emissions per unit of output produced, while the retailer decides the retail price and order quantity. We solve the model under the centralized and decentralized scenarios respectively, and based on centralized decision-making mode we propose a coordination contract that can achieve the Pareto improvement of two margin's profit. Through numerical examples we find that as the impact of carbon emission on demand increases, the strategies of both the manufacturer and retailer change obviously, we also validate the effectiveness of the contract.

Key words: Demand; Price; Cost of production; Emissions per unit of products; EOQ

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INTRODUCTION

With the intensification of global warming, more and more attention focused on the emission reduction, especially the carbon dioxide emission reduction of greenhouse gases. In order to achieve the purpose of emission reduction, many companies try and use a variety of alternative methods, including replacing inefficient equipment, redesigning products and packaging, using environmentally friendly fuels and so on. However, people tend to overlook another important source of carbon emissions which is caused by the business practices and operational strategies. Over the past decade, many scholars began to focus on research in this area, such as Benjaafar et al. found that only by adjusting the operation can significantly reduce carbon emissions with slight increase in costs. Especially the expanded research on the EOQ model is particularly striking, for example Turkay (2008) by introducing environmental standards into EOQ model, he revised the standard model and analyzed it in five different ways included with carbon taxes and carbon compensation and so on. Chen, Benjaafar, and Elomri (2012) studied the extended EOQ model in ordering, inventory and purchase process with constraints on carbon emission. But Bouchery, Ghaffari, Jemai, and Dallery (2012) further extended the classical EOQ model into multi-objective problems with a binding emission reduction. Recently, Daria, Alessandro, and Fabio (2014) also established a sustainable model EOQ by integrating the environmental factors that influence the traditional EOQ model.

However, most of these studies assume that the demand for product is a determined constant or a demand of price elasticity, but in nowadays green concept is relatively mature, the environmental performance of the product will certainly influence demand. And many research results have confirmed that, for example Kleindorfer, Singhal, and Van Wassenhove (2005) and Sarkis, Zhu, and Lai (2011) found that customers will continue to exert influence on companies until they reduce their impact on the environment. Kassinis and Soterious (2003) found that if customers have doubts on their products were not environmentally friendly and in turn it would fall in demand correspondingly. Klassen and Mclaughlin (1996), Elsayed and Paton (2005), Vachon and Klassen (2008) found that by reducing the environmental impact of their products will increase market share, and improving the environmental performance can do it too. Thus, with the spread and strengthen awareness of environmental protection, it is not hardly to find that the impact of indicators about environmental performance on market demand is getting more significant. Therefore, we need to consider the impact of environmental performance on demand when conducting research on operation and management. For manufacturers, the environmental behavior is not always compatible with the profit-driven behavior, considering the impact of environmental performance on demand, they should weigh the relationship between environmental behavior and profits. Hoffman and Bazerman (2005) and Pagell and Wu (2009) also stressed the importance of the balance between them.

Therefore, based on the existing EOQ model that introduce environmental factors alone, this paper further studies the decision problem on product pricing, ordering and carbon emissions with a two-echelon decision model, which consists of one manufacturer and one retailer and faced with price-and-carbon-emission dependent demand. For the two centralized and decentralized decision-making model between upstream and downstream, this paper constructs corresponding decision models.

1. MODEL PREPARE AND ASSUMPTIONS

1.1 Description of the Problem

We construct a two-echelon supply chain that consist with a single manufacturer and a single retailer, and the manufacturers produce only one kind of product and retailers sale them to customers. Suppose that market demand that retailers face with is not only depended on the sales price, but also sensitive to the carbon emissions of per unit product. In order to balance costs and benefits, the problems confronted with manufacturers is how to choose the level of carbon emissions of per unit product and wholesale prices; and retailers need to determine the optimal sales price and order quantity of their product.

