Impact of Chinese Carbon Trading Market Establishment

From the consumer, producer and environment perspective

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Abstract

Chinese national carbon trading market has been running recently since July, 2021. Before 2021, carbon trading markets have been held only in certain big cities in China. This article aims to find out how the emission trading scheme would affect the industry of pollutant emitting as well as help the environment protection. This article mainly focuses on the Chinese domestic carbon trading market. China uses a three-stage evolution, from no government interference to pilot local market and finally the nationwide carbon trading market. Some simplified models have been set up to simulate the actual market of carbon trading in real life, with mostly intermediate microeconomics knowledge. Further analysis gives out some propositions: 1) The consumer's utility change from the limited permits is not single-dimensional, and under some conditions would result in a decrease in consumer's utility. 2) Introducing carbon limits will definitely decrease producer surplus, resulting in a increase on price of unit sales and a decrease on output level, and in some regions enterprises can be even worse off in the third than in the second depending on carbon price. 3) The ETS (Emission Trading Scheme) can have a huge impact on reducing carbon emission, and would also lead to the development of low-carbon technologies. Further research are needed in order to acquire a more detailed model.

Key Words: Carbon Trading, Three Stages, Perfect Competitive Market, Monopolist Behavior

1. Introduction

With the rapid grow of economy and technology in recent years, the carbon dioxide emission has posed a huge threat on human, large amount of carbon dioxide emission will lead to the greenhouse effect and causing many environmental disasters. Under the critical circumstance, countries have long been trying to push a consensus on reducing carbon dioxide emission. After the Kyoto Protocol, methods to cut the emission have been proposed, and the carbon trading market has been gradually established in countries around the world. With the future planning of carbon peak and carbon neutralization proposed by Chinese government, China aims to reach the peak of emission before 2030 and achieve totally carbon neutrality by 2060. In July 2021, Chinese government have announced that the national carbon trading market was officially in operation. The announcement surely grasped the public attention, especially with the recent hot topic of carbon neutrality and carbon emission peak.

As a mean to cut the emission from the supplier's side, the carbon trading market, or "emission trading scheme (ETS)" has been established for enterprises to trade carbon dioxide emission licenses for the amount need beyond the government given amount. Currently in China the government give out a limited number of permits that allow a discharge of the pollutants over a set of period, and firms are required to hold the permits in equal amounts with the actual amount of what they emits.

When a manufacturer produces more pollution than its permits, it had to purchases carbon emission quota in the trading market, and thus will increase the marginal production cost, ultimately in a perfect competitive market will lead to an equilibrium in sales units, with the unit sales price of products increased and overall emission decreased. For those producing with less pollutants, they could sell their permits on the market for a profit. In a way, ETS provide a potential profit to reward low carbon emission and punish those with high pollution. By introducing externalities (government control of emission amount) into the original non-governed market, given carbon emission a property right, and as the Coase Theorem stated, an equilibrium will be achieved.

The Emission Trading Scheme has proved to be a efficient method of reducing carbon emissions globally, and China just started a national trading market in July,2021. Therefore, it is of profound practical significance to investigate the impact of carbon trading on related industries and total carbon emissions.

2. Modeling

Using the knowledge mentioned in the Intermediate Microeconomics class, this paper establishes a relatively simplified model for this problem, and then analyzes the impact of government controlling enterprise carbon emissions and establishing carbon trading market on reducing total emissions.

The model contains three parts, the first stage is a perfect model without government interference, and no limitation on carbon emission. The second stage includes in a local carbon permits trading market where unit price of carbon permits can vary hugely between regions, which is what China had been running until 2021. And the third and final stage is a domestic and national trading market where all authorized enterprises are allowed to sell and buy permits at a uniform price.

2.1 Preparation

First given the assumption of perfect market condition, in which case the market is effective and with little transaction costs. Assume there are only one company in the industry (for example the electricity power generation industry) and is in a monopoly situation, and another firm in a different carbon emitting industry (for example the oil industry). This assumption is based on the fact that the power generation industry is often treated as a national infrastructure and have a high regionally supply tendency, resulting in a monopoly situation in most countries in the world.

At the beginning, the enterprise is free to choose the output of production and the corresponding carbon emissions. Carbon emission is a negative externality for some other industry, such as the environmental protection industry, which will lead to environmental degradation. Also, the carbon dioxide emission could be seen as a harmful public bads, which is both nonexcludable and nonrival. Before the government's participation, carbon emissions do not have property rights to begin with. Therefore, companies in the environmental protection industry cannot interfere with the scale of carbon emissions of enterprises in the power generation industry, and can only make choices according to carbon emissions.

Then, it is assumed that the production function of enterprises in the power generation industry are concave, and the technology presents a decreasing RTS, that is, after a certain scale, the marginal revenue decrease and marginal cost increase, but the marginal cost of large enterprises is lower than that of many small enterprises, due to its large scale and high fixed cost input. At this time, the problem faced by the power industry is determine the price and output to maximize profits.

