Advances in Economics, Business and Management Research, volume 106
Fourth International Conference on Economic and Business Management (FEBM 2019)

Multi-objective Programming Model for Enterprise Decision-making Under the Interaction of Progressive Carbon Tax and Carbon Trading

Lu-lu Ding*
School of Management
Jiangsu University
Zhenjiang, China
1175119024@qq.com

Ji-jian Zhang
School of Finance and Economics
Jiangsu University
Zhenjiang, China

Xing Yin
School of Finance and Economics
Jiangsu University
Zhenjiang, China

***Abstract*—By constructing a multi-objective programming model, this paper studies the decision-making problem of the enterprise under the interaction of progressive carbon tax and carbon trading, and draws the optimal distribution ratio between carbon emission rights and carbon tax, and discusses the tax rate and carbon trading. The relationship between prices affects the substitution effect between the stepped carbon tax and carbon trading, and further analyzes how the substitution effect affects the company's carbon emissions decisions. The study finds that the optimal proportion of carbon emission rights decreases with the increase of carbon emissions, and decreases with the increase of carbon trading unit price; the optimal output decreases with the increase of carbon trading unit price σ. It decreases as the carbon emissions of production units increase.**

Keywords*—progressive carbon tax; carbon trading; interaction; carbon emission decision; multi-objective planning

I. Introduction

In response to the global warming crisis, the Chinese government has proposed an emission reduction target of "40%-50% lower than the 2005 carbon emissions per unit of GDP by 2020", which will eventually be decomposed into enterprises with production functions. To promote carbon reduction in enterprises, the intensity of carbon regulation will increase. Carbon trading and carbon tax are considered to be the most effective market instruments for corporate carbon reduction[1-2]. Both carbon trading and carbon tax have their own advantages and disadvantages, while the compound carbon emission reduction policy takes into account the advantages of carbon trading and carbon tax, and it also ensures the contradiction between carbon emission reduction and economic development while ensuring the achievement of emission reduction targets[3]. Mandell[4] theoretically proves that in a particular market, the government's use of both policies is more economically efficient than a single policy by constructing a stochastic model; LEF et al.[5] comprehensively considers the impact of carbon trading and carbon tax on different industries, and finds that the carbon trading and carbon tax policies at the same time have a much smaller impact on the GDP loss of the petrochemical industry than the carbon tax alone.

Some scholars have studied the impact of the carbon tax rate on carbon emission reduction effects. Weng Z X[6] measured the carbon emission reduction effect in 2020 by setting different tax rates, he found that the higher the tax rate, the better the carbon emission reduction effect. Dong et al.[7] used the CGE model of 30 provinces and regions in China to study the impact of carbon tax on various provinces. The study shows that under the scenario of carbon tax of 120 yuan/t, the power sector has the most obvious emission reduction effect by 2030 (19 billion t CO_2/a). Studies have shown that the composite carbon emission reduction policy is better than the single policy, the changed tax rate is better than the single tax rate. However, they are less concerned with the interaction between carbon trading and carbon tax on emission reduction entities, and the combination of carbon tax with variable tax rate and carbon trading is relatively lacking in considering the decision-making of emission reduction entities.

As a direct participant of carbon emissions and a source of carbon emissions, research enterprises have become an important issue in how to deal with the relationship between social responsibility and self-interest, environmental protection and self-interest under the new emission reduction policy. Based on this, this paper starts from the influence of the interaction between progressive carbon tax and carbon trading on enterprises, and constructs a multi-objective planning model to study a series of decision-making problems of enterprises.

II. Basic Assumptions and Model Building

For ease of modeling, the following is a descriptive statistic for each variable required, as shown in Table I:

A. Basic Assumptions

Hypothesis 1: The enterprise is in a completely competitive market, the price(P) of the product is determined by the total output(Q) of the whole industry. The product cost(C) of the enterprise is split into two parts: the cost (C_1) without environmental factors and the payment (C_2) for the environment, and the product cost: $C = C_1 + C_2$

$MC_1(q) = a + b \cdot q$, $C_1 = \int_0^q MC_1(q)dq$.

