Analysis of the Social Welfare Effect of Environmental Regulation Policy Based on a Market Structure Perspective and Consumer

Lijie Wang and Jianjun Lu *

College of Economics and Management, China Agricultural University, Beijing 100083, China; wanglijie1928@cau.edu.cn
* Correspondence: ljjun@cau.edu.cn; Tel.: +86-010-6273-7830

Received: 13 November 2019; Accepted: 18 December 2019; Published: 21 December 2019

Abstract: With the implementation of regulatory policies, some new problems are emerging, such as uneven governance effects, large differences in economic growth, and social welfare inequalities. In order to promote the sustainable development of both the economy and the environment, it is necessary to provide theoretical explanations for the above phenomena. Thus, this paper constructs a theoretical model of social welfare effects based on the Cournot model. Additionally, the scenario analysis method is used to analyze the social welfare effects of environmental control policies from the perspective of market structure and consumer preferences. The findings of the scenario analysis are as follows: (1) the social welfare effect of environmental subsidy policy is greater than the social welfare effect of environmental tax policy when the absolute difference between the external value of environmentally friendly goods and non-environmental goods is less than 7.4 units and (2) the implementation of environmental subsidy policies or environmental tax policies will improve social welfare when the market structure is a completely competitive market and when both of the externalities of environmentally friendly commodities and non-environmental commodities are not the same at intervals (0, 0.335) and (−0.335, 0). We conclude that (1) the government should consider externalities, market powers, and consumer preferences when implementing environmental regulation policies and (2) the government can achieve a trend toward the development of environmentally friendly goods by guiding consumer preferences and harnessing market power.

Keywords: environmental regulation policy; market structures; consumer preferences; social welfare

1. Introduction

The relationship between environmental pollution and economic growth presents an inverted U-shaped environmental Kuznets curve [1,2]. China’s economic development level is still at the present stage of the neoclassical model [3], which is at the left of the U-shaped environmental Kuznets curve. However, environmental pollution increases the cost of social health and hinders sustained economic development and social welfare [4]. In order to reverse the trend of environmental and ecological deterioration, there is a need to integrate ecological civilization into economic construction and make the relationship between China’s economic growth and environmental reach the turning point and right side of the environmental Kuznets curve. The Chinese government has implemented a series of environmental regulation measures including laws and regulations, administrative regulations, and economic policies. For example, the state and local governments have issued more than 110 environmental documents [5], river chiefs and lake chiefs, a national carbon emissions trading system in 2017 [6], and an environmental tax in 2018 [7].
These implementations of environmental regulation policies have improved the environmental quality by effectively tackling the main sources of environment pollution. For example, in terms of air quality, the number of prefecture-level cities which met the air quality standards in 2018 increased by 6.5% compared with 2017, and the proportion of good air quality reached 79.3%. In terms of freshwater resources, the proportion of I–III water in 2018 was 71%, an increase of 6.5% compared with 2017. However, the effects of environmental regulation still have problems of regulatory objects and regional imbalances, large differences in economic damage, and unequal distribution of environmental benefits. For example, the air pollution control effect of the environmental regulation policy is better than the water pollution control effect [8], and in terms of the regional differences in the costs and benefits of the environmental regulation policy [9], the eastern region has shown an improvement in the quality of economic growth, while the central and western regions have shown a decline in the quality of economic growth [10]. These problems make the choice and implementation of environmental regulation policies difficult. Only by comprehensively analyzing the specific characteristics of environmental regulation and the conditions for implementing environmental regulations can we obtain the double dividend of improving the environmental quality and avoiding a loss of economic benefits [11–13].

Based on this background, this paper constructs social welfare models that include the government, firms, and consumers, based on the Cournot model, which is used to comprehensively analyze both market structure conditions of environmental regulation objects and environmental regulation measures. Additionally, a scenario analysis is used to analyze the social welfare effects of environmental regulation policies in different market environments.

This study reveals the relationship between environmental regulation policies, market structure, consumer preferences, and social welfare. To the best of our knowledge, this is the first paper to introduce consumer preferences and market structure into the social welfare impact of environmental regulation policies. More importantly, this study provides some new insights into the implementation of environmental regulation policies in the face of different market structures and consumer preferences.

First, unlike the current expectation of implementing environmental tax policies for environmental regulation, no matter what market structure the goods market is in, when environmental goods and non-environmental externalities cannot be measured, it is more appropriate to implement environmental subsidy policies. Second, the social welfare effects of environmental regulation policies are influenced by externalities, market structure, and consumer preferences, which can cause social welfare losses due to environmental regulation policies. Finally, when it is in a completely competitive market structure, but the externalities of goods are large, environmental regulation policies will bring the improvement of social welfare.

The remainder of this paper is organized as follows: Section 2 presents the most related literature review of the effect of environmental regulatory policies, such as tax policy and subsidy policies. The model settings including the Cournot model and equilibrium analysis are provided in Section 3. In Section 4, we continue to analyze the social welfare effects of environmental regulation policies. Five scenarios of three market structures are analyzed in Section 5. Finally, in the Conclusions, some suggestions and future research directions are summarized.

2. Literature Review

Environmental regulation policy is the key to achieving the double dividend of environmental pollution reduction and economic growth by bringing the relationship to the turning point of the Kuznets curve [14]. Because environmental taxation and environmental subsidy policies have the advantages of being low cost and having the ability to incentivize compatibility for polluters, they have become common policies in environmental regulation policies, but environmental governance effects vary according to different conditions [15].

The advantage of environmental taxation is that the difference between the marginal social cost and the private cost is once again applied to the enterprise cost through government taxation. However, there are differences in the effectiveness of environmental taxation policies because of the
difficulty in accurately measuring social costs and the structure of the tax system. Lu et al. [16] concluded that the environmental tax policy could not produce “blue dividends”, and Li et al. [17] found that if China strengthened the intensity of environmental regulation, it would reduce the economic growth rate by 1% through CGE model simulation. Goodstein [18] found that 3 million workers were unemployed within 15 years of the implementation of clean air regulations in the United States. An empirical study by Li and Zhu [19] found that the impact of environmental regulation on enterprise employment was significantly positive.

