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Modeling the Linkage between Vertical Contracts and Strategic Environmental Policy: Energy Price Marketization Level and Strategic Choice for China

Ying Li [1], Wing-Keung Wong [2,3,4], Ming Jing Yang [5], Yang-Che Wu [5,*] and Tien-Trung Nguyen [6]

[1] China Center for Special Economic Zone Research, Shenzhen University, Shenzhen 518060, China; liying11@szu.edu.cn
[2] Department of Finance, Fintech & Blockchain Research Center, and Big Data Research Center, Asia University, Taichung City 41354, Taiwan; wong@asia.edu.tw
[3] Department of Medical Research, China Medical University Hospital, Taichung City 40402, Taiwan
[4] Department of Economics and Finance, The Hang Seng University of Hong Kong, Hongkong 999077, China
[5] Department of Finance, College of Finance, Feng Chia University, Taichung 40724, Taiwan; mjyang@fcu.edu.tw
[6] Faculty of Accounting and Finance, Nguyen Tat Thanh University, Ho Chi Minh 70000, Vietnam; trungblc@gmail.com
* Correspondence: wuyangche@fcu.edu.tw

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Abstract: The lower price of energy leads to higher coal consumption in China. The idea of an "environment-for-trade policy" could be used to achieve an international competitive advantage, which, in turn, has important implications. To address the issue, we develop properties to examine the link between the low price of energy and strategic environmental policy in China and investigate the choice of policy instruments in a strategic environmental policy model with vertical contracts. In addition, to contribute to the literature on strategic environmental policy, this paper also develops properties to investigate different choices of instruments for the environmental policy and includes the degree of energy marketization for the wholesale price in the study. To do so, we assume that the wholesale price of the polluting input increases with the market price. By using this assumption, this paper analyzes the effects of two instruments of the environmental policy on social welfare and concludes that there is no reason to expect both downstream and upstream firms to establish a high wholesale price. Due to the low level of marketization, when the government selects an emission tax as the policy instrument, the optimal tax rates should be higher than the marginal damage of emissions. However, the optimal resource tax is uncertain when its effect on environmental damage is taken into account. In other words, the resource tax is ineffective as a policy instrument. Our results can be used to draw some practical policies for countries to use their energy effectively. To promote energy sustainability, governments should liberate resource prices and reform the system to get efficient environmental policies.

Keywords: strategic environmental policy; marketization degree; vertical structure

1. Introduction

China is the world's largest producer and consumer of coal, accounting for approximately 47.5% of global coal production and 50.2% of global consumption (according to the BP Statistical Review of World Energy, updated 2020). Since China introduced reforms and opening-up, coal consumption has increased annually by 6.82%, while China's GDP has increased at a 9.5% annual pace, confronted by energy shortages and environmental pollution. China intends to reach a carbon peak by 2030 and become carbon neutral by 2060 which means giant coal reduction. Though China's coal power policy has alleviated the overcapacity problem of coal power generation [1], it is difficult for China to announce a "coal phase-out" at present [2]. Therefore, it is necessary to conduct further research on the effectiveness of energy policy in the context of carbon neutrality.

One explanation for China's high coal consumption is the low price of coal. Stavropoulos et al. [3] demonstrated a U-shaped relationship between China's environmental regulations and industrial competitiveness. Wu et al. [4] also showed that there was a U-shaped relationship between environmental regulation and green total factor energy efficiency in China. At the industry level, Wu and Lin [5] demonstrated a U-shaped relationship between environmental regulation and efficiency in China's iron and steel industry. From the above empirical results, it can be seen that the government has compromised environmental regulations to gain a competitive advantage. The low price of coal reduces the incentive to eliminate outdated industrial capacity and suppresses the input of R&D, which in turn is a key factor (along with the low cycling deadlock) responsible for the insufficiency of innovation dynamics and the weak industrial upgrading. The low price of coal drives an economy powered by coal consumption and environmental damage. The above literature provides the background for the present study of "environment-for-trade policy" which is based on the strategic environmental policy model.