Hypothesis 2: The tax rate of the progressive carbon tax increases with increasing carbon emissions, then the carbon tax, as shown in Fig. 1:

Hypothesis 3: The ratio of carbon emission rights purchased by enterprises in the carbon trading market to carbon emissions is $\mu(0 \le \mu \le 1)$, then there is:

$$C_2 = (\mu \cdot \rho \cdot \sigma + \lceil \mu \rceil \cdot \omega) + \int_0^{(1-\mu)\rho} f(\rho)\, d\rho$$

and: $\rho = \theta \cdot q - \beta$

B. Model Building

As a rational economic man, enterprises have natural profit-seeking motives, but enterprises must pursue their own interests to maximize the carbon emission reduction targets. Therefore, enterprises have two goals: profit maximization and carbon emission efficiency. And the carbon emission efficiency is expressed by the carbon emission cost per unit of emissions . Details as follows:

P_1: Highest carbon emission reduction efficiency.

$$Min\gamma(\mu) = C_2 \cdot \rho^{-1}$$

$$S.T \begin{cases} \omega_m \le \omega \le \omega_M \\ 0 \le \mu \le 1 \\ \sigma_m \le \sigma \le \sigma_M \end{cases}$$

$$T(\rho) = \int_0^{\rho} f(\rho)\, d\rho$$

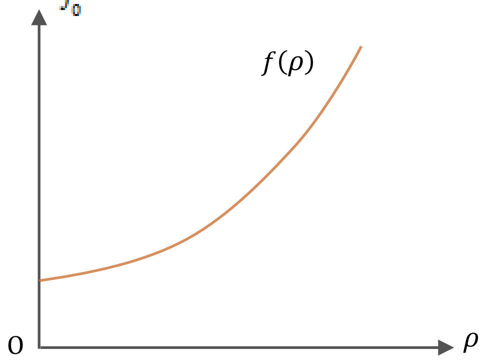

Fig. 1. Relationship between carbon tax rate and carbon emissions.

P_2: Maximizing corporate profits.

$$Max\Pi(q,\mu) = P \cdot q - C(q,\mu)$$

$$S.T \begin{cases} 0 < q \le q_{max} \\ \Pi > 0 \\ P \ge MC \end{cases}$$

C. Model Solving

Solve the above model:

$$\begin{cases} \mu_o = 1 - \rho^{-1} \cdot f^{-1}(\sigma) \\ q_o = b^{-1} \cdot (P - \sigma \cdot \theta - a) \end{cases}$$

According to the expression obtained by the solution, the following conclusions can be drawn: (1) The ratio of the optimal purchase of carbon emission rights to total emissions is negatively correlated with carbon emissions, it also negatively correlated with the unit price of carbon trading.

(2) The carbon emission efficiency $\gamma(\mu)$ increases first and then decreases with the increase of μ. At the critical value μ_o, $\gamma(\mu)$ takes the minimum value, that is, the carbon emission efficiency is the highest.

(3) Corporate profits are negatively correlated with carbon emissions per unit of product , and negatively correlated with the unit price of carbon trading.

III. Numerical Simulation

Since China does not implement a carbon tax policy currently, it is unable to obtain actual data. Therefore, this study uses Matlab software to simulate the model constructed in the previous article, and further analyzes the characteristics of the model and its interpretation.

The tax rate function is set to $f(\rho) = 4.5 \times 10^{-3}\rho^2 + 30$,the carbon allowance obtained by the enterprise is 30t, the product unit price is 1200 yuan, transaction fee is 300 yuan, the carbon emission trading price fluctuates between [30, 60] yuan per ton, and the specific transaction price will change with the supply and demand relationship of the market, the marginal cost function of the enterprise is $MC_1(q) = 200 + 0.2q$.