Environmental subsidies are usually incentives for the positive externalities of the environment, but the effects of environmental subsidies are also different. For example, the elimination of fossil energy subsidies to increase green energy subsidies was found to be conducive to reducing pollutant emissions [20,21] with a negligible impact on economic growth [22]. However, some scholars believe that the energy subsidy reform would cause certain losses to the economy [23]. On the other hand, technical subsidies improve the environmental quality by stimulating innovation to reduce environmental pollution, and the impact on the economy is also uncertain. The results of Wei and He [24] showed that technical subsidies could achieve economic growth while achieving energy conservation and emission reduction, while Nemet and Baker [25] thought that the effect of technical subsidies was uncertain on economic growth.

The effects of a combination of environmental taxes and environmental subsidies, remain different. Guo et al. [26] found that direct government funding and tax incentives could promote green technology innovation, but the promotion of government tax incentives to green technology innovation was not significant. Yuan and Zheng [27] found that the U-shaped relationship between environmental regulation and clean technology innovation was generally not affected by government subsidies. Additionally, the negative effects of environmental regulations on clean technology innovation would be weakened by government subsidies. Tong et al. [28] found that the combination of taxation, subsidies, and other policies could achieve economic pollution while ensuring economic growth by constructing a general equilibrium model. However, Yang [29] believed that the net impact of environmental taxation and environmental subsidies on clean technology innovation was positive, depending on the alternative elasticity of fossil energy and clean energy. The results of Bjørner [30] that environmental subsidy policies could improve resource utilization and reduce pollutants more than environmental tax policies.

In order to explain these differences and give environmental regulation policy recommendations, most scholars have used the neoclassical growth model, endogenous growth model, and dynamic general equilibrium model to assess the impacts of environmental regulation on environmental and economic factors through assessing the impacts of environmental pollution or environmental quality on consumer utility, health quality, and production function [31,32].

Both Li et al. [33] and Weng et al. [34] implemented research that is more related to our study. In their works, they consider the effect of regional imbalances on environment regulations, and propose a regional unbalanced carbon tax scheme. The main difference of their paper from our study is that they consider the regional imbalances and use an improved two-region computable general equilibrium (CGE) model, whereas we consider the perspective of market structure and use the improved Cournot model. Moreover, we investigate and compare the welfare of different environment regulations under different market structure and different consumer preferences.

However, the environmental and economic growth model, including consumers, businesses and governments, is flawed in that it cannot analyze the effects of environmental regulation from the perspective of market structure. Since the impacts of environmental regulation will be affected by different market structures, given that China is a developing country and the market economy is not perfect, it is necessary to consider the impact of the market structure on environmental regulation. In order to give full play to the effects of environmental regulation, it is necessary to achieve the dual benefit of environmental benefits and economic growth by guiding consumer preferences and using market mechanisms [35]. This direction is important both in theory and in policy practice.
However, it has not received the attention it deserves, so this paper constructs a social welfare function that includes the government, firms, and consumers. Additionally, we analyze the impacts of consumer preferences and market structure on the results of environmental regulation policies. Then, environmental protection recommendations are given for different market structures, consumer preferences, and externalities. Compared with the existing literature, the contribution of this paper lies in: (1) introducing the market structure perspective into the analysis of the effects of environmental regulation policies by combining consumer preferences and environmental regulation policies and (2) establishing the social welfare theory model including firms, governments, and consumers and applying it to analyze the social welfare effects of environmental regulation policies.

3. Model Formulation

3.1. Cost Function of Both Firm Types

Suppose there are two types of firms, environmental protection firms and non-environmental protection firms, whose outputs are environmentally friendly commodities and non-environmentally friendly commodities. Here, the difference between environmentally friendly goods and non-environmentally friendly products is that the production process uses clean technology and pollution technology, respectively, there is no difference in the output of goods, and there is an alternative between goods.

Drawing on the production functions of environmental and non-environmental firms defined by Acemoglu et al. [36] and Jing and Zhang [37], it is assumed that the cost of environmental protection firms is \( C^Y_i = A^Y(w + k)q^Y_i = c^Y_i q^Y_i \) and the quantity is \( \bar{N} \), while the cost of non-environmental protection firms is \( C^N_i = A^N(w + k)q^N_i = c^N_i q^N_i \) and the quantity is \( N \); \( w \) and \( k(j = Y, N) \) respectively represent labor and capital costs; \( A(j = Y, N) \) represents clean technology and pollution technology. Still following the assumptions of three scholars, the cost of environmental protection firms is higher than that of non-environmental protection firms, namely \( C^Y_i > C^N_i \).

3.2. Utility Function of the Consumer

In the traditional consumer selection function, consumer utility is only a function of the actual consumer goods and is not affected by the goods’ production process. However, with the development of environmental pollution and ecological damage, consumers are affected by survival and physical and mental health, so consumers not only pay attention to commodities but also to the production process of consumers, so consumer utility is also affected by the environmentally friendly production process. This is an extension of the traditional utility function in this paper, which is consistent with the utility functions of Andreoni and Levinson [38] and Lieb [39].

Using the utility function defined by Jason and Philip [40], therefore, the utility function of a representative consumer is represented by:

\[
U = y + (a + a^+) \sum N q^Y_i + (a + a^-) \sum N q^N_i - \frac{B}{2} \left( \frac{\sum N q^Y_i}{\sum N q^Y_i} \right)^2 + \left( \frac{\sum N q^N_i}{\sum N q^N_i} \right)^2 - b \left[ \left( \sum N q^Y_i \right) \left( \sum N q^N_i \right) \right] \tag{1}
\]

where \( y \) is a numeraire good, \( a, B \) and \( b \) are parameters, and \( B \geq b \). \( a^+ \) is positive and represents a preference for environmentally friendly goods; \( a^- \) is negative and represents a dislike. However, the terms \( a^+ \) and \( a^- \) represent perceived positive or negative non-market values that consumers can have for environmentally friendly commodities and non-environmentally friendly commodities, respectively. It is assumed that these preferences are unchanged across consumers. Both variables are necessary since the purchase of environmentally friendly commodities could mean an increase in demand for environmentally friendly goods or a decrease in demand for non-environmentally friendly goods. These differences in utility could arise from consumer attempts to internalize a perceived externality that they associate with an environmentally friendly goods or non-environmentally friendly goods.
3.3. Market Equilibrium