1.2 Model Symbol Description

w	wholesale prices of products
p	retail prices of products
g	carbon emissions of per unit product
$c(g)$	production costs of per unit product, is a function of g
$D(p, g)$	market demand, is a function of p and g
Q	retailer order quantity
A	retailers fixed order fee
h	unit product unit time inventory costs accounted for the percentage of retail purchase costs
πs	profit of upstream manufacturer
πx	profit of downstream retailer in one order cycle
π	profit in the supply chain

1.3 Model Hypothesis

1) Use carbon emissions of per unit product to characterize the impact of carbon emissions on demand and production costs of per unit product, because of carbon emissions of per unit product is a standard of environmental quality in many industries;
2) Consumers can observe the carbon emissions of per unit product by some effective methods, because in many countries where promote carbon label will quantify the carbon footprint in various stages of the life cycle (Hua, Cheng, & Wang, 2009), and then consumers can perceive carbon emissions of per unit product.
3) We assume that the demand is a joint function of the price and carbon emissions of per unit product, and the demand on the price and the carbon emissions of per unit product is monotonically decreasing. Like Yalabik and Fairchild (2011), we use the following linear demand function: $D(p, g)=a-bp-kg$ ($a, b, k>0$), where a is the scale of market demand, b is the market sensitivity to price, k is the customer sensitivity to carbon emissions of per unit product. That is, when the price rises by one unit, the demand reduces b; and when carbon emissions of per unit product increases by one unit, the demand reduces k. In this demand function, a, b, k are all not affected by manufacturers and retailers.
4) In terms of production costs, Vörös (2002) and Saadany, Jaber, and Bonney (2011) all agree that along with the improvement on environmental quality of their product, the cost of production will increase correspondingly; on the contrary, production cost will decline. In this way, if we use $1/g$ to represent the environmental quality of the product, the production cost of per unit product is monotonically decreasing with carbon emissions of per unit product.

Thus, referring to Bouchery cost curve given to carbon emissions, we assume that the production cost function of per unit product is $c(g)=m+\frac{t}{g}$ ($m, t>0$), where the parameter m represents the general preparation cost of production of per unit product, and t is the cost sensitivity to the environmental protection of product. This means that the production cost of per unit product is bound to be greater than m, and it is monotonically decreasing with carbon emissions of per unit product.

2. THE ESTABLISHMENT AND SOLUTION OF THE MODEL

2.1 Under Decentralized Decision-making, the Decision of Manufacturers and Retailers

Due to the effects of carbon emissions of per unit product on demand, and the carbon emissions amount of per unit product depends on the option of manufacturer about the carbon emission level, different from the existing correlation model, in the model of this paper it considers the decision options of upstream manufacturers (ie, manufacturers need to make decisions on wholesale prices and carbon emissions amount of per unit product). Under the architecture of manufacturer-Stackelberg game, this section will study how to select the appropriate strategy, in which manufacturers can anticipate the best response of retailer to their any given strategy, and determine its wholesale price w and carbon emissions of per unit product g; then after the observation of manufacturer's decision the retailers determine its sale price p and the corresponding order quantity Q. The function of retailers and manufacturers profit are:

$$\pi_x(p,Q)=\left[p-w-\frac{A}{Q}\right]D(p,g)-\frac{Qhw}{2}=(p-w-\frac{A}{Q})(a-bp-kg)-\frac{Qhw}{2} \quad (1)$$

$$\pi_s(w,g)=[w-c(g)]D(p,g)=(w-m-\frac{t}{g})(a-bp-kg) \quad (2)$$

From the profit function of retailers given by the formula (1) it is not difficult to find that: the profit of retailers is not only affected by p and Q, but it is also associated with w, g. For any given w and g, retailers determine the sales price p and the order quantity Q to maximize their own profits.

Take partial derivative of formula (1) with respect to p and Q respectively, then make it equal to zero, then

$$a-2bp-kg+bw+\frac{bA}{Q}=0 \quad (3)$$

$$\frac{A}{Q^2}(a-bp-kg)-\frac{hw}{2}=0 \quad (4)$$

Property 1: sales price p is inversely proportional to the order quantity Q, and the relationship formula is.

$$p=\frac{a-kg+bw}{2b}+\frac{A}{2Q}$$

Take the formula of property 1 into equation (4), then

$$hwQ^3-(a-kg-bw)AQ+bA^2=0 \quad (5)$$

Property 2: under the given wholesale price w and carbon emissions of per unit product g, to maximize profits, the order quantity Q made by retailers need do satisfy formula (5).