TABLE I. Descriptive Statistics for Each Variable

variable	symbol	variable	symbol
Enterprise production	q	Initial carbon allowance	β
Product unit price	P	transaction fee	ω
Production unit product carbon emissions	θ	Carbon emissions that companies need to pay	ρ
Product cost without carbon emissions	C_1	Cost of carbon emissions paid by enterprises	C_2
Unit carbon emission tax rate	α	Carbon emission trading unit price	σ
Product unit environmental cost	γ	Total profit of the enterprise	$\Pi(q,v)$

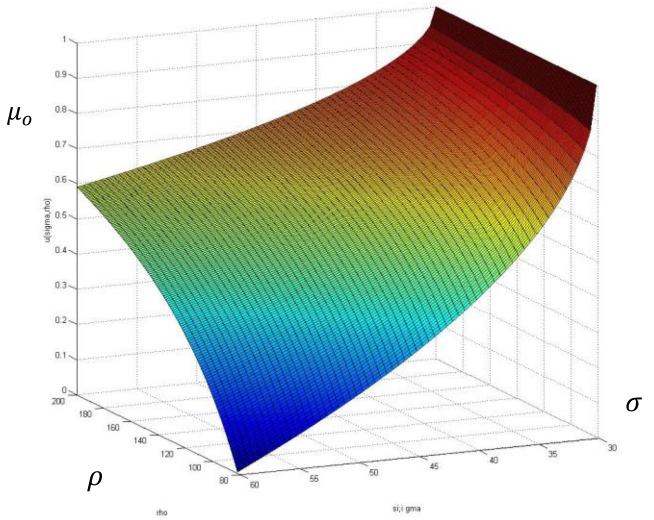

Fig. 2. Relationship between μ_o, ρ and σ.

(1) As shown in Fig. 2, the ratio of the optimal purchase of carbon emission rights to total emissions(μ_o) decreases as the carbon emission (ρ) and the carbon trading unit price (σ) increases, when the carbon transaction unit price $\sigma \rightarrow \sigma_m$, regardless of the scope of the company's carbon emissions, the optimal carbon emission outsourcing ratio always has $\mu_o \rightarrow 1$. When the company's emissions are large($\rho \rightarrow \infty$) , the company will tend to purchase carbon emission rights.

(2) At $\mu \in [0,\mu_o)$, the carbon emission efficiency decreases as μ increases. At $\mu \in (\mu_o,1]$, the carbon emission efficiency increases as μ increases. At μ_o, $\gamma(\mu)$ takes the minimum value, that is, the carbon emission efficiency is the highest, as shown in Fig.3.

(3) As shown in Fig. 4, the maximum profit value of the enterprise is affected by the carbon emission of the unit product and the unit price of the carbon transaction. The maximum profit value$Max\Pi$ increases as the carbon emission$(\theta)$of the unit product decreases, and increases as the unit price(σ) of the carbon transaction decreases.

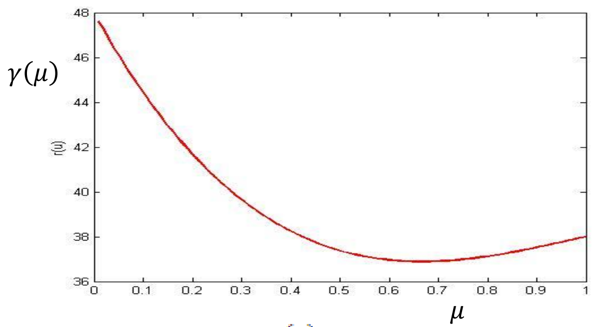

Fig. 3. Relationship between $\gamma(\mu)$ and μ.