Consumers maximize utility under budget constraints, namely:

$$\text{Max } U = y + (a + a^+) \sum_i q_i^y + (a + a^-) \sum_i q_i^n - \frac{b}{2} \left[ \left( \sum_i q_i^y \right)^2 + \left( \sum_i q_i^n \right)^2 \right] - b \left[ \left( \sum_i q_i^y \right) \left( \sum_i q_i^n \right) \right]$$  \hspace{1cm} (2)

subject to:

$$p_i^y q_i^y + p_i^n q_i^n + y = m. \hspace{2cm} (3)$$

The profit equation for environmental protection firms and non-environmental firms is given by:

$$p_i^y = (a + a^+) - B \sum q_i^y - b \sum q_i^n \hspace{2cm} (4)$$

$$p_i^n = (a + a^-) - B \sum q_i^n - b \sum q_i^y. \hspace{2cm} (5)$$

From (4) and (5), the profit function of environmental firms and non-environmental firms can be obtained as follows:

$$\pi_i^y = q_i^y \left[ (a + a^+) - B \sum q_i^y - b \sum q_i^n \right] - A^Y (w + k) q_i^y \hspace{2cm} (6)$$

$$\pi_i^n = q_i^n \left[ (a + a^-) - B \sum q_i^n - b \sum q_i^y \right] - A^N (w + k) q_i^n. \hspace{2cm} (7)$$

Complementary slackness conditions for environmental firms without a comparative advantage are given by:

$$q_i^y \geq 0, a + a^+ - B(Q^Y + q_i^y) - bQ^N - A^Y (w + k) q_i^y \leq 0. \hspace{2cm} (8)$$

Complementary slackness conditions for non-environmental firms without a comparative advantage are given by:

$$q_i^n \geq 0, a + a^- - B(Q^N + q_i^n) - bQ^Y - A^N (w + k) q_i^n \leq 0. \hspace{2cm} (9)$$

If we assume symmetry for both type firms, the equilibrium quantities are as follows:

$$q_i^y = \frac{B(N + 1)(a + a^+ - A^Y (w + k)) - bN(a + a^- - A^N (w + k))}{B^2(N + 1)(N + 1) - b^2NN} \hspace{2cm} (10)$$

$$q_i^n = \frac{B(N + 1)(a + a^- - A^N (w + k)) - bN(a + a^+ - A^Y (w + k))}{B^2(N + 1)(N + 1) - b^2NN} \hspace{2cm} (11)$$

4. Welfare Effects of Environmental Regulation Policy

In our model, welfare is the difference between utility and costs, plus any externalities. Therefore, welfare is given by:

$$W = U - C^Y (Q^Y) - C^N (Q^N) + \Phi + \Psi. \hspace{2cm} (12)$$

Because environmentally friendly goods generally bring positive externalities, non-environmental products bring negative externalities. So, \( \Phi \) represents positive externalities and is greater than or equal to zero, and \( \Psi \) represents negative externalities and is less than or equal to zero.
### 4.1. Welfare Effects of Environmental Regulation Policy without Externalities

In this section, we focus on subsidies and taxes and assume that there are no externalities, namely \( \Phi = 0 \) and \( \Psi = 0 \). Demand changes either through a subsidy for environmentally friendly goods or a tax for non-environmentally friendly goods. A possible subsidy for environmentally friendly goods of \( \tau^+ \) and a possible tax for non-local goods of \( \tau^- \) give us similar demand functions to Equations (4) and (5), except the changes in demand come from taxes and subsidies \( \tau \) instead of environmentally friendly good preferences. Therefore, the marginal impacts of environmental subsidy policies and environmental tax policies on production are as follows:

\[
\frac{\partial q_i^Y}{\partial \tau^+} = \frac{\partial q_i^Y}{\partial \alpha^+} = \frac{B(N + 1)}{B^2(N + 1)(N + 1) - b^2\overline{N}N} > 0
\]  
(13)

\[
\frac{\partial q_i^N}{\partial \tau^+} = \frac{\partial q_i^N}{\partial \alpha^+} = \frac{-b\overline{N}}{B^2(N + 1)(N + 1) - b^2\overline{N}N} < 0
\]  
(14)

\[
\frac{\partial q_i^Y}{\partial \tau^-} = \frac{\partial q_i^Y}{\partial \alpha^-} = \frac{B(N + 1)}{B^2(N + 1)(N + 1) - b^2\overline{N}N} > 0
\]  
(15)

\[
\frac{\partial q_i^N}{\partial \tau^-} = \frac{\partial q_i^N}{\partial \alpha^-} = \frac{-b\overline{N}}{B^2(N + 1)(N + 1) - b^2\overline{N}N} < 0.
\]  
(16)

From (13) to (16), it can be seen that when one unit of environmentally friendly goods is subsidized by one unit, environmentally friendly goods are increased by \( \frac{B(N + 1)}{B^2(N + 1)(N + 1) - b^2\overline{N}N} \) and non-environmentally-friendly goods are decreased by \( \frac{-b\overline{N}}{B^2(N + 1)(N + 1) - b^2\overline{N}N} \). When one unit is taxed on non-environmental goods, the non-environmental goods are decreased by \( \frac{b\overline{N}}{B^2(N + 1)(N + 1) - b^2\overline{N}N} \) and environmentally-friendly goods are increased by \( \frac{b\overline{N}}{B^2(N + 1)(N + 1) - b^2\overline{N}N} \).

Due to the existence of \( \overline{N} \) environmental firms and \( N \) non-environmental firms, \( Q = Q^Y + Q^N = \overline{N}q_i^Y + Nq_i^N \), the marginal impacts of implementing environmental subsidy policies on environmentally friendly commodities or implementing environmental taxation policies on non-environmental commodities on the sum of commodities are as follows:

\[
\frac{\partial Q}{\partial \tau^+} = \frac{\partial Q}{\partial \alpha^+} = \frac{B(N + 1)\overline{N} - b\overline{N}\overline{N}}{B^2(N + 1)(N + 1) - b^2\overline{N}N}
\]  
(17)

\[
\frac{\partial Q}{\partial \tau^-} = \frac{\partial Q}{\partial \alpha^-} = \frac{B(N + 1)\overline{N} - b\overline{N}\overline{N}}{B^2(N + 1)(N + 1) - b^2\overline{N}N}.
\]  
(18)