Solving formula (5) and combining with property 1, obtain the equation about p and Q, namely $p(w, g)$, $Q(w, g)$. Take $p(w, g)$ into formula (2) and then

$$\pi_s(w,g)=(w-m-\frac{t}{g})[a-bp(w,g)-kg] \quad (6)$$

In which $\frac{\partial p(w,g)}{\partial w}=\frac{1}{2}-\frac{A}{2Q^2}\frac{\partial Q(w,g)}{\partial w}$,

$\frac{\partial p(w,g)}{\partial g}=-\frac{k}{2b}-\frac{A}{2Q^2}\frac{\partial Q(w,g)}{\partial g}$, but

$\frac{\partial Q(w,g)}{\partial w}=\frac{hQ^3+AbQ}{A(a-kg-bw)-3hwQ^2}$,

$\frac{\partial Q(w,g)}{\partial g}=\frac{AkQ}{A(a-kg-bw)-3hwQ^2}$

From the above, it is known that Q is consistent with the monotonic property of w and g. Take partial derivative of formula (6) with respect to w and g respectively, then make it equal to zero, then

$$(a-bp-kg)-b(w-m-\frac{t}{g})\frac{\partial p(w,g)}{\partial w}=0 \quad (7)$$

$$\frac{t(a-bp-kg)}{g^2}-(k+b\frac{\partial p(w,g)}{\partial g})(w-m-\frac{t}{g})=0 \quad (8)$$

Theorem 1 Constitute equation group by combining with formula (5), (7) and (8), then by solving the equations we can respectively obtain the wholesale price w, carbon emissions of per unit product g and order quantity Q of manufacturers and retailers which would help to maximize their profits.From theorem 1 it is not difficult to find out that the order quantity Q is interact with the carbon emissions of per unit product g; but this doesn't mean that the price p have no impact on the above variables, reasoned from property 1 we can confirm that p is closely related to Q, and then p is definitely determined by w and g.

By solving the equation group of Theorem 1, we can get the corresponding value of Q, w and g. The value of w and g is the wholesale price and carbon emissions of per unit product that made by manufacturer who want to maximize their profits; and then p and Q are the required price and order quantity of retailers to realize their maximization profits goal in manufacturer-led context.

In our actual life, along with the growing popularity of the concept of environmental protection, consumer attach more and more importance on the carbon emissions of products, and the influence of carbon emissions of per unit product on demand is constantly increasing, that is, the value of k is getting larger. In this case, both the manufacturer and retailer are bound to change their decisions accordingly. However, in decentralized decision-making it maybe not so easy to achieve the overall optimal, so we will further focus on the following issue to discuss the decision of different parties in centralized decisions.

2.2 Under Centralized Decision-making, the Decision of Manufacturers and Retailers

In this section we will discuss how can the manufacturer and retailer joint together to make decisions which would help to maximize the benefits of the whole supply chain, that is we need to determine the retail price p, carbon emissions of per unit product g and order quantity Q so that can gain profit maximization of the entire supply chain.

Now, the profit function of the supply chain is:

$$\pi(p,g,Q)=(p-m-\frac{t}{g}-\frac{A}{Q})(a-bp-kg)-\frac{Qh(m+\frac{t}{g})}{2} \quad (9)$$

Theorem 2 In order to maximize the profits of the whole supply chain, it need to make decisions on the retail price p, carbon emissions of per unit product g and order quantity Q, take first-order partial derivative of formula (9) with respect to p, g and Q respectively, then make it equal to zero and get the equations. At this time make p, g and Q to meet the following equations:

$$a + bm - 2bp + \frac{bt}{g} + \frac{bA}{Q} - kg = 0$$

$$\frac{t(a-bp-kg)}{g^2} - k(p - m - \frac{t}{g} - \frac{A}{Q}) + \frac{Qht}{2g^2} = 0$$

$$\frac{A(a-bp-kg)}{Q^2} - \frac{h(m+\frac{t}{g})}{2} = 0$$

By solving the equations in theorem 2, we can get the value of p, g and Q, which can make the maximization profit of the whole supply chain come true, namely get the optimal decision in centralized decision-making mode.

In decentralized decision-making the optimal profit of retailers and manufacturers is π_x^1 and π_s^l, but in centralized decision-making the overall profit of the supply chain is $\pi(p, g, Q)^2$, then there must be $\pi_x^1 + \pi_s^l \le \pi(p, g, Q)^2$, this also means that the decentralized decision failed to achieve the overall optimum. In order to achieve the overall optimization, we will further design the cooperation contract of the two parties in centralized decision-making.