In this paper, we extend the literature on strategic environmental policy to investigate the choice of environmental policy instruments when the energy marketization degree of the wholesale price is included. Some relevant studies, see, for example, Liu et al. [6], Dai and Cheng [7], Ouyang et al. [8], Li et al. [9], Tan and Lin [10], and Sha et al. [11], have shown that the marketization level of energy prices in China is low, implying that the energy prices in China have been distorted seriously. For example, Liu et al. [6] showed that all the energy price distortion indexes in China are greater than one every year between 2003 and 2017, reflecting that the energy prices have been subsidized heavily in general in China. Thus, the marketization level of energy prices in China is a very important problem. To bridge a gap in the literature, we contribute to the literature to address the issue by including the energy marketization degree of the wholesale price in this study. The main questions to be addressed are the following: Is there a low energy price and large energy consumption when vertical contracts of upstream and downstream firms are allowed? Which kind of environmental policy instrument should be implemented?

The remainder of the paper is organized as follows. In Section 2, we present the model. In Section 3, we analyze the optimal marketization degree of the wholesale price. In Sections 4 and 5, we discuss the optimal resource tax and the environmental tax, respectively, when the energy marketization degree is included. Section 6 concludes.

2. Literature Review

Strategic environmental policy is an extension of strategic trade policy in the field of energy and the environment. Strategic trade policy holds that the government may use export subsidies or R&D subsidies to lower product costs for domestic manufacturers, so as to occupy a larger share in the international market and make domestic manufacturers get monopoly profits, which exceed the amount of government subsidies. That is, the benefits of manufacturers exceed the losses of taxpayers (Brander and Spencer [12]). However, under international trade rules, direct subsidies for products are prohibited, so scholars turn to the study of more subtle environmental subsidies. Barrett [13] and Ulph [14] first proposed the concept of strategic environmental policy, which is similar to strategic trade policy. Their concern is whether the government has the motivation to obtain a competitive advantage in international trade by lowering environmental standards, and what impact this will have on the overall welfare of the country. Barrett [13] believes that the government has the motivation to lower environmental standards to gain competitive advantages in international trade, but the marginal cost of emission reduction brought by loose environmental policies is less than the marginal damage of pollution (ecological dumping), which will damage the overall welfare. As a result, he thinks strong government environmental standards may be the best option. Greaker [15] believes that strategic environmental policies are different from ecological dumping, which is based on the premise that strict environmental policies will hamper competitiveness. However, according to the Porter hypothesis (Porter and Van der Linde [16]), strong environmental policies best serve the interests of a country's export sector. Rather than simply increasing costs, strict environmental policies can lead to green technology innovations that reduce compliance costs and enhance companies' competitiveness. At present, most articles on ecological dumping do not explicitly address how environmental policies affect costs, but instead, assume that both total and marginal costs increase in the rigor of environmental policies (Barrett [13]). The article of Greaker [15] shows that although total cost increases, this is not necessarily the case for marginal cost increases. When existing technologies to reduce emissions have economies of scale, strong environmental policies stimulate competitiveness. Therefore, governments should take advantage of this by instituting strict emission quotas or higher emission taxes. Lapan and Sikdar [17] compare the impact of different environmental policy instruments on overall welfare. In a noncooperative equilibrium, the price of emission permits (both nontradable and tradable) always exceeds the domestic marginal damage caused by pollution. Among them, international tradable permits produce the lowest pollution and the highest welfare. To sum up, we can find that strategic environmental policies are different from loose environmental policies and more different from ecological dumping. The government can maximize welfare by implementing relatively strict environmental policies.

There is a close link between vertical market structures and international environmental policies. Bonanno and Vickers [18] believed that environmental policies would cause downstream exporters to tend to adopt vertical relationships to establish connections with upstream suppliers. Governments set environmental policies to balance pollution control with a competitive advantage, while companies responded by forming vertical relationships. Therefore, vertical contracts can be regarded as the vertical relationship between downstream exporters and upstream suppliers to improve their strategic position in the international market.