When the numbers of environmental firms and non-environmental firms are the same, when one unit of environmentally friendly goods is subsidized or one unit of non-environmental-friendly goods is taxed, the total quantity of goods will be increased and decreased by the same number \( \frac{B(N + 1)\overline{N} - b\overline{N}\overline{N}}{B^2(N + 1)(N + 1) - b^2\overline{N}N} \). According to (12), the marginal impact of environmental subsidy policies on social welfare is as follows:

\[
\frac{dW}{d\tau^+} = \frac{B(N + 1)\overline{N}(a + \alpha^+ - A^Y(w + k)) - B(N + 1)\overline{N}(a + \alpha^- - A^N(w + k))}{B(N + 1)\overline{N}(a + \alpha^+ - A^Y(w + k)) - B(N + 1)\overline{N}(a + \alpha^- - A^N(w + k))}.
\]  
(19)
When the market is a competitive market, the marginal impact of environmental subsidy policies on social welfare is:

$$\frac{dW}{d\tau^+} = B\left(q_i^\gamma \frac{dQ_i^Y}{d\tau^+} + q_i^N \frac{dQ_i^N}{d\tau^+}\right). \quad (20)$$

Similarly, the marginal impact of environmental taxation policies on social welfare is:

$$\frac{dW}{d\tau^+} = \frac{B(N+1)N(a+\alpha^- - A_Y(w+k)) - bNN(a+\alpha^- - A_Y(w+k))}{B^2(N+1)(N+1) - b^2NN} - B\left(q_i^\gamma \frac{dQ_i^Y}{d\tau^+} + q_i^N \frac{dQ_i^N}{d\tau^+}\right). \quad (21)$$

When the market is a competitive market, the marginal impact of environmental taxation policies on social welfare is:

$$\frac{dW}{d\tau^-} = B\left(q_i^\gamma \frac{dQ_i^Y}{d\tau^-} + q_i^N \frac{dQ_i^N}{d\tau^-}\right). \quad (22)$$

From (19) and (21), it can be seen that the marginal impacts of environmental taxation policies and environmental subsidy policies on social welfare are vague when the market is a non-competitive market without considering externalities. From Equations (20) and (22), it can be seen that when the market is a competitive market, the social welfare effect increases when the subsidies for environmentally friendly goods increase, and the social welfare effect decreases when the tax increases for non-environmental products.

### 4.2. Welfare Effects of Environmental Regulation Policy with Externalities

The concept and theory of externalities have been fully researched and developed, and the discussion of them is beyond the scope of this article. The externality theory of this paper follows the externality theory in Pigou’s welfare economics, which is caused by the influence of enterprise production on other producers and the difference between social cost and private cost (or social income and private income). Therefore, the government needs to implement a tax policy or a subsidy policy to correct it.

We assume that externality is a function of the good, namely $\Phi = qN(q_i^Y)$ and $\Psi = \psi N(q_i^N)$, where $\varphi > 0$, $\psi < 0$. According to the analysis of the environmental subsidy policy, when the environmental subsidy policy is implemented for environmentally friendly commodities, the marginal impact of the externality is:

$$\frac{d\Phi}{d\tau^+} = \frac{d\Phi}{d\alpha^+} = \frac{qN B(N+1)}{B^2(N+1)(N+1) - b^2NN} \quad (23)$$

$$\frac{d\Psi}{d\tau^+} = \frac{d\Psi}{d\alpha^+} = -\psi Nb \frac{N}{B^2(N+1)(N+1) - b^2NN}. \quad (24)$$

The marginal impact of implementing environmental subsidy policies on the overall social welfare is:

$$\frac{dW}{d\tau^+} = \frac{d\Phi}{d\tau^+} + \frac{d\Psi}{d\tau^+} + B(N+1)N(a+\alpha^- - A_Y(w+k)) - B(N+1)N(a+\alpha^- - A_Y(w+k)) - B\left(q_i^\gamma \frac{dQ_i^Y}{d\tau^+} + q_i^N \frac{dQ_i^N}{d\tau^+}\right) \quad (25)$$

When the market is a competitive market, the overall social welfare marginal impact is:

$$\frac{dW}{d\tau^+} = \frac{d\Phi}{d\tau^+} + \frac{d\Psi}{d\tau^+} + B\left(q_i^\gamma \frac{dQ_i^Y}{d\tau^+} + q_i^N \frac{dQ_i^N}{d\tau^+}\right). \quad (26)$$
Similarly, when implementing environmental tax policies for non-environmental goods, the marginal impact of externalities is:

\[
\frac{d\Psi}{d\tau} = \frac{d\Psi}{d\alpha} = \frac{\psi N B(N + 1)}{B^2(N + 1)(N + 1) - b^2N^2} \tag{27}
\]

\[
\frac{d\Phi}{d\tau} = \frac{d\Phi}{d\alpha} = \frac{-\phi N b N}{B^2(N + 1)(N + 1) - b^2N^2} \tag{28}
\]

The marginal impact of implementing an environmental tax policy on overall social welfare is:

\[
\frac{dW}{d\tau} = \frac{d\Phi}{d\tau} + \frac{d\Psi}{d\tau} - B(N + 1)N(a + \alpha^+ - A^N(w + k)) - B(N + 1)N(a + \alpha^- - A^N(w + k)) - B\left(q_i^Y \frac{dQ^Y}{d\tau} + q_i^N \frac{dQ^N}{d\tau}\right) \tag{29}
\]

When the market is a competitive market, the overall social welfare marginal impact is:

\[
\frac{dW}{d\tau} = \frac{d\Phi}{d\tau} + \frac{d\Psi}{d\tau} + B\left(q_i^Y \frac{dQ^Y}{d\tau} + q_i^N \frac{dQ^N}{d\tau}\right) \tag{30}
\]

From (25) and (29), it can be seen that when considering the externalities, when the market is a non-competitive market, the overall social welfare effect of the environmental tax policy and the environmental subsidy policy is vague. From (26) and (30), it can be seen that when the market is a competitive market, the overall social welfare effect increases when the subsidies for environmentally friendly goods increase, and the overall social welfare effect decreases when the tax increases for non-environmental products.

5. Scenario Analysis of Environmental Regulation Policies

This section sets specific parameters to analyze the social welfare effects of environmental regulation policies under different situations. Here, we provide hypothetical numerical examples where \(a = 10\), \(B = 1\), \(b = 0.5\), \(c^Y = 1.5\), \(c^N = 1\) and \((\alpha^+, \alpha^-)\) are \((0,0)\), \((1,0)\), \((0, -1)\), \((0.5, -0.5)\) and \((1, -1)\), which respectively represent five different preference scenarios.

