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SELECTION OF TECHNOLOGICAL DECISION-MAKING BEHAVIOR OF ENTERPRISES IN OLIGOPOLY MARKET UNDER ENVIRONMENTAL TAX POLICY

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Abstract

This paper examines the technical decision-making behavior of two enterprises by using Cournot model of simultaneous decision-making in duopoly market. It is concluded that, when both enterprises adopt traditional technology production, environmental tax is levied, environmental welfare exists rather than environmental welfare does not exist; second, when one enterprise uses traditional technology production and the other enterprise uses green technology production, environmental subsidy will lead to the absence of double dividend; third, when both enterprises adopt green technology production, whether environmental tax has no effect on enterprise output and social welfare, and enterprise output and social welfare are only affected by the cost of adopting green technology.

Key words: environmental tax, oligopoly, Cournot equilibrium

1. Introduction

In order to deal with the environmental problems caused by economic growth, our government has begun to implement environmental policy reform. In particular, the decision of the State Council in November 2009 to reduce carbon dioxide emissions per unit of GDP by 40 to 45 per cent in 2020 compared with 2005 and its inclusion as a binding indicator in the medium- and long-term planning for national economic and social development shows the determination of our government to tackle environmental problems.

In the gradual reform of environmental policy, the government should note that the reform of the environment should no longer rely on mandatory administrative orders, but should exert the power of market mechanism. In academic circles, there are two main viewpoints on how to internalize the external effect of environmental negative through market mechanism, one is environmental tax based on Pigu tax, the other is emission trading based on Coase property right theory. However, due to the high cost of property right definition and the unclear subject of property right, it is difficult to carry out emission trading in practice. Therefore, environmental tax has become a common and feasible environmental protection measures.

According to the Organization for Economic Cooperation and Development (OECD), environmental taxes are defined as :" Environmental taxes are designed to improve the environment by pricing environmental uses, and tax instruments are designed to discourage a form or mode of consumption by comparing prices, improving market signals, reducing levels of harmful emissions from production and consumption, and encouraging environmentally friendly uses to reduce environmental degradation, which are called environmental taxes ." In developed countries, environmental taxes have accumulated rich experience, especially with the Netherlands, Sweden, Norway and other OECD countries as the representative, according to the principle of "who pollutes, who pays ", the implementation of environmental protection taxes, including fuel tax, water pollution tax and soil protection tax series of taxes, after many years of practical testing, it has indeed played the role of reducing pollution emissions, protecting the environment, and becoming a useful experience in the implementation of environmental tax in China.

According to the theory of "double dividend" of environmental tax, environmental tax should not only protect environment and improve environmental quality, but also promote economic and social development. So as the main body of environmental tax collection, the decision-making behavior of sewage enterprises is very important. In addition to insisting on "who pollutes, who pays" and letting sewage enterprises bear the cost of pollution, it is more important to urge enterprises to change their mode of production and improve their production technology (Li Hongxia 2014). So, under the policy of implementing environmental tax, will enterprises choose green production technology, and how should the government adjust the policy to guide enterprises to adopt green production technology? This paper introduces game theory to analyze firm behavior, that is, Cournot model based on simultaneous decision making to analyze the choice of technology decision under environmental tax policy.

The following arrangements of this paper are as follows: the second section will summarize the existing research contents of environmental tax, the third section will

construct the manufacturer's production function under the Cournot model, and analyze the manufacturer's technical selection behavior. Section 4 gives relevant policy recommendations according to the previous analysis.

2. Literature review

Domestic and foreign scholars focus on the following three aspects:

How the government should determine the optimal tax rate. Pigou 1920 proposed a tax method to correct externalities. He thinks the optimal tax rate is a marginal social loss per unit of environmental tax, also known as the "valley tax rate "(Pigou A C 1920). Unlike Pigou's environmental considerations, Ramsey assuming no economic externalities exist, from the point of view of raising tax revenue, the optimal tax rate should be the most effective way to raise tax revenue (Ramsey F P 1927). Although both views have merit, Pigou ignore the fact that the one-off return of taxes to society can cause tax distortions, and while Ramsey assumptions simplify the analysis. In reality, there is little behavior without economic externality. Then scholars found it impossible to raise income and protect the environment, Goulder take the United States example to study, after establishing a multi-sectoral CGE model, optimal environmental tax rate is lower than the “Pigou tax” (Goulder L H, rate Parry I W, Williams R C 1999). Bovenberg, Goulder and Parry explained this phenomenon, it is believed that this is due to the existence of tax interaction effect. The problem of optimal tax rate abroad started earlier. In recent years, the study of environmental tax has also arisen in China. Zhang and Baranzini note that an optimal tax rate should be equal to the marginal emission reduction cost of environmental emissions (Zhang Zhongxiang, Andrea Baranzin 2004). Chen Shiyi takes the carbon tax as an example, uses the directional distance function (DDF) to estimate the marginal emission reduction cost of carbon dioxide emissions, and then estimates the reasonable value of the future carbon tax rate in China (Chen Shiyi 2011). Based on the externality theory, Li Qiyun and others used the general equilibrium model (CGE) to investigate the efficiency characteristics of environmental tax and the determinants of optimal environmental tax under the condition of suboptimal conditions. Their model proves that when there are other distorting taxes, the tax rate of the optimal environmental tax should be lower than the Pigou tax rate, and advocates the "iterative" method to determine the optimal environmental tax rate in China (Li Qiyun, Zong Bin, Li Zhengyu 2007).