In a framework of strategic environmental policy and vertical contracts, Hamilton and Stiegert [19] investigated vertical contracts between downstream and upstream firms and found that international competition will cement a price union between the two. In an empirical analysis of EU-28 countries, Cadoret et al. [20] found that European governments use environmental taxes in a Pigouvian way by doing what Hamilton and Requate [21] demonstrated, that is, given vertical contracts, the Pigouvian tax is the optimal policy to levy on a polluting input under global output and price competition. Huang and Chen [22] utilized Hamilton and Requate [21]'s vertical market model to analyze competitive choice and found that the optimal strategic noncooperative environmental trade policy will coincide with Pigouvian taxes under both output and price competition, and there will be a noncooperative environmental policy between governments. Xing and He [23] framed a vertical structure market model to show that trade liberalization of the intermediate input between two countries reduces the environmental tax, causing each country's environmental standard to race to the bottom. However, the above phenomenon occurs when the environmental pollution effect is moderate. While the environmental pollution effect is preponderant, free trade increases the environmental tax in each country.

3. The Model

Because there are some similarities between the environment-for-export hypothesis and the subsidy-for-export hypothesis, we adopt the basic settings regarding enterprises used by Brander and Spencer [12] in this paper. We modify the Brander–Spencer model (Brander and Spencer [12]) with two countries to be the production-marketing model with two different markets: domestic (d) and foreign (f) markets, by framing the model around a decentralized vertical market structure that supports a traded good in both domestic and foreign markets in which there are upstream and downstream firms in the domestic market (home country). The upstream firm is competitive and produces a polluting input (E_i) that will be used by a downstream firm to produce a finished good (x_i) to, subsequently, be sold in the international market. We assume that both upstream and downstream firms produce only for the international market; that is, there is no consumption in the producing countries. The terms of the contract written by the downstream firm in country i specify a wholesale price for the polluting input, ϖ_i, and fixed transfer payment, F_i, to be exchanged between the downstream and upstream firms. We use the signed vertical contract introduced by Hamilton and Requate (2004), who argued that the polluting input's wholesale price is independent of the market price. However, we question this argument: when downstream and upstream firms sign a vertical contract, the market price is an important reference.

China has changed its price system, including the price system for energy, from a dual-track system to a market-oriented system since 1978. However, the marketization process of the prices of many products, including the prices of different energy, is still relatively slow, and the prices of many products, including energy, are still seriously distorted (Liu et al. [6], Dai and Cheng [7], Ouyang et al. [8], Li et al. [9], Tan and Lin [10], and Sha et al. [11]). The distortion results in suppressing the prices of natural resources, including energy, leading to unnecessary overuse of energy and damaging the environment in China further (Lin and Du [24]). So, we assume that both the wholesale and market prices have a positive correlation θ with $\theta = \frac{\varpi_i}{\omega_i}$ $(\theta > 0)$. If ω is the market price of the polluting input organized by the upstream firm, then θ represents the marketization degree; on the other hand, if the downstream firm in country i does not contract with the upstream firm, perhaps due to antitrust laws in country i, then $\varpi_i = \omega_i$ and $F_i = 0$. We assume that $F'(\theta) < 0$ in our model. We model the nonmarket behaviors for Chinese enterprises by using the nonmarket transactions under vertical contracts such that the larger the value of θ, the more market-oriented the energy price. When θ is equal to 1, the energy price is fully marketized, and the transfer payment between enterprises is 0.

3.1. The Demand Function

We assume that the following utility function of the consumer in the international market is linear such that

$$U(x_d, x_f, m) = u(x_d, x_f) + m,$$

where $u(x_d, x_f) = \alpha(x_d + x_f) - \frac{1}{2}(\beta x_d^2 + 2x_d x_f + \beta x_f^2)$, and m is the size of the fixed transfer specified in the contract. At the same time, we assume that $\alpha > 0$ and $\beta > 1$ and assume that the inverse demand function for the downstream international market consumption good produced in the home country to be $p_d = \alpha - \beta x_d - x_f$; produced in the foreign country to be $p_f = \alpha - \beta x_f - x_d$.

3.2. Technology

As mentioned above, the upstream firm produces a polluting input (E_i) which is consumed by the downstream firm to produce a finished good (x_i). We assume that the production of x_i requires the use of two inputs: a polluting-energy input E_i and a "clean" input L_i. Following the Cobb–Douglas production function, and, for simplicity, we assume equal exponents for both inputs, i.e., $x_i = L_i^{1/2} E_i^{1/2}$, where $i = d, f$. Then, the cost function is $C_i = 2(\varpi_i l_i)^{1/2} x_i$. The wholesale price of the energy input is ϖ_i, and the price of the clean input is l_i, where $i = d, f$.