From the consumer's side, we can simplify the utility function of an ordinary consumer in the market contains two parameters: the unit price of electricity power and the level of environmental protection measured by the amount of carbon emission. It's a well-behaved preference that satisfies the monotonic and convex conditions.
Lastly, the government's method of giving out carbon permits acts like a specific tax, where for every unit of power generated the enterprise a fixed amount of carbon emission allowance. Because of the decreasing RTS identity of the firm, after a transition output level the firm needs to buy for carbon permits.
Following functions are given with conditions above. Assumptions are made for intermediate microeconomics courses.
The market total demand function on electricity power

$$D_e = C_M - p_e$$

The utility function for a regular consumer

$$U_{consumer}(p_e, y, P) = (C_{Max} - p_e)^a \cdot y^b (C_{pol} - P)^{1-a-b}$$

The utility function for power generating enterprise

$$U_{power}(p_C, CPR) = p_c + \rho \cdot CPR^{\omega}$$

The utility function for oil enterprise

$$U_{oil}(p_C, CPR) = p_c + \epsilon \cdot CPR$$

The cost function for power generating firm

$$c(y) = C_1 + \beta y$$

The carbon emission amount function

$$cb(y) = \theta y^2$$

The limit for carbon emission per unit of power electricity

$$CB(y) = \mu y$$

Now, the question is simplified to a comprehensive application of microeconomics knowledge learned in the lecture, including mostly Consumer's preference, Monopolist Behavior, Exchange, profit maximization and cost minimization.
See **Table 1** for explanations of the notations used.

2.2 First Stage: No Government

In this stage, the enterprise in the environmental protection industry cannot interfere with the company in the power generation industry, so the only conditions are the budget constraint/market total demand and the technology function/marginal cost of the firm. No carbon limitation needs to be considered, the company only wants to maximize its profit.
To solve the market equilibrium in this situation, the company wishes

$$MR = MC$$

$$\therefore profit\ \Pi_1 = (C_M - y_1) \cdot y_1 - C_1 - \beta y_1$$

$$also\ satisfy\ \frac{\partial \Pi_1}{\partial y} = (C_M - \beta) - 2 \cdot y_1 = 0$$

$$\to y_1 = \frac{C_M - \beta}{2}$$

$$p_1 = C_M - y_1 = \frac{C_M + \beta}{2}$$

$$\therefore pollution\ P_1 = \theta {y_1}^2 = \theta \cdot (\frac{C_M - \beta}{2})^2$$

This way, the company earns the highest profit.

2.3 Second Stage: Pilot Local Market

This stage corresponds to the period when there are only a few local carbon trading market in several cities in China, and each market is running individually, enterprise can only purchase carbon permits at their location. This is also a simplified scenario, because every market can be treated separately as a exchange, with money on one axis and permits on the other axis of an Edgeworth Box. The price of the carbon permits should be negotiated between two enterprises.

However, there are two constraints for the power generating company, one is its utility function and the other is its cost function. The assumption is that company wants to produce power the more the better inside the budget constraint, and the main limit is of marginal cost. To satisfy this condition, the utility for power generation enterprise is a quasi-linear function with regard to money as is shown above. Now to solve this case:

$$U_{power} = p_c + \rho \cdot CPR^{\omega}$$
$$U_{oil} = p_c + \epsilon \cdot CPR$$

$$satisfy\ \frac{\frac{\partial U_{power}}{\partial p_c}}{\frac{\partial U_{power}}{\partial CPR}} = \frac{\frac{\partial U_{oil}}{\partial p_c}}{\frac{\partial U_{oil}}{\partial CPR}} \qquad \therefore \frac{1}{\rho \cdot \omega \cdot CPR^{\omega-1}} = \frac{1}{\varepsilon}$$

$$\therefore CPR = (\frac{\rho \cdot \omega}{\varepsilon})^{\omega-1}$$

That is, with ρ, ω, ϵ given, the amount of carbon emission power generating enterprise required is fixed. Now solve for the price. The price satisfies the condition

$$MR = MC$$

Demand function is $D_e = C_M - p_e$

The level y_b when carbon emission just equal to permit is

$$cb(y_b) = \theta {y_b}^2 = \mu y_b = CB(y_b)$$

$$\therefore y_b = \frac{\mu}{\theta}$$

Initial cost function is

$$c(y) = C_1 + \beta y$$

$$\therefore revised\colon\ c''(y) = \begin{cases} C_1 + \beta y & , y \le y_b \\ C_1 + \beta y + p_c \cdot (y - y_b) = (\beta + p_c) \cdot y + C_1 - p_c \cdot y_b & , y > y_b \end{cases}$$

If the output level of power in the first stage is below y_b, then putting a permit limitation will not affect the firm's choice of output.