3. CONTRACT DESIGN

The principle of contract design is that, under the premise of ensuring the optimal overall profit, it should promote the retailer and manufacturer have motivation to accept contract and the designed contract should achieve the profits of retailers and manufacturers on Pareto improvement. That is to say in the designed contract the profit level achieved by manufacturers or retailer is not less than that in the decentralized decision-making, and the profit of manufacturers and retailers in the designed contract are respectively no less than π_s^l and π_x^1. In other words, our contract is mainly about the distribution of the profits $\triangle\pi$ produced by the change of decision model, where we change the decentralized decision-making into the centralized decision-making.

The contract considered in this paper is the wholesale price contract model, the wholesale price w is determined by the manufacturer and retailer jointly, and under centralized decision-making the manufacturer and retailer will make their decision respectively according to the product carbon emissions g_2, sales price p_2 and order quantity Q_2.

3.1 Contract Design Requirements

In this contract, the production costs of per unit product is $c(g_2)$, the demand is $D_2 = D(p_2, g_2)$. Then the profit of manufacturers and retailers is respectively π_s^* and π_x^*:

$$\pi_s^* = [w - c(g_2)]D_2 \qquad (10)$$

$$\pi_x^* = (p_2 - w - \frac{A}{Q_2})D_2 - \frac{hQ_2 c(g_2)}{2} \qquad (11)$$

And $\pi_s^* \ge \pi_s^1, \pi_x^* \ge \pi_x^1$.

Theorem 3 when the range of wholesale price w is in (w_{min}, w_{max}), in this contract the profit of the manufacturer and the retailer is at least not less than that of the decentralized decision, now the increased profit of manufacturers and the retailers respectively is:

$\Delta\pi_x = (w_{max} - w)D_2$ and $\Delta\pi_s = (w - w_{min})D_2$,

and $\Delta\pi = (w_{max} - w_{min})D_2$,

In where, $w_{min} = \dfrac{\pi_s^1 + c(g_2)D_2}{D_2}$,

$$w_{max} = \frac{(p - \frac{A}{Q_2^2})D_2 - \frac{hQ_2 c(g_2)}{2} - \pi_x^1}{D_2}.$$

3.2 In Contract the Determination of Wholesale Price

The determination of wholesale price w is not only determined by manufacturers, it does have relationship with the negotiation ability of manufacturers and retailers. We use the Nash negotiation model to discuss the value of w. Assume that the bargaining power of manufacturers is a($0<a<1$), and then negotiating capacity of the retailer is $1-a$. Then it translates optimal determination of w^* to solve the problem R.

$$R: \underset{w}{Max}\{[w - c(g_2)]D_2 - \pi_s^1\}^{\alpha}$$
$$\{(p_2 - w - \frac{A}{Q_2^2})D_2 - \frac{hQ_2 c(g_2)}{2} - \pi_x^1\}^{(1-\alpha)} \qquad (12)$$

Solve formula (12), and

$$w^* = c(g_2) + \frac{\pi_s^1 + \alpha\Delta\pi}{D_2},$$

in where $\Delta\pi = \pi(p, g, Q)^2 - \pi_x^1 - \pi_s^1 \qquad (13)$

Theorem 4 There is an optimal wholesale price contract $\{(w^*, g_2), (p_2, Q_2)\}$, making the overall supply chain keep coordinated. Among them, $w^* \in (w_{min}, w_{max})$ meets formula (13).

By the theorems 3 and 4, we can see that in the optimal contract the profits of manufacturer is increased $\triangle\pi_s = a\triangle\pi$, while the profit of the retailer is increased $\triangle\pi_x = (1-a)\triangle\pi$. Thus, the profit distribution of manufacturers and retailers is closely related to their negotiating ability under contract, the stronger the bargaining power they have, the greater revenue they gain.

In this contract, we not only make the supply chain to achieve optimal profits, but also improve the profits of manufacturers and retailers.

4. CASE ANALYSIS

4.1 Case Background and Data

A retailer X ordered a product from the manufacturer S, each subscription fee A is \$100, the unit product unit time inventory costs accounted for the percentage of retail purchase costs is h=20%, and in the demand function $D(p, g)=a-bp-kg$, a=200, b=3; but in the cost function $c(g)=m+\frac{t}{g}$, m=5, t=100.

In different period, the protection requirements on environment of people are different, then it will inevitably lead to the different value of k in each period. In current, it is generally believed that the impact of the price level on demand is much greater than that of carbon emissions. We will further discuss for the different value of k (that is, when people's environmental protection concept is not the same), and when the impact on demand and the degree of relative influence on the price is not the same, how is the impact on all parties in decision-making.