3.3. Policy Instruments

We will investigate two policy instruments: a tax on input t and a tax on emissions τ. For each policy instrument, each unit of energy input generates a δ amount of the by-product emissions. The value of δ is determined by the abatement technology chosen by the downstream firm. Thus, after generating δ emissions per unit, the cost of energy input should be $A(\delta)$, with $A(\overline{\delta}) = 0$, in which $A' < 0$ and $A'' > 0$. Thus, the market price of the energy input is $\omega_i = \omega_{i0} + t_i + A(\delta) + \tau_i \delta$, and the government receives revenue by getting the environmental policy instruments $T = (\tau_i \delta + t_i) E_i$ in which the emission E creates environmental damage $D = D(\delta E_i)$, where $i = d, f$.

This is a two-stage game. In the first stage, the governments of the domestic (d) and foreign (f) countries choose the value of their environmental instrument simultaneously. Thereafter, in the second stage, after observing the policy choices in the first stage, each country's upstream and downstream firms decide on the wholesale price of energy, and thereafter, the downstream firm selects its output for the international market.

4. The Optimal Marketization Degree

4.1. The Profit Maximization Problem

First, we solve the profit maximization problem for the downstream firms given the policies chosen by the two governments. We then solve the profit maximization of the downstream firms with the existence of vertical contracts. Finally, we investigate a tax on emissions and a tax on input. For identical countries, we focus mainly on the home firm and home government.

4.2. Output Game of Downstream Firms

Similarly, in the output game, downstream firms producing the consumption goods will offer their output to the international market simultaneously. In this stage, the wholesale price of the energy input (ϖ_d, ϖ_f) and the taxes $\left(\tau_d, \tau_f\right)$ or $(\ t_d, t_f)$ are already given. Because firms minimize their unit costs of production by choosing the optimal factor combination, the profit functions can be written as:

$$\pi_d(x_d, x_f) = (\alpha - \beta x_d - x_f)x_d - C_d - F_d \tag{1}$$

and

$$\pi_f(x_d, x_f) = (\alpha - \beta x_f - x_d)x_f - C_f - F_f. \tag{2}$$

By using the first-order condition for the downstream firm, the equilibrium quantities become:

$$x_d^*(\varpi_d(\theta)) = \frac{2\beta(\alpha - c_d) - (\alpha - c_f)}{4\beta^2 - 1} \tag{3}$$

and

$$x_f^*(\varpi_d(\theta)) = \frac{2\beta(\alpha - c_f) - (\alpha - c_d)}{4\beta^2 - 1}, \tag{4}$$

where $c_d = 2[\theta_d(\omega_{d0} + t_d + A(\delta) + \tau_d\delta)l_d)]^{1/2}, c_f = 2[\theta_f(\omega_{f0} + t_f + A(\delta) + \tau_f\delta)l_f)]^{1/2}$ are the marginal costs of the downstream firms in the home and foreign countries, respectively. Thus, the equilibrium profit of the downstream home firm becomes:

$$\pi_d^*(\varpi_d(\theta)) = \beta(x_d^*)^2 - F^d = \beta[\frac{2\beta(\alpha - c_d) - (\alpha - c_f)}{4\beta^2 - 1}]^2 - F_d. \tag{5}$$

Under the model setup as discussed above, we first obtain the following lemma:

Lemma 1. *In a Cournot manner, equilibrium quantities are decreasing in their own tax rates, regardless of the tax type, because quantities are strategic substitutes. Thus, regardless of the tax type, if the home country government increases the tax rate, the profit of the downstream firms will decrease.*

Proof. First, emission tax is selected as the policy instrument. Differentiating (5) with respect to τ_d:

$$\frac{\partial \pi_d^*}{\partial \tau_d} = \frac{\partial \pi_d^*}{\partial x_d^*}\frac{\partial x_d^*}{\partial c_d}\frac{\partial c_d}{\partial \tau_d} = 2\beta x_d^*(-\frac{2\beta}{4\beta^2 - 1})\sqrt{\frac{l_d\theta_d}{\omega_d}}\delta < 0.$$