5.1. Competitive Market

In the case of a perfect competitive market equilibrium, prices equal marginal costs. At this time, the consumer surplus and social welfare are maximized. Since there are no economic profits in competitive markets, welfare is equal to the consumer surplus plus any tax payments received or minus any subsidy payments made by a governing body. Since corporate profits are zero, corporate profits are not listed in Table 1; in addition, externalities are listed separately and are not part of \(W\), because externalities cannot be measured by tools such as price.
Table 1. Competitive Example

| α⁺ | 0 | 1 | 0 | 0.5 | 1 |
|---|---|---|---|-----|---|
| α⁻ | 0 | 0 | -1 | -0.5 | -1 |
| Q^Y | 5.33 | 6.67 | 6.00 | 6.33 | 7.33 |
| Q^N | 6.33 | 5.67 | 5.00 | 5.33 | 4.33 |
| W | 51.17 | 57.17 | 45.50 | 51.17 | 52.17 |
| Externalities | 5.33Φ + 6.33Ψ | 6.67Φ + 5.67Ψ | 6.00Φ + 5.00Ψ | 6.33Φ + 5.33Ψ | 7.33Φ + 4.33Ψ |

Subsidy of 1 for Q^Y

| Q^Y | 6.67 | 8.00 | 7.33 | 7.67 | 8.67 |
| Q^N | 5.67 | 5.00 | 4.33 | 4.67 | 3.67 |
| W | 50.50 | 56.50 | 44.83 | 50.50 | 51.50 |
| Externalities | 6.67Φ + 5.67Ψ | 8.00Φ + 5.00Ψ | 7.33Φ + 4.33Ψ | 7.67Φ + 4.67Ψ | 8.67Φ + 3.67Ψ |

Tax of 1 for Q^N

| Q^Y | 6.00 | 7.33 | 6.67 | 7.00 | 8.00 |
| Q^N | 5.00 | 4.33 | 3.67 | 4.00 | 3.00 |
| W | 50.50 | 56.50 | 44.83 | 50.50 | 51.50 |
| Externalities | 6.00Φ + 5.00Ψ | 7.33Φ + 4.33Ψ | 6.67Φ + 3.67Ψ | 7.00Φ + 4.00Ψ | 8.00Φ + 3.00Ψ |

Consumer preferences for environmentally friendly and non-environmentally friendly products can have an impact on goods production. From the first column to the third column in Table 1, we can see that when environmentally friendly goods are preferred, namely α⁺ = 1, the output of environmentally friendly goods will be improved and the number of non-environmentally friendly products will be reduced, but overall more goods will be produced. When non-environmentally friendly good consumption is reduced, namely α⁻ = -1, the output of environmentally friendly goods will be improved and the number of non-environmentally friendly products will be reduced, but fewer goods will be produced overall. When the preference for environmentally friendly goods and the aversion to non-environmentally friendly goods exist simultaneously, namely α⁺ = 0.5 and α⁻ = -0.5, the output of environmentally friendly goods will be improved, the number of non-environmentally friendly products will be reduced, and the overall quantity will be unchanged.

Regardless of which preference is present, when a one-unit subsidy is applied to environmentally friendly goods, the output of environmentally friendly commodities will be increased, and the output of non-environmentally friendly commodities will be reduced, and the total output will be increased. When a unit of tax is applied to environmentally friendly goods, the output of environmentally friendly commodities will be increased, the output of non-environmentally friendly commodities will be reduced, and the total output will be decreased.

We observe from Table 1 that regardless of whether it an environmental subsidy policy or an environmental tax policy is implemented, social welfare is reduced when we do not consider these externalities. Only through external adjustment can social welfare be improved. This conclusion is consistent with the first theorem of social welfare, that is, the optimal allocation of social resources and the Pareto optimally are achieved in a perfectly competitive market equilibrium, and there is no way to improve social welfare. Therefore, implementing environmental tax policies and environmental subsidy policies will reduce social welfare without considering externalities.

5.2. Market Power

Regarding the numerical case of market power, ten enterprises and one enterprise of each type are respectively set up to represent different market forces, just like the oligopoly and monopolistic...
competition market in market theory. The results of the relevant parameters are listed in Tables 2 and 3, respectively. Different from Table 1, because the market forces exist, the company obtains positive profits, so the company’s profits are listed in Tables 2 and 3. When there is no preference for environmentally friendly goods and no preference for non-environmental products, the profits of environmentally friendly companies and non-environmental companies will increase accordingly.

Table 2. Ten Firms of Each Type.

| α⁺ | 0 | 1 | 0 | 0.5 | 1 |
|----|---|---|---|-----|---|
| α⁻ | 0 | 0 | −1 | −0.5 | −1 |

No subsidies or taxes

| Q_Y | 5.05 | 6.20 | 5.57 | 5.89 | 6.72 |
|-----|------|------|------|------|------|
| Q_N | 5.89 | 5.36 | 4.74 | 5.05 | 4.22 |
| π_Y | 2.55 | 3.84 | 3.11 | 3.46 | 4.51 |
| π_N | 3.46 | 2.88 | 2.25 | 2.55 | 1.78 |
| CS  | 44.95 | 50.22 | 39.97 | 44.95 | 45.64 |
| W   | 50.96 | 56.94 | 45.32 | 50.96 | 51.94 |

Externalities

| 5.05Φ + 5.89Ψ | 6.20Φ + 5.36Ψ | 5.57Φ + 4.74Ψ | 5.89Φ + 5.05Ψ | 6.72Φ + 4.22Ψ |
|----------------|----------------|----------------|----------------|----------------|

Subsidy of 1 for Q_Y

| Q_Y | 6.20 | 7.34 | 6.72 | 7.03 | 7.86 |
|-----|------|------|------|------|------|
| Q_N | 5.36 | 4.84 | 4.22 | 4.53 | 3.70 |
| π_Y | 3.84 | 5.39 | 4.51 | 4.94 | 6.19 |
| π_N | 2.88 | 2.35 | 1.78 | 2.05 | 1.37 |
| CS  | 50.22 | 56.48 | 45.64 | 50.92 | 52.30 |
| W   | 50.74 | 56.88 | 45.22 | 50.88 | 51.99 |