Secondly, " double dividend " theory research. Tullock first put forward the theory of "extra income "(Tullock G 1967), After that, Research on environmental taxes is expanding, Pearce used the term "double dividend" in studying carbon tax reform (D.W.Pearce 1991). Although there is no clear definition of double dividend in academia, it is generally believed that, the first dividend is that the collection of environmental taxes contributes to environmental improvement, that is environmental dividends; the second dividend is that the introduction of environmental taxes can reduce the distortion of other taxes to the market, improve efficiency, increase output, even promote employment. That is non-environmental dividend (Liu Ye Zhou Zhibo 2010). Academic research focuses on the existence of dual dividends. Shiro, Takeda developed a multisectoral dynamic equilibrium model in the study of CO2 taxes (DCGEM), simulated the carbon dioxide situation in 1995-2095, found that compared to the carbon tax when it was used for total tax returns. When carbon tax revenue is used to reduce the tax burden on other distorting taxes, the extra cost of the entire tax system is reduced, and social welfare increased (ShiroTakeda 2006). In his research, Si believes that the optimal environment is difficult to achieve in reality, So the analysis is based on suboptimal conditions, it is found that the added value of the economic welfare effect of environmental tax is zero. That is, the "double dividend" hypothesis is not true. It can only exist after introducing non-homogeneous assumptions, And the optimal tax rate level is above the Pigou tax rate level (Si Yanwu 2010). Whether there is a difference in the conclusion that the academic community produces dual benefits, Mainly because of the difference in the hypothetical premise of the study, some scholars have begun to study what impresses double welfare, Bayindir-Upmann and Raith, for example, examined double dividends in the case of monopolistic trade unions, efficient bargaining and power management (Bayindir-Upmann，Raith 2003).

Manufacturer's production decision-making behavior. Generally, the method of game theory is used to study the behavior of firms in oligopoly market. According to the subject of the game, it can be divided into the game between the manufacturer and the government and the game between the manufacturer and the manufacturer. Katsoulacos and Xepapadeas studied the influence of emission tax on the number of enterprises in the context of oligopoly market. Game analysis is divided into two stages, the first stage is set by the government tax rate (welfare maximization), the second stage all enterprises decide whether to enter the industry (Katsoulaco, Xepapadeas 1995). Gao Hewen puts forward a three-stage game, in which he thinks that incumbent enterprises may prefer higher emission tax, because it can hinder potential competitors from entering the market and guarantee the monopoly interests of incumbents. Governments may also favor high tax rates because they block entry for potential competitors, meaning less damage to the environment (Gao Hewen 2012). In the game between manufacturers, Zhang Qian and others studied the influence of environmental preference and environmental tax on enterprise technology decision under the model of Cournot equilibrium. The improvement of environmental tax rate will certainly lead to green technology innovation

(Zhang Qian, Liu Dan, Zhang Jinxia, 2014).
By summarizing the previous literature, it is not difficult to find that the study of firm behavior in oligopoly market is mainly based on Cournot model of simultaneous game and Stackelberg model analysis of time series. By using the Stackelberg model, Liu Ye and Zhou Zhibo analyze the influence of environmental tax on manufacturers in oligopoly market (Liu Ye, Zhou Zhibo 2011). This paper attempts to discuss another situation in oligopoly market, that is, Cournot equilibrium model with simultaneous decision-making, and analyze different production technology behavior among manufacturers under environmental tax constraints.

3. CONSTRUCTION AND ANALYSIS OF THE MODEL

1. Description of models and assumptions

Assume that there are only two manufacturing enterprises in the market and produce homogeneous products. Assume that the demand function faced by the enterprise is

$$P(Q) = 1 - Q \qquad (1)$$

Among them, $Q = q_1 + q_2$, q_1 、 q_2 are the production function of two enterprises. P represents the market price.