Then, we consider the input tax. Differentiating (5) with respect to t_d:

$$\frac{\partial \pi_d^*}{\partial t_d} = \frac{\partial \pi_d^*}{\partial x_d^*}\frac{\partial x_d^*}{\partial c_d}\frac{\partial c_d}{\partial t_d} = 2\beta x_d^*(-\frac{2\beta}{4\beta^2-1})\sqrt{\frac{l_d\theta_d}{\omega_d}} < 0.$$

Hence, if the home country government increases the tax rate, the profit of the downstream firms will decrease. □

4.3. Output Game Given a Vertical Contract

Now, we consider the profit maximization problems of the downstream firms given the existence of vertical contracts. In the contract stage of the subgame, the upstream and downstream firms sign contracts on the marketization degrees of the polluting inputs' wholesale prices. Thereafter, the downstream firms can produce the consumption goods and compete in the international market. To make the contracts, the upstream firms must commit to earning positive profits. Hence, in this subgame, downstream firms will choose the terms (θ_d, F_d) to maximize their profit, which is subject to a positive profit constraint in the upstream market as shown in the following:

$$\max_{\varpi_d, F_d} \beta[\frac{2\beta(\alpha-c_d)-(\alpha-c_f)}{4\beta^2-1}]^2 - F_d, \tag{6}$$

such that

$$(\varpi_d - \omega_d)E_d - F_d \geq 0. \tag{7}$$

In this stage, the taxes τ_i, t_i are already given, and the energy input's market price is certain, where $i = d, f$. Substituting (7) into (6), we can model the profit maximization problem of the downstream firms constrained by the assumption that the upstream firms earn a nonnegative profit:

$$\max_{\varpi_d(\theta_d)} \pi^* = \beta(x_d^*)^2 + (\varpi_d - \omega_d)E_d^*. \tag{8}$$

Using Shephard's lemma (i.e., $\frac{\partial C_d}{\partial \varpi_d} = E_d$) and differentiating (8) with respect to θ_d, the first-order necessary condition is obtained as follows:

$$\begin{aligned} &\frac{\partial \pi^*}{\partial \theta} = \frac{\partial(\pi_d^*+F_d)}{\partial x_d^*}\frac{\partial x_d^*}{\partial \varpi_d}\frac{\partial \varpi_d}{\partial \theta} + 2(\varpi_d - \omega_d), \\ &\frac{x_d^*}{L}\frac{\partial x_d^*}{\partial \varpi_d}\frac{\partial \varpi_d}{\partial \theta} + \frac{\partial(\pi_d^*+F_d)}{\partial x_f^*}\frac{\partial x_f^*}{\partial \varpi_d}\frac{\partial \varpi_d}{\partial \theta} = 0. \end{aligned} \tag{9}$$

Substituting $\frac{\partial \pi_d^*}{\partial x_d^*} = 0$ into (9), we obtain:

$$\theta_d = 1 - \frac{L_d}{2\beta\omega_d} < 1. \tag{10}$$

If the foreign downstream firm also adopts a contract, the terms of the profit-maximizing contract for the foreign firm are identical to that implied by (10). We summarize the results in the following lemma:

Lemma 2. *Regardless of the tax type, the effect of taxes on the sum profit of upstream and downstream firms is uncertain.*

Proof. First, we select the emission tax as the policy instrument. Differentiating (5) with respect to τ_d:

$$\frac{\partial T^*}{\partial \tau_d} = \frac{\partial T^*}{\partial x_d^*}\frac{\partial x_d^*}{\partial c_d}\frac{\partial c_d}{\partial \tau_d} = \delta\frac{x_d^{*2}}{L_d} + 2x_d^*\frac{\tau_d \delta}{L_d}(-\frac{2\beta}{4\beta^2-1})\sqrt{\frac{l_d\theta_d}{\omega_d}}\delta.$$