4.2 Calculation Results and Analysis

4.2.1 Decentralized Decision-making

Take the values of function and parameter into the formula of the equations group (a), and solve the equations about p, w and g. We take different values of k to judge the impact of different degree emphasis on carbon emissions on decision-making. By using software we solve the equations and obtain the value of p, w and g, and then get the value of Q. Table 1 shown below are results calculated by using calculation tool.

Table 1
The Functions and Data in Decentralized Decision-making

k	p	g	w	Q	$D(p, g)$	$\pi_s(w, g)$	$\pi_x(p, Q)$
0.1	50.4883	53.1414	39.0887	33.25229	43.22096	1392.014	232.7439
0.2	49.9219	37.9989	38.7241	33.18104	42.63452	1325.611	220.4316
0.4	49.0983	27.3088	38.1946	33.07436	41.78158	1233.926	202.9214
0.5	48.7585	24.5896	37.9763	33.02932	41.4297	1197.714	195.8371
0.6	48.4473	22.585	37.7765	32.98736	41.1071	1165.336	189.4162
0.8	47.8849	19.7767	37.4156	32.91012	40.52394	1108.7	177.9869
1.0	47.3788	17.8658	37.090	32.83898	39.9978	1059.65	167.9298
2.0	45.2832	13.1645	35.7506	32.52574	37.8214	875.7323	127.9734
3.0	43.5402	11.1243	34.6397	32.24062	36.0065	743.5476	97.11477
4.0	41.9608	9.9397	33.6368	31.96036	34.3588	638.2537	70.99381
5.0	40.4702	9.1577	32.6938	31.67453	32.8009	550.2032	47.96077
6.0	39.0275	8.6046	31.7848	31.37562	31.2899	474.4522	27.16978

When k=0, t=0, the results in decentralized decision-making

p	w	Q	$D(p, g)$	$\pi_s(w, g)$	$\pi_x(p, Q)$
51.2033	38.6255	34.65577	46.3901	1559.89	315.7661

From Table 1 we can see the decision-making changes caused by the changes of k value, and the carbon emissions of per unit product g fluctuations drastically, but the change of the wholesale price p, w and order quantity Q is relatively small. Along with the k value increases, the value of g is decreasing, this is mainly because people pay more and more emphasis on carbon emissions. Both manufacturers and retailers are more concerned about the demand changes of that, and manufacturers will continue to reduce the value of g to obtain a certain demand (which is based on the change of cost is not dramatic), but retailers are trying to maintain their demand through adjustment of price; then the two together make the demand maintain at a relatively stable level.

In the small range of k value (0.1~1), due to the impact of p on demand is much greater than g, then the value of p at this time maintains at a relatively stable level, and the decrease of g value is relatively large in this interval, but in backward the amplitude of the reduction in g value is getting smaller, this is mainly due to the restriction of cost function.

When the value of k keeps increasing and eventually exceeds the interval (2~6) of b values, namely the impact of carbon emissions of per unit product on demand is greater than that of price, the amplitude of the reduction in p value starts increasing, but he amplitude of the reduction in g value begins to being inhibited. Especially when the k value exceeded the value of b, the amplitude of the reduction in g value becomes smaller. Because the influence of g on demand is less than p and subjected to cost, to maintain a certain demand, the only way is to reduced p.

From Table 1, we also find that in the process of the increasing of k value, the maximum profits are decreasing for both manufacturers and retailers. This is mainly due to the k value to a certain extent also reflects the quality of goods, and to achieve such a quality level need to pay more cost on production, so the profits will decline. But with the progress of technology, the production costs are no longer so high to achieve such a level of quality, so profits will increase as a result.

4.2.2 Centralized Decision-making

Take the parameter into the formula of the equations group (b), and solve the equations about p, g and Q. By using software we solve the equations and obtain the value of p, g and Q, and then get the corresponding profit. The specific results are as follows shown Table 2.