Externalities

| 6.20Φ + 5.36Ψ | 7.34Φ + 4.84Ψ | 6.72Φ + 4.22Ψ | 7.03Φ + 4.53Ψ | 7.86Φ + 3.70Ψ |
|----------------|----------------|----------------|----------------|----------------|

Tax of 1 for Q_N

| Q_Y | 5.57 | 6.72 | 6.09 | 6.41 | 7.24 |
|-----|------|------|------|------|------|
| Q_N | 4.74 | 4.22 | 3.59 | 3.91 | 3.07 |
| π_Y | 3.11 | 4.51 | 3.71 | 4.10 | 5.24 |
| π_N | 2.25 | 1.78 | 1.29 | 1.53 | 0.94 |
| CS  | 39.97 | 45.64 | 35.97 | 40.66 | 42.05 |
| W   | 50.06 | 56.15 | 44.57 | 50.20 | 51.31 |

Externalities

| 5.57Φ + 4.74Ψ | 6.72Φ + 4.22Ψ | 6.09Φ + 3.59Ψ | 6.41Φ + 3.91Ψ | 7.24Φ + 3.07Ψ |
|----------------|----------------|----------------|----------------|----------------|

Unlike a perfectly competitive market, social welfare changes are different when subsidies are applied to environmentally friendly goods. By comparing Tables 2 and 3, it can be seen that when there is only one enterprise per type, regardless of the preference, environmental subsidy policies for environmentally friendly commodities will increase social welfare accordingly. However, when there are 10 enterprises for each type of goods, when implementing environmental subsidy policies for environmentally friendly goods, social welfare will increase only in terms of the preference for environmentally friendly goods and the non-preference for non-environmentally friendly products, but it will decrease in other situations. In summary, the effect of implementing environmental subsidy policies for environmentally friendly commodities on social welfare will be affected by market power and consumer preferences.

In the same way as a perfectly competitive market, when taxation is imposed on non-environmental goods without considering negative externalities, any preference will reduce social welfare, because
the impact of taxation on the reduction of non-environmentally friendly commodity production is greater than the impact on the increase in the production of environmentally friendly commodities.

Based on the above, without considering the influence of externalities, the social welfare effect of the government’s implementation of environmental subsidy policies is better than the social welfare effect of implementing environmental tax policies through comparing the social welfare effects of environmental taxation policies and environmental subsidy policies.

Table 3. One Firm of Each Type.

| α*  | 0    | 1    | 0    | 0.5  | 1    |
|-----|------|------|------|------|------|
| α−  | 0    | 0    | −1   | −0.5 | −1   |

No subsidies or taxes

|       |         |       |       |       |       |
|-------|---------|-------|-------|-------|-------|
| QY    | 3.33    | 3.87  | 3.47  | 3.67  | 4.00  |
| QN    | 3.67    | 3.53  | 3.13  | 3.33  | 3.00  |
| πY    | 11.11   | 14.95 | 12.02 | 13.44 | 16.00 |
| πN    | 13.44   | 12.48 | 9.82  | 11.11 | 9.00  |
| CS    | 18.39   | 20.55 | 16.35 | 18.39 | 18.50 |
| W     | 42.94   | 47.98 | 38.18 | 42.94 | 43.50 |

Externalities

|       | 3.33Φ + 3.67Ψ | 3.87Φ + 3.53Ψ | 3.47Φ + 3.13Ψ | 3.67Φ + 3.33Ψ | 4.00Φ + 3.00Ψ |

Subsidy of 1 for QY

|       |         |       |       |       |       |
|-------|---------|-------|-------|-------|-------|
| QY    | 3.87    | 4.40  | 4.00  | 4.20  | 4.53  |
| QN    | 3.53    | 3.40  | 3.00  | 3.20  | 2.87  |
| πY    | 14.95   | 19.36 | 16.00 | 17.64 | 20.55 |
| πN    | 12.48   | 11.56 | 9.00  | 10.24 | 8.22  |
| CS    | 20.55   | 22.94 | 18.50 | 20.66 | 20.88 |
| W     | 44.12   | 49.46 | 39.50 | 44.34 | 45.12 |

Externalities

|       | 3.87Φ + 3.53Ψ | 4.40Φ + 3.40Ψ | 4.00Ψ + 3.00Ψ | 4.20Φ + 3.20Ψ | 4.53Φ + 2.87Ψ |

Tax of 1 for QN

|       |         |       |       |       |       |
|-------|---------|-------|-------|-------|-------|
| QY    | 3.47    | 4.00  | 3.60  | 3.80  | 4.13  |
| QN    | 3.13    | 3.00  | 2.60  | 2.80  | 2.47  |
| πY    | 12.02   | 16.00 | 12.96 | 14.44 | 17.08 |
| πN    | 9.82    | 9.00  | 6.76  | 7.84  | 6.08  |
| CS    | 16.35   | 18.50 | 14.54 | 16.46 | 16.68 |
| W     | 41.32   | 46.50 | 36.86 | 41.54 | 42.32 |

Externalities

|       | 3.47Φ + 3.13Ψ | 4.00Φ + 3.00Ψ | 3.60Φ + 2.60Ψ | 3.80Φ + 2.80Ψ | 4.13Φ + 2.47Ψ |

5.3. Externalities

The implementation of both environmental subsidy policies for environmentally friendly commodities and environmental taxation policies for non-environmentally friendly commodities are related to positive externalities and negative externalities that cannot be market-priced. After considering externalities, the optimal environmental regulation policy options will be changed due to the positive and negative externalities and size.

In a fully competitive market, social welfare will be reduced when environmental subsidies are used for environmentally friendly goods or environmental tax policies are used for non-environmentally friendly goods if externalities are not considered. However, considering the externalities, as long as the positive externalities of environmentally friendly goods and the negative externalities of non-environmentally friendly goods are in the (0, 0.335) and (−0.335, 0) range, the social welfare effects
of implementing subsidies or taxation policies are the same, as shown in Table 4. When deviating from the critical value, that is, when the positive externalities and the negative externalities are not located in the same interval of \((0, 0.335)\) and \((-0.335, 0)\), i.e., they are located in the interval of \((0.5, +\infty)\) and \((-\infty, 0)\), social welfare will be increased whether an environmental subsidy policy or an environmental tax policy is implemented.