Then, we consider the tax on input. Differentiating (5) with respect to t_d:

$$\frac{\partial T^*}{\partial t_d} = \frac{\partial T^*}{\partial x_d^*}\frac{\partial x_d^*}{\partial c_c}\frac{\partial c_c}{\partial t_d} = \frac{x_d^{*2}}{L_d} + \frac{2x_d^*}{L_d}t_d(-\frac{2\beta}{4\beta^2-1})\sqrt{\frac{l_d\theta_d}{\omega_d}}.$$

Thus, regardless of the type of tax, its effect on the sum profit of upstream and downstream firms in the home country is uncertain. □

We summarize the results in the following proposition:

Proposition 1. *When the marketization degree of the equilibrium wholesale price for the downstream firm in country i is not enough* ($\theta < 1$)*, the vertical contract price below the regulated price of the polluting input—energy; that is,* $\varpi_d < \omega_d$*, and a positive lump-sum payment to the upstream firm; that is,* $F_i > 0$.

Proof. The proof can be obtained by applying Equation (7). □

By committing to pay an input price at a lower marketization degree, the home downstream firm shifts its reaction function to the right. That is, even though a lump-sum transfer offsets the increasing downstream firm's profit, the input price at a lower marketization degree permits output to expand, to alter the set of credible actions from the rivalry firm, and to increase the oligopoly rent in the international market.

Vertical contracts may not exist in many developing countries, but the government often sets a low energy price, for example, the contract coal price in China. The marketization degree of the control price decreases with the level of government administration. As a result, many developing countries entice their firms to expand output by artificially controlling low energy prices.

5. Policy Instrument: An Emission Tax

In stage one of the environmental policy game, the home and foreign governments select the policy instruments such as environmental tax rates to maximize their respective net benefits. In this section, we discuss the theory when our policy instrument tax becomes the emission tax.

For simplicity, we assume that governments do not impose input taxes at the same time. Thus, the welfare consists of profits of the two firms, tax revenues, and disutility from pollution. In this situation, the home government will choose τ_d to maximize

$$W(\tau_d) = \pi_u(\tau_d) + \pi_d(\tau_d) + \tau_d\delta E_d - D(\delta E_d), \tag{11}$$

and the foreign government will choose τ_f to maximize

$$W(\tau_f) = \pi_u(\tau_f) + \pi_d(\tau_f) + \tau_f\delta E_f - D(\delta E_f). \tag{12}$$

Under this model setup, we obtain the following proposition:

Proposition 2. *If firms in country* i *employ vertical contracts and if the policy instrument is an emission tax, the optimal noncooperative tax rates under competition will be higher than the marginal damage of emissions.*

Proof. Consider the problem of the home country regulator (government). The first-order condition for the home regulator is:

$$\frac{\partial \pi_d}{\partial x_f}\frac{\partial x_f}{\partial \tau_d} + \theta\delta E_d + (\theta\omega_d - \omega_d + \delta\tau_d - \delta\frac{\partial D}{\partial E_d})\frac{\partial E_d}{\partial \tau_d} = 0. \tag{13}$$

For simplicity, we first consider $\theta\delta E_d = 0$. First, we rewrite (13) as:

$$\frac{\partial \pi_d}{\partial x_f}\frac{\partial x_f}{\partial \tau_d} + (\theta\omega_d - \omega_d + \delta\tau_d - \delta\frac{\partial D}{\partial E_d})\frac{\partial E_d}{\partial \tau_d} = 0. \tag{14}$$

Since $\frac{\partial x_f(\tau_d,\tau_f)/\partial \tau_d}{\partial x_d(\tau_d,\tau_f)/\partial \tau_d} = \frac{\partial x_f^*(\varpi_d,\varpi_f)/\partial \varpi_d}{\partial x_d^*(\varpi_d,\varpi_f)/\partial \varpi_d}$, we obtain:

$$\delta(\frac{\partial D}{\partial E_d} - \tau_d) = (\frac{\partial \pi_d}{\partial x_f}\frac{\partial x_f}{\partial \tau_d})/\frac{\partial E_d}{\partial \tau_d} + (\varpi_d - \omega_d) = 0. \tag{15}$$