Following the assumptions of Antelo and Loureiro(2009) and Liu Ye, Zhou Zhibo (2011) on discharge, that is e_i

The amount of sewage discharged by the enterprise is proportional to the production function of the enterprise,. In order to simplify the analysis, the following assumptions are proposed: $e_i = \varepsilon q_i \ \varepsilon \in (0,1)$

$$e_i = \begin{cases} q_i & \text{Traditional technology production} \\ 0 & \text{Green technology production} \end{cases}$$

Environmental damage caused by pollution D, generally determined by the size of the discharge, assuming that the loss function of the discharge to the environment is:

$$D = \frac{1}{2} dE^2$$

(2)
The E represents the total environmental pollution emissions of enterprises, that is $E = e_1 + e_2$. d represents the government's preference for pollution control. The greater the d value, the more the government prefers to control pollution, the smaller the d value, the less the government prefers to control pollution. And in order to ensure that both enterprises adopt traditional technology, tax is positive, order $\frac{1}{2} < d < 1$

Because only considering whether the enterprise adopts green production technology, it is assumed that the average production cost of the two enterprises is c related to the production strategy only adopted by the enterprise. The extreme assumption of production cost by Liu Ye and Zhou Zhibo (2011) is that when enterprises adopt traditional technology to produce, the c is 0, and when enterprises adopt green technology to produce, the c is a constant.

$$C = \begin{cases} 0 & \text{Traditional technology production} \\ c & \text{Green technology production} \end{cases}$$

0<c<1 are assumed to guarantee the level of output,
Based on the above assumptions, the profit function of the enterprise can be obtained:

$$\pi_i = (1 - c_i - Q)q_i - te_i$$

(3)
What kind of technical strategy is adopted by the enterprise to realize the profit maximization, which is the choice behavior of the enterprise under the comprehensive consideration of the government policy factor and the production cost constraint.
The government's decision is aimed at maximizing social welfare. The general academic circles believe that social welfare consists of consumer surplus CS 、 enterprise profits π , tax revenue R sum of deducting environmental losses D.

$$W = \sum_{i=1}^{2} \pi_i + CS + R - D$$

(4)
Of which.

$$CS = \frac{1}{2} Q^2$$

。

2. **Model solving**

3.1 Both enterprises choose traditional production at the same time.

When both enterprises choose traditional production , enterprise strategy is （c_1,c_2） =(0,0);(e_1,e_2)=(q_1,q_2). Find out the equilibrium output of Cournot equilibrium at this time:

$$q_1 = \frac{1 + T_2 - 2T_1}{3} \qquad q_2 = \frac{1 + T_1 - 2T_2}{3}$$

(5)
The profit function of the two enterprises is:

$$\pi_1 = \frac{(1+T_2-2T_1)^2}{9} \qquad \pi_2 = \frac{(1+T_1-2T_2)^2}{9}$$

(6)

The social welfare function is:

$$W = \frac{1}{2}(1-d)Q^2 + (1-Q)Q = \frac{1}{2}(1-d)(\frac{2+2T_1-4T_2}{3})^2 + \frac{1-2T_1+4T_2}{3} \times \frac{2+2T_1-4T_2}{3}$$

(7)

FOC:

$$\frac{\partial W}{\partial T_1} = 1-2T_1+4T_2-d(2+2T_1-4T_2) = 0$$

(8)

In the optimal equilibrium state, the environmental tax levied by the government on the two enterprises is equal.

$$T_1 = T_2 = T = \frac{2d-1}{2(d+1)}$$

(9)

bring in (5),(7) get

$$q_1^* = \frac{1}{2(d+1)} \qquad q_2^* = \frac{1}{2(d+1)}$$

Balanced levels of pollution emissions are:

$$E = Q^* = \frac{1}{d+1}$$

(10)

The level of social welfare is:

$$W = \frac{9}{4(d+1)} - \frac{d}{2}$$

From the beginning of the government without environmental control to the next start of environmental tax collection, it is not difficult to find that the level of pollution emissions in equilibrium is lower than that in the absence of environmental tax. Government initial environmental tax is indeed able to promote the "environmental welfare" increase. When we turn our eyes to enterprises, it is not difficult to find that the output level of both enterprises has declined at this time, and the "second welfare" in the dual welfare does not exist.