But, if the output level of power exceeds y_b, the new cost function has a higher marginal cost of p_c, to solve the monopolist's best output level now:

$$profit\ \Pi_2 = (C_M - y_2) \cdot y_2 - C_1 + p_c \cdot y_b - (\beta + p_c) y_2$$

$$also\ satisfy\ \frac{\partial \Pi}{\partial y_2} = (C_M - \beta - p_c) - 2 \cdot y_2 = 0$$

$$\rightarrow y_2 = \frac{C_M - \beta - p_c}{2}$$

$$p_2 = C_M - y_2 = \frac{C_M + \beta + p_c}{2}$$

$$\therefore pollution\ P_2 = \theta {y_2}^2 = \theta \cdot (\frac{C_M - \beta - p_c}{2})^2$$

Final constraint is that carbon emission amount beyond μy_b must be equal to CPR, solve for p_c:

$$cb(y_2) - CB(y_2) = \theta {y_2}^2 - \mu y_2 = (\frac{\rho \cdot \omega}{\varepsilon})^{\omega - 1}$$

$$\therefore \theta \cdot \left(\frac{C_M - \beta - p_c}{2}\right)^2 - \mu \cdot \frac{C_M - \beta - p_c}{2} = \left(\frac{\rho \cdot \omega}{\varepsilon}\right)^{\omega-1}$$

$$\therefore \frac{\theta}{4} \cdot {p_c}^2 + \left(\frac{\theta \cdot C_M - \theta \cdot \beta + \mu}{2}\right) \cdot p_c + \frac{\theta \cdot (C_M - \beta)^2}{4} - \frac{\mu \cdot (C_M - \beta)}{2} - \left(\frac{\rho \cdot \omega}{\varepsilon}\right)^{\omega-1} = 0$$

$$\therefore p_c = \frac{-\left(\frac{\theta \cdot C_M - \theta \cdot \beta + \mu}{2}\right) + \sqrt{\left(\frac{\theta \cdot C_M - \theta \cdot \beta + \mu}{2}\right)^2 - \theta \cdot (\frac{\theta \cdot (C_M - \beta)^2}{4} - \frac{\mu \cdot (C_M - \beta)}{2} - \left(\frac{\rho \cdot \omega}{\varepsilon}\right)^{\omega-1})}}{\frac{\theta}{2}}$$

From the above analysis, we can see that price in carbon trading market is determined by enterprises and can vary dramatically.

2.4 Third Stage: Nationwide Trading Market

In the third stage, with the market becomes a nationwide market and allows all firm to come in, the model shifts from a exchange scenario consists of only local firm to a perfect competitive market, where all firms are free to enter and exit. Different from the second stage, in this case the price of carbon permits become uniform and is a given constant, p_m .

Therefore, for every firm in the market, price of carbon permit has been set and only need to solve for profit maximization:

$$Revised:\ c'''(y) = \begin{cases} C_1 + \beta y & ,y \leq y_b \\ C_1 + \beta y + p_m \cdot (y - y_b) = (\beta + p_m) \cdot y + C_1 - p_m \cdot y_b & ,y > y_b \end{cases}$$

Still,

$$profit\ \Pi_3 = (C_M - y_3) \cdot y_3 - C_1 + p_m \cdot y_b - (\beta + p_m) y_3$$

$$also\ satisfy\ \frac{\partial \Pi}{\partial y_3} = (C_M - \beta - p_m) - 2 \cdot y_3 = 0$$

$$\rightarrow y_3 = \frac{C_M - \beta - p_m}{2}$$

$$p_3 = C_M - y_3 = \frac{C_M + \beta + p_m}{2}$$

$$\therefore pollution\ P_3 = \theta {y_3}^2 = \theta \cdot (\frac{C_M - \beta - p_m}{2})^2$$

This is a simple form much like the first stage, with the adding parameter of carbon price.

3. Model Analysis

Now that the relationship and expressions are deduced for all three stages, we shall compare whether these changes have brought an increase in preference for consumer, producer and the third party(environment protection industry).

3.1 Consumer's Side

Consumer mainly focus on the utility , which is

$$U_{consumer} = (C_{Max} - p_e)^a \cdot y^b \cdot (C_{pol} - P)^{1-a-b}$$

As price of power increase or pollution increase, the utility of this ordinary consumer decreases. From the expression, price $p_1 < p_2, p_1 < p_3$, suggesting the price part of the utility decrease as the carbon trading market was introduced. On the other hand, $P_1 > P_2, P_1 > P_3$, suggesting the pollution part of the utility increases. Also, output level y decreases by limiting carbon emission. Therefore, by setting different parameters of C_{Max}, C_{pol}, a, b, different results may be received. In reality, most consumer tends to value the price of power electricity more than the pollution level, and in most cases a increase in price is dominant to decrease the consumer's utility.