When $\theta\delta E_d \geq 0$, we obtain:

$$\delta(\frac{\partial D}{\partial E_d} - \tau_d) = (\frac{\partial \pi_d}{\partial x_f}\frac{\partial x_f}{\partial \tau_d} + \theta\delta E_d)/\frac{\partial E_d}{\partial \tau_d} + (\varpi_d - \omega_d) = \theta\delta E_d/\frac{\partial E_d}{\partial \tau_d} < 0, \tag{16}$$

and thus, the assertions of Proposition 2 hold. □

As noted in Proposition 1, output competition in the international market induces the upstream and downstream firms to form a price alliance in which the marketization degree of the wholesale price is low. Then, the downstream firms can boost competitiveness in the international market. However, the external costs of environmental damage are not included in the firm's costs. If governments do not include such damage, overconsumption of resources and environmental pollution are inevitable. The rapid growth of developing countries is a cause of ecological dumping. In turn, if the government imposes a severe environmental tax, the market price of the polluting inputs will include the external costs. Since the market price is the preponderant reference of the wholesale price, social welfare will be maximized.

6. Policy Instrument: An Input Tax

We now investigate the policy instrument of an input tax to maximize the welfare of the home country. Here, we assume that governments do not impose emission taxes at the same time. The welfare consists of the profit of upstream and downstream firms in the home country, the tax revenues of polluting input, and the environmental damage. Hence, under coordination, the welfare is:

$$W(t_i) = \pi_u(t_i) + \pi_d(t_i) + t_i E_i - D(\delta E_i). \tag{17}$$

Under this model setup, we obtain the following proposition:

Proposition 3. *When the policy instrument is a tax on the polluting input, the optimal noncooperative environmental policy under competition could be higher or lower than the Pigouvian tax.*

Proof. The first-order condition for the home regulator is:

$$\frac{\partial \pi_d}{\partial x_f}\frac{\partial x_f}{\partial t_d} + \theta E_d + (\theta\omega_d - \omega_d + t_d - \delta\frac{\partial D}{\partial E_d})\frac{\partial E_d}{\partial t_d} = 0. \tag{18}$$

To simplify, we first consider $\theta E_d = 0$. First, we rewrite (11) as:

$$\frac{\partial \pi_d}{\partial x_f}\frac{\partial x_f}{\partial t_d} + (\theta\omega_d - \omega_d + t_d - \delta\frac{\partial D}{\partial E_d})\frac{\partial E_d}{\partial t_d} = 0. \tag{19}$$

Since $\frac{\partial x_f(t_d,t_f)/\partial t_d}{\partial x_d(t_d,t_f)/\partial t_d} = \frac{\partial x_f^*(\varpi_d,\varpi_f)/\partial \varpi_d}{\partial x_d^*(\varpi_d,\varpi_f)/\partial \varpi_d}$, we obtain:

$$\delta(\frac{\partial D}{\partial E_d} - t_d) = (\frac{\partial \pi_d}{\partial x_f}\frac{\partial x_f}{\partial t_d})/\frac{\partial E_d}{\partial t_d} + (\varpi_d - \omega_d) = 0. \tag{20}$$

When $\theta E_d \geq 0$, we obtain:

$$\delta\frac{\partial D}{\partial E_d} - t_d = (\frac{\partial \pi_d}{\partial x_f}\frac{\partial x_f}{\partial t_d} + \theta E_d)/\frac{\partial E_d}{\partial t_d} + (\theta - 1)\omega_d < 0. \tag{21}$$

However, since $0 < \delta < 1$, we cannot ascertain which variable is bigger between the resource tax and the Pigouvian tax. Thus, the optimal noncooperative environmental policy under competition could be higher or lower than the Pigouvian tax and the assertions of Proposition 3 are proven. □

Given a tax on the polluting input as the policy instrument, determining the optimal noncooperative environmental policy is difficult. We offer two reasons.

First, by analyzing the comparative advantage of environmental policy instruments for both upstream and downstream firms, we can attribute the uncertainty to the variable δ. The resource tax is levied on the polluting input, yet the environmental damage is caused by the emissions as a by-product of the final product. Thus, in the welfare function, the resource tax and the environmental damage are not equal. On the other hand, when the environmental damage is the only deduction from the welfare function, the resource tax is unable to effectively control pollution and the resource tax is levied on energy producers. However, the market price of the polluting input increases with the resource tax rate. Thus, it is important for countries to have a more efficient polluting input pricing mechanism. The effect of the resource tax will be significantly reduced when the input price is controlled and may also induce an uncertain relationship between the resource tax and the Pigouvian tax.