3.2 Single enterprises choose green production technologies.

And we assume that enterprise 1 chooses the traditional production technology, and enterprise 2 chooses the green production technology, that is $(c_1,c_2)=(0,c)$; $(e_1,e_2)=(q_1,0)$, bring it into the production function of the enterprise

$$q_1 = \frac{1+c+2T_1}{3} \qquad q_2 = \frac{2-c+T_2}{3}$$

(11)

Balanced levels of pollution emissions are:

$$E = q_1 = \frac{1+c+2T_1}{3}$$

(12)

The social welfare function is:

$$W = \frac{1}{2}Q^2 + (1-Q)Q - cq_2 - \frac{1}{2}dq_1^2$$

$$= \frac{8-8c+2T_1+11c^2+8T_1c-T_1^2}{18} - \frac{1+2c+4T_1+c^2+4T_1c+4T_1^2}{18}d$$

(13)

FOC:

$$\frac{\partial W}{\partial T_1} = \frac{2+8c-2T_1}{18} - \frac{4+4c+8T_1}{18}d = 0$$

(14)

Solved

$$T_1 = \frac{2d+2dc-4c-1}{4d+1}$$

(15)

It can be obtained by replacing it with (11) and (12) forms

$$q_1^* = \frac{8d+8dc-8c}{3(4d+1)} \quad q_2^* = \frac{2d+2c-10dc+2}{3(4d+1)} \qquad E = \frac{8d+8dc-8c}{3(4d+1)}$$

(16)

At this point, the level of social welfare is:

$$W^* = \frac{(8-8c+11c^2)(4d+1)^2 + (2d+4dc-4c-1)(10d+36dc+4c+1}{18(4d+1)^2}$$
$$+ \frac{(1+2c+c^2)(4d+1)^2 + 4(2d+4dc-4c-1)(6dc-3c+6d)}{18(4d+1)^2}d$$

(17)

It is not difficult to find from (15) that the symbol of the optimal environmental tax is uncertain. Whether the government collects environmental taxes or gives environmental subsidies (negative environmental taxes)

depends on the emission costs of enterprises and the government's pollution control preferences.

In the case of a single enterprise as a polluting enterprise, if the government imposes a positive environmental tax, the output of the enterprise that adopts the pollution production will decrease, the total social emission will decrease, and the social welfare will decrease. As total pollution emissions fell, the first dividend of the double dividend was obtained, while the second dividend was not obtained because of the decline in social welfare. If the pollution enterprises are given pollution control subsidies, the output of the polluting enterprises will increase, which means that the overall pollution emissions of the society will rise, while the social welfare will still fall, and neither of the dual benefits will be obtained at this time.

3.3 Green production technologies adopted by both enterprises

The emissions of both companies are 0 and the cost of production is c, that is $(c_1,c_2)=(c,c);(e_1,e_2)=(0,0)$. At this point, the government only taxes pollution emissions, so no matter how much tax is levied, it has no effect on the maximization of enterprise output and profit.

$$q_1 = \frac{1-c}{3} \qquad q_2 = \frac{1-c}{3} \tag{18}$$

Pollution emissions at equilibrium: $E = Q = \frac{2(1-c)}{3}$

Social welfare level is:

$$W = \frac{1}{2}Q^2 + (1-Q)Q = \frac{2c^2-10c+8}{9} \tag{19}$$

It is not difficult to see from the above formula that when both enterprises adopt green production technology, environmental tax does not have any effect on them, and their output is only related to the cost of adopting green production technology. The greater the cost of green production, the lower the output level. This compares to the use of traditional technology for production without tax, the same cost, can have higher output. This requires the government to subsidize enterprises that use green production technology or develop green production technology.

4. Policy recommendations

(1) Government's determination to combat pollution has an important impact on environmental protection. In the analysis of duopoly market, it is not difficult to find that when one enterprise adopts green production technology and another enterprise adopts traditional technology to produce, the government's pollution control preference has an impact on the output level of the enterprise. In today's increasingly serious environmental pollution, the government should actively support pollution control, and should not muddle through their pollution behavior because polluting enterprises can create higher economic benefits. Especially when the interests of the central government are inconsistent with the interests of the local government, the local government should consider the overall situation and make a strict assessment of the discharge volume of sewage enterprises. Otherwise, environmental tax cannot be strictly implemented, will still cause social and environmental welfare losses.

(2) China's environmental tax reform should be accompanied by certain administrative controls. Reform should be carried out step by step and cannot be accomplished overnight. Although the use of market means to achieve the internalization of pollution externalities is what we hope to reduce the loss of social welfare. However, from the above analysis, it is not difficult to see that environmental taxes cannot fully bring environmental benefits. At this time, in order to protect the environment, we should still give certain administrative control to reduce the discharge of sewage enterprises.

(3) While the government carries out environmental tax reform, enterprises should be subsidized with technology. It is not difficult to see that the cost of green technology will have a great impact on the output and social welfare of enterprises. If only the tax system reform is carried out, and the green technology use or R & D of the enterprise is not subsidized, the enterprise will increase the pollution emission from the angle of maximizing its own interests. That is, the single adherence to the principle of "who pollutes, who pays" will bring distortion of enterprise behavior and externality of government behavior. Therefore, the government should introduce relevant technology subsidy policies to subsidize enterprises that carry out R & D or adopt green technology.

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