Proposition 1: Consumer's preference does not have a monotonic correspondence with carbon trading market, but is likely to be decreased.

3.2 Producer's Side

Producer's focus is on the total profit Π. As the trading market and carbon permits come into the market the marginal cost of the enterprise increase by the price of carbon, which would result in a decrease in output level and increase in sales price. But in total, the producer's condition cannot be better than before, and total surplus will also decrease. This is a perfect example of government intervention affects the market.

Proposition 2: Issuing carbon emission permit decreases producer surplus and lower its profit.

3.3 Environment Protection

For the third party that has to endure carbon dioxide emissions created by the producer, in the model the measurement for their degree of satisfaction concerned only on the pollution level of the producer, that is P.

It's clear that pollution level P present positive correlation with the output level y, the less y the better.

$$cb(y) = \theta y^2$$

The expression of the output level y:

$$y_1 = \frac{C_M - \beta}{2}, \qquad y_2 = \frac{C_M - \beta - p_c}{2}, \qquad y_3 = \frac{C_M - \beta - p_m}{2}$$

Its obvious that the establishment of trading market reduced output level, which consequently reduce the amount of carbon emissions. As for the second stage and the third stage, depending on the price of carbon permits different results can be stated. However, by looking at the whole market, because more enterprises are required by government to limit carbon emission, total amount of pollutant is surely decreased.

Proposition 3: Introducing carbon trading market can effectively reduce carbon emissions, and national trading market can further protect the environment.

3.4 Between Stage Two And Stage Three

The expressions for stage two and stage three are very much alike except for the price of carbon permits. In the models above, price in the local market is deduced from the exchange scenario and is a very small market where there are only two participants. Stage three, however, the model just

gives a fixed price p_m , and assumes it is constant. In fact, this price of p_m comes from a equilibrium of thousands of enterprises on the market (for China currently is 2245), so the main difference between two stages is the amount of firm and the stability of the production.
Price of the local market can vary considerably, for example in Beijing and GuangDong price are very high and price in ChongQing is much lower, which may also results in arbitrage such that heavy industry would gather in low price cities.
In stage three, initial uniform price is in the middle of the price section before, historical data also proves it. But with government gradually decrease permits of carbon per unit of power generated, price will gradually increase. To take it a step further, increasing carbon price will indirectly increase the investment value and economic benefits of green energy technology. The higher carbon price means that the emission cost of enterprises is becoming more and more expensive, and the economy of fossil fuels is greatly reduced. In sharp contrast, the cost-effectiveness of emerging clean energy technologies will be greatly improved, such as hydrogen production from renewable energy, carbon capture and storage technology (CCS), etc.

4. Conclusion

Although the model is rough and simplifies a lot for calculation, some clear conclusions do correlate with the reality. No doubt that the carbon trading market makes a huge different in reducing the total amount of carbon emissions, and as carbon permit per unit of production decreases, enterprises are forced to either improve their producing efficiency or to take on other low-carbon technology. However, we must also see that the cost of environment enhancement is producer's profit, and possibly consumer's utility. In the long term, as permits allowed is too little and price on carbon market exceeds even the cost of new energy resources, industry will be forced to upgrade the energy structure. Of course, it will take a long time.
The carbon trading market also give government another method to control the industry. A rise in carbon prices will indirectly improve the investment opportunities of natural gas industry, and would also give a comparative advantage for the high-cost decarbonization technology. As of now, the current carbon price level is approaching 100 euros in the European Union carbon market. Rising carbon price brings development opportunities for biomass utilization, making biomass energy such as liquid biofuels, biogas and particles more competitive than fossil energy, and can encourage enterprises to invest in technologies and projects in greenhouse gas emission reduction. Furthermore, CCS business is also becoming a very cost-effective and promising industry. All of these might hurt some companies' profit in the short term, but will certainly contribute a huge part in environment protection.

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Appendix

Table 1

The meaning of variables and functions

Notes	Meaning
$\boldsymbol{D_e}$	Total market demand
$\boldsymbol{p_e}$	Unit price of power in the market
y	Output level of the firm
$\boldsymbol{y_b}$	Output level that carbon produced is equal to the allowed amount
P	Pollution level
$\boldsymbol{U_{consumer}}$, $\boldsymbol{U_{power}}$, $\boldsymbol{U_{oil}}$	Utility for consumer, power generating enterprise and oil enterprise
$\boldsymbol{p_c}$	Price of carbon on trading market
$\boldsymbol{CPR}$	Carbon emission power generating enterprise required
c(y)	Cost function of the firm
cb(y)	Carbon emission function of the firm
CB(y)	Carbon permits function of the government
Π	The firm's profit
$\boldsymbol{p_m}$	Price of carbon on the national carbon trading market
others	parameters