Table 4. Externality threshold in a competitive market.

| \((a^+, a^-)\) | (0,0) | (1,0) | (0,−1) | (0.5,−0.5) | (1,−1) |
|---------------|-------|-------|---------|-------------|---------|
| No taxes or Subsidies | (0.335,−0.335) | (0.335,−0.335) | (0.335,−0.335) | (0.335,−0.335) | (0.335,−0.335) |
| W | 50.835 | 50.835 | 50.835 | 50.835 | 50.835 |
| Subsidies | 50.835 | 50.835 | 50.835 | 50.835 | 50.835 |
| Taxes | 50.835 | 50.835 | 50.835 | 50.835 | 50.835 |

In a market with market power, if the externalities are not considered, the social welfare effect of implementing environmental subsidy policies for environmentally friendly commodities is higher than the social welfare effect of implementing taxation policies for non-environmentally friendly commodities. However, after considering the externalities, as long as the absolute value of the negative externalities minus the positive externalities is greater than 7.4, the social welfare effect of implementing environmental taxation policies for non-environmentally friendly goods is higher than that of environmental protection products. The relevant results are listed in Table 5.

Table 5. Externality threshold under monopoly market power.

| \((a^+, a^-)\) | (0,0) | (1,0) | (0,−1) | (0.5,−0.5) | (1,−1) |
|---------------|-------|-------|---------|-------------|---------|
| No taxes or Subsidies | (0,−7.4) | (0,−7.4) | (0,−7.4) | (0,−7.4) | (0,−7.4) |
| W(One Firm) | 15.782 | 21.858 | 15.018 | 18.298 | 21.3 |
| Subsidies | 17.998 | 24.3 | 17.3 | 20.66 | 23.882 |
| Taxes | 18.158 | 24.3 | 17.62 | 20.82 | 24.042 |
| No taxes or Subsidies | (0,0.335) | (0,0.335) | (0,0.335) | (0,0.335) | (0,0.335) |
| W(Ten Firms) | 7.374 | 17.276 | 10.244 | 13.59 | 20.712 |
| Subsidies | 11.076 | 21.064 | 13.992 | 17.358 | 24.61 |
| Taxes | 14.984 | 21.922 | 18.004 | 21.266 | 28.592 |

6. Conclusions

Based on the Cournot model, this study constructed a social welfare model including government, enterprises, and consumers. Additionally, this model was used to comprehensively analyze both the market structure conditions of environmental regulation objects (the production processes of both firm types adopt cleaning technology and pollution technology respectively, but the output of both type firms is a substitute) and environmental regulation measures (cleaning technology subsidies and environmental pollution taxes). By introducing consumer preferences, we analyzed the social welfare effects of environmental tax policies and environmental subsidy policies under different scenarios in order to provide a theoretical explanation for the existence of different effects of environmental regulation, different types of economic damage, and an unequal distribution of environmental benefits. Our conclusions are as follows:

First, the social welfare effects of environmental subsidy policies and environmental tax policies will be affected by externalities, market structure, and consumer preferences. When the market power and externalities cannot be measured, it is impossible to accurately estimate the social welfare effects of both environmental regulation policies. Second, regardless of whether the market structure is a completely competitive market or a monopoly market, when the absolute difference between the external value of environmentally friendly goods and non-environmentally friendly goods is less than 7.4 units, the social welfare effect of environmental subsidy policy is greater than the social welfare effect of environmental tax policy. Third, when the market structure is a completely competitive market and when the externalities of both environmentally friendly commodities and non-environmentally...
friendly commodities are not the same at intervals (0, 0.335) and (−0.335, 0), the social welfare will be improved by the implementation of environmental subsidy policies or environmental tax policies. Fourth, when the market structure is completely competitive and the externalities are small, that is, in the interval (0, 0.335) and (−0.335, 0), the social welfare will be reduced by the implementation of environmental subsidy policies or environmental tax policies.

The theoretical analysis and numerical simulation results can provide suggestions for implementing environmental regulation policies. On the one hand, unlike the current expectation of implementing environmental taxation policies no matter what market structure the commodity market is in, when the environmentally friendly goods and non-environmental externalities cannot be measured, the government implements environmental subsidy policies more appropriately. On the other hand, when environmentally friendly commodities and non-environmental commodities are close to a perfectly competitive market structure and their externalities are small, the government can realize the trend of market development toward environmentally friendly commodities by cultivating and guiding consumer preferences and utilizing the market’s own strength.

Although this paper introduces market structure and consumer preferences into the analysis of environmental regulation policies, it is limited to a comparatively static analysis and cannot reflect the dynamic changes of environmental pollution or governance. This has been reflected in previous scholars’ research. Therefore, in future research, the integration of market structure and consumer preferences with neoclassical growth models, endogenous growth models, or dynamic general equilibrium models will be worthwhile.

**Author Contributions:** J.L. designed the entire research framework and coordinated the work; L.W. performed the research and wrote the paper. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by The National Social Science Fund of China (16AGL012), for which we express our gratitude here.