In fact, many resource-rich developing countries, which preponderantly focus on rapid growth and have an imperfect legal system, still retain low energy prices, such as China, India, and Brazil. Unfortunately, their rapid growth is always accompanied by environmental damage and overconsumption of resources. China, for example, has a low degree of energy pricing marketization (Dai and Cheng [7], Ouyang et al. [8], and Li et al. [9]). The effectiveness of the resource tax is partly offset by environmental damage. China's economy has been developing rapidly, bringing many problems, such as excessive consumption of nonrenewable energy and environmental damage. Hence, reasonably raising the resource tax rate in China is urgently needed.

7. Conclusions and Policy Implications

With the growth of the international economy, more and more multinational corporations join the multinational production line based on their comparative advantage. The different environmental policy instruments of governments play important roles as the adjusted mechanism tools in each country for this purpose.

The price of coal is one of the main important factors that drive an economy that is powered by both coal consumption and environmental damage. The low price of coal is the main reason that reduces the incentive to eliminate the outdated industrial capacity for innovation dynamics and suppresses the R&D of energy consumption. There are many studies, for example, Brander and Spencer (1985), Hamilton and Stiegert (2010), and Cadoret et al. (2020) that recommend governments make some environmental policies to reduce the damage caused by the emissions of CO_2. Xing and He (2011) apply the model for the vertical structure market to show that trade liberalization of the intermediate input between two countries reduces the environmental tax, causing each country to reduce its environmental protection standard.

The previous literature provides the background theory for the present study to adopt the environment-for-trade policy which is based on the strategic environmental policy model. Using the model of adopting the strategic environmental policy to incorporate the marketization degree of the wholesale price and given the existence of vertical contracts, in this paper, we assume that the wholesale price of the polluting input increases with the market price. By using this assumption, we examine the effects of two instruments of the environmental policy on social welfare and conclude that there is no reason to expect both downstream and upstream firms to establish a high wholesale price. When the government selects an emission tax as the policy instrument, we should expect a higher tax rate. However, the optimal resource tax is uncertain when its effect on environmental damage is taken into account.

The contributions of our paper include new findings in the applications of the trade theory. We find that the main reason why trade contributes to the destruction of environmental resources is that the cost of environmental resources is not reflected in the market price. Our conclusion is consistent with the literature regarding pollution haven (Ji [25]) and carbon leakage (Zhang et al. [26]). Compared to Ji [25] and Zhang et al. [26], we all conclude that unintended transfer payment causes competition distortion which leads to environmental pollution and carbon leakage. The cost of exploitation of natural resources and environmental damage is not adequately reflected in market prices of goods or services; is one of the main reasons trade contributes to the destruction of environmental resources. The model shows that improvement of the energy market price formation mechanism can reduce the negative impact of strategic environmental policy. Our results can be used to draw some practical policies for countries, especially developing countries, to use their energy effectively. For example, given a low energy price, the output can be artificially expanded, which will lead to overconsumption of resources and an increase in environmental pollution. Hence, to promote sustainability, governments should liberate resource prices and reform the system to get efficient environmental policies.

A limitation of the theory developed in our paper is that we assume there is no international demand for the polluting input. Thus, an extension of the model developed in this paper could include relaxing the assumption in the modeling. Another extension could include developing a powerful model for some more general cases by including the incentives we described in our model set-up to be important factors in the modeling. In addition, this research only sets up a methodology background for the environment-for-trade policy based on the marketization degree of getting vertical contracts. Thus, another piece of extension of our paper is to apply the model developed in our paper to real historical data with implementation in practical inference.

In this paper, we develop a model to examine the link between the low price of energy and strategic environmental policy in China, examine the choice of policy instruments in a strategic environmental policy model with vertical contracts, and investigate different choices of instruments for the environmental policy. Extensions of our paper could include applying our approach to develop models for oil [27], CO_2 emissions [28], growth [29], price [30], international trade [13], environmental policy [14–17], and other policies [18].

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