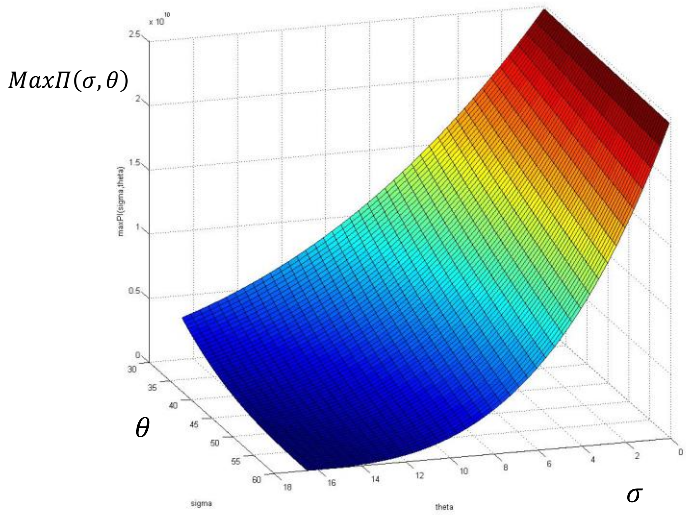

Fig. 4. Relationship between the $Max\Pi(\sigma,\theta)$,θ and σ.

IV. CONCLUSIONS

From the micro level, this paper constructs a two-level multi-objective programming model for enterprise decision-making problems, which provides accurate mathematical expressions for decision-making problems under the dual factors of stepped carbon tax and carbon trading.

(1) When the carbon emission (ρ) tends to be infinite, the ratio of the amount of carbon emission purchased and the total emission tends to be at upper limit 1 $(\lim_{\rho\rightarrow\infty}(\mu) \rightarrow 1)$.

(2) When the carbon emission(ρ) is at a higher level, the carbon emission efficiency corresponding to $\mu = 1$ is significantly higher than the carbon emission efficiency corresponding to $\mu = 0$, ie $\lim_{\mu\rightarrow 1^-}\gamma(\mu) < \lim_{\mu\rightarrow 0^+}\gamma(\mu)$, This means, when the company's carbon emission is large, it should give priority to buying carbon trading rights.

(3) For the company's maximum profit value $Max\Pi\,(\sigma,\theta)$, more aggressive company is to implement emission reduction measures, greater profit value obtained; Smaller the unit price $(\sigma)$of carbon transaction, greater the profit of the enterprise.

ACKNOWLEDGMENT

This study was funded by the National Natural Science Foundation funded project "Research on the Dynamic Mechanism and Guidance Strategy of Low Carbon Transformation in High Carbon Industry from the Perspective of Technology-Institutional Double Unlocking" (Approval No. 71673117).

References

[1] H Qiao, ZR Li., "International Comparison and Efficiency Analysis of Carbon Tax Policy,"[J]. Management Review, 2010, vol. 22(6), pp. 85-92.

[2] LH Xie, "Carbon trading or carbon tax?" [J]. Theory and policy, financial commentary, 2011,vol. 3(6), pp. 103-110.

[3] M J Shi, Yuan Y N, Zhou S L, et al., "Carbon tax, cap-and-trade or mixed policy: which is better for carbon mitigation? [J]. Journal of management science in China, 2013, vol. 16(9), pp. 9-19.

[4] Mandell S., "Optimal mix of emissions taxes and cap-and-trade," Journal of Environmental Economics and Management, 2008, vol. 56(2), pp. 131-140.

[5] LEF C F, LIN S J, LFWIS C., "Analysis of the impacts of combining carbon taxation and emission trading on different industry sectors," Energy Policy, 2008, vol. 36(2), pp. 722-729.

[6] ZX Weng, CY Cheng, CZ Ge, et al., "Analysis of the carbon mitigation policies in China from the perspective of carbon tax,"[J] Environmental protection science, 2018, vol. 44(03), pp. 1-7.

[7] H Dong, H Dai, Y Geng, et al., "Exploring impact of carbon tax on China's CO_2 reductions and provincial disparities," [J] Renewable and Sustainable Energy Reviews, 2017, vol. 77, pp. 596-603.