**Conflicts of Interest:** The authors declare no conflict of interest.

**References**

1. Grossman, G.M.; Krueger, A.B. *Environmental Impacts of a North-American Free-Trade Agreement*; NBER: Cambridge, MA, USA, 1993; pp. 13–56.
2. Selden, T.M.; Song, D.Q. Neoclassical growth, the j-curve for abatement, and the inverted u-curve for pollution. *J. Environ. Econ. Manag.* 1995, 29, 162–168. [CrossRef]
3. Li, D.; Xu, X.; Jiang, H. An analysis of the welfare economics of China’s economic national investment rate. *Econ. Res. J.* 2012, 47, 46–56.
4. Chen, S.; He, L. Environment, health and economic growth: A study of optimal energy tax income distribution. *Econ. Res. J.* 2017, 52, 120–134.
5. Bao, Q.; Shao, M. Does environmental regulation inhibit pollution emissions? *Econ. Res. J.* 2013, 48, 42–54.
6. Wang, Y.; Zhao, H. The impact of China’s carbon trading market on regional carbon emission efficiency. *China Popul. Resour. Environ.* 2019, 29, 50–58.
7. Fan, Q. Environmental regulation, income distribution imbalance and government compensation mechanism. *Econ. Res. J.* 2018, 53, 14–27.
8. Cao, Y.-H.; You, J.-X.; Liu, H.-C. Optimal environmental regulation intensity of manufacturing technology innovation in view of pollution heterogeneity. *Sustainability* 2017, 9, 1240. [CrossRef]
9. Wang, J.; Ma, H.; Cao, Q.; Ma, Y. Cost-benefit measurement and mode selection of regional environmental governance in China. *Economist* 2017, 67–77.
10. Huang, Q.; Gao, M. The quantitative and qualitative effects of environmental regulation on economic growth—Based on the test of simultaneous equations. *Economist* 2016, 53–62.
11. Pearce, D. The role of carbon taxes in adjusting to global warming. *Econ. J.* 1991, 101, 938–948. [CrossRef]
12. Patuelli, R.; Nijkamp, P.; Pels, E. Environmental tax reform and the double dividend: A meta-analytical performance assessment. *Ecol. Econ.* 2005, 55, 564–583. [CrossRef]
13. Bovenberg, A.L.; de Mooij, R.A. Environmental tax reform and endogenous growth. *J. Public Econ.* 1997, 63, 207–237. [CrossRef]
14. Porter, M.E.; Vanderlinde, C. Toward a new conception of the environment-competitiveness relationship. *J. Econ. Perspect.* 1995, 9, 97–118. [CrossRef]
15. Tao, J.; Hu, X. Research on the impact of environmental regulation on the quality of China’s economic growth. *China Popul. Resour. Environ.* 2019, 29, 85–96.
16. Lu, H.; Liu, Q.; Xu, X.; Yang, N. Can environmental protection tax achieve “decontamination” and “growth”?—Based on the perspective of China’s sewage charges. *China Popul. Resour. Environ.* 2019, 29, 130–137.
17. Li, G.; Dong, M. Strengthening the impact of environmental regulation policies on the chinese economy—Based on the assessment of the cge model. *China Ind. Econ.* 2014, 4, 5–17.
18. Goodstein, E. Jobs and the environment: An overview. *Environ. Manag.* 1996, 20, 313–321. [CrossRef]
19. Li, D.; Zhu, J. The role of environmental regulation and technological innovation in the employment of manufacturing enterprises: Evidence from China. *Sustainability* 2019, 11, 2982. [CrossRef]
20. Schmitt, D. What prospects for coal subsidies—Concluding comment. *Energy Policy* 1995, 23, 557. [CrossRef]
21. Shi, G.; Zhou, L.; Zheng, S.; Zhang, Y. Environmental subsidies and pollution control—Based on empirical research in the power industry. *Econ. Res. J.* 2016, 15, 1439–1462.
22. Welsch, H. Coal subsidization and nuclear phase-out in a general equilibrium model for germany. *Energy Econ.* 1998, 20, 203–222. [CrossRef]
23. Yao, X.; Jiang, Z. Reforming fossil energy subsidies can support clean energy development. *J. Financ. Res.* 2011, 184–197.
24. Wei, W.; He, X. R&d subsidies and sustainable growth—Scenario analysis based on dynamic computable general equilibrium. *Econ. Manag. J.* 2013, 35, 1–12.
25. Nemet, G.F.; Baker, E. Demand subsidies versus r&d: Comparing the uncertain impacts of policy on a pre-commercial low-carbon energy technology. *Energy J.* 2009, 30, 49–80.
26. Guo, Y.; Xia, X.; Zhang, S.; Zhang, D. Environmental regulation, government r&d funding and green technology innovation: Evidence from China provincial data. *Sustainability* 2018, 10, 940.
27. Yuan, L.; Zheng, X. The coupling effect of environmental regulation and government subsidies on technological innovation of enterprises. *Resour. Sci.* 2017, 39, 911–923.
28. Tong, J.; Wu, K.; Xue, J. Research on the optimal allocation of China’s environmental finance and taxation system—on the ways to realize the coordinated development of economic growth and environmental governance. *Nankai Econ. Stud.* 2017, 6, 40–58.
29. Yang, F. Environmental taxes, environmental subsidies and clean technology innovation: Theory and experience. *Collect. Essays Financ. Econ.* 2017, 8, 19–27.
30. Bjørner, T.B.; Jensen, H.H. Energy taxes, voluntary agreements and investment subsidies—a micro-panel analysis of the effect on danish industrial companies’ energy demand. *Resour. Energy Econ.* 2002, 24, 229–249. [CrossRef]
31. Fan, Q.; Zhou, X.; Zhang, T. Dynamic environmental tax externality, pollution accumulation path and long-term economic growth—Also on the choice of environmental tax levy point. *Econ. Res. J.* 2016, 51, 116–128.
32. Huang, M.; Lin, S. Pollution damage, environmental management and sustainable economic growth—Based on an analysis of the five-sector endogenous economic growth model. *Econ. Res. J.* 2013, 48, 30–41.
33. Li, Z.; Dai, H.; Sun, L.; Xie, Y.; Liu, Z.; Wang, P.; Yabar, H. Exploring the impacts of regional unbalanced carbon tax on co2 emissions and industrial competitiveness in liaoning province of China. *Energy Policy* 2018, 113, 9–19. [CrossRef]
34. Weng, Z.; Dai, H.; Ma, Z.; Xie, Y.; Wang, P. A general equilibrium assessment of economic impacts of provincial unbalanced carbon intensity targets in China. *Resour. Conserv. Recycl.* 2018, 133, 157–168. [CrossRef]
35. Yu, L.; Zhang, W.; Bi, Q. Research on the effect of environmental tax on the green transformation of enterprises. *China Popul. Resour. Environ.* 2019, 29, 112–120.
36. Acemoglu, D.; Aghion, P.; Bursztyn, L.; Hemous, D. The environment and directed technical change. *Am. Econ. Rev.* 2012, 102, 131–166. [CrossRef]
37. Jing, W.; Zhang, L. Environmental regulation, opening up and green technology advancement of Chinese industry. *Econ. Res. J.* 2014, 49, 34–47.
38. Andreoni, J.; Levinson, A. The simple analytics of the environmental kuznets curve. *J. Public Econ.* **2001**, *80*, 269–286. [CrossRef]

39. Lieb, C.M. The environmental kuznets curve and flow versus stock pollution: The neglect of future damages. *Environ. Resour. Econ.* **2004**, *29*, 483–506. [CrossRef]

40. Winfree, J.; Watson, P. The welfare economics of “buy local”. *Am. J. Agric. Econ.* **2017**, *99*, 971–987. [CrossRef]