Table 2
Data Operation in Centralized Decision-making

k	p	g	Q	$D(p, g)$	$\pi(p, g, Q)$
0.1	36.1629	58.2706	112.9512	85.68424	2371.405
0.2	36.151	41.1171	105.8836	83.32358	2235.576
0.4	36.1375	29.0041	97.3051	79.98586	2050.383
0.5	36.1329	25.9208	94.2235	78.6409	1978.006
0.6	36.1291	23.6463	91.5933	77.42492	1913.676
0.8	36.1231	20.4565	87.2437	75.2655	1802.026
1.0	36.1186	18.282	83.7078	73.3622	1706.366
2.0	36.1061	12.8982	71.8767	65.8853	1355.296
3.0	36.1010	10.5218	64.3881	60.1316	1111.879
4.0	36.0994	9.1094	58.8119	55.2642	924.0758
5.0	36.0998	8.1483	54.3167	50.9591	771.7853
6.0	36.1017	7.4410	50.5132	47.0489	644.7247

When k=0, t=0, the results in centralized decision-making

p	Q	$D(p, g)$	$\pi(p, g, Q)$
36.2032	135.1965	91.3904	2716.476

From Table 2, we can find that in the centralized decision-making, among the change of decision variables caused by the k value, the price p essentially is unchanged, while carbon emissions of per unit product g and order quantity Q appears a larger fluctuation. With the increase of value k, the value of g and Q continues to decrease.

In the small interval of k value (0.1~1), the value of p presents a very weak trend of downward, but the decrease trend of g value is rather obvious, but in backward the amplitude of the reduction in g value is getting smaller. The decrease of g value is mainly due to purpose of maintaining a certain demand, but it is based on the change of cost is not dramatic.

In the larger interval of k value (2~6), the downward trend of p value becomes more weak, and until the k value exceed 6 the value of p rebounds; and the amplitude of the decline in g value becomes smaller. This is mainly because the impact of g on demand is increasing, and limited by the cost, the decline of g value is not sharp as before, but the impact of p is relatively small, through increasing p value can also help to maximize profits.

In a centralized decision-making, the retail price of product p is lower than that in decentralized decision-making, the carbon emissions of per unit product g maintains the same level as it in decentralized decision-making, but compared with decentralized decision-making the order quantity of Q value is much higher, suggesting that centralized decision-making contributes to the reduction of retailer's ordering costs. This is mainly because that, given parameters, retailers need to increase demand by reducing the price and decrease the ordering cost by increasing the quantity of orders, which makes the total profit on the whole supply chain greater than those of decentralized decision-making.

Therefore, through our designed contracts can the increased-profits part be well distributed, which would improve the profits of manufacturers and retailers, and at this time the carbon emissions is equal to or even less than that in decentralized decision-making. In other words, our coordination contract not only achieve the optimal of overall profits and gain the Pareto improvement on manufacturers and retailers, but also it ensure no increase in carbon emissions, and even play a key role in emission reduction, in turn help to achieve a win-win goal.

CONCLUSION

The carbon emissions of products not only associate with product demand, but also affect the production costs, considering the impact of carbon emissions of the product as a strategy choice will have a significant impact on the corresponding decision-making of manufacturer and retailers. When the carbon emissions of the product is reduced, with the rise in demand for the product the cost is also rising; on the contrary, the demand and costs will fall down. In the context of manufacturer-led, it must also consider the impact on the demand of product when retailers adjust the price, and retailers must consider the impact of the manufacturer's wholesale price and carbon emissions on demand.

Based on the given models and functions, the simulation is carried out on the basis of the instance. No matter in decentralized decision-making or centralized decision-making, along with the impact of carbon emissions on demand is getting seriously, in order to maximize profits, the decision should change accordingly. And when k=0, t=0, the problem is converted to the two stage problem in which the demand depends only on the price, the calculated results of this problem are shown in Table 1 and Table 2. We can find that the profits obtained in this case are greater than those when we consider the impact of carbon emissions on demand, but this is built on the basis that people are indifference with the environment and manufacturers produce their products with the lowest cost m (without considering the impact on environment). It is obvious that in nowadays' world, this kind of consideration is more and more not applicable.

Thus, it does have great significance for the enterprise to concern about the impact of carbon emissions on demand, especially in nowadays the concept of national environmental protection continue to strengthen. Therefore no matter upstream manufacturers or downstream retailers must keep up with the trend, considering the impact of carbon emissions in the every process of production and operation.

In addition, under the premise of at least without any increase of carbon emissions, by designing the contract based on the centralized decision-making mode, we achieve the Pareto improvement of the manufacturer and retailer profit.

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