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A Study on the Optimal Carbon Tax and Effects under the Background of Carbon Tariffs: A Theoretical Analysis Based on Oligopoly Competition Model*

Yaxian Dai, Hongjin Xiang#

School of Economics, Nanjing Audit University, Nanjing, China
Email: studai00@163.com, #xhongjin@yahoo.com

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Abstract

Against the backdrop of the EU's implementation of a carbon border regulation mechanism in 2026, it is crucial for developing countries to address this issue. This paper is based on a two-stage oligopoly competition model, considering that some of the products produced by developing countries are used for export and some are used for domestic sales. Factors such as carbon emissions reduction and production cost differences between developed and developing countries are included to explore the optimal setting of carbon taxes in developing countries and the impact of carbon tariffs on welfare, trade, and environmental effects in developing countries. The research results indicate that: 1) the optimal carbon tax setting in developing countries is related to the production costs and carbon tariff coefficients of developed countries. There is a negative correlation with production costs in developed countries and a positive correlation with carbon tariff coefficients. 2) The social welfare of developing countries increases with the increase of production costs in developed countries; with the increase in carbon tariffs imposed by developed countries, the social welfare of developing countries first decreases and then increases. 3) The profits of enterprises in developing countries first decrease and then increase with the increase of production costs in developed countries; with the increase in carbon tariffs imposed by developed countries. 4) The environmental pollution of developing countries will increase with the increase of production costs in developed countries, and decrease with the increase of carbon tariffs. Based on this, this article proposes relevant policy recommendations for developing countries.

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#Corresponding author.

Keywords

Carbon Tariffs, Carbon Tax, Welfare Effect, Oligopoly Competition Model

1. Introduction

The current global climate issue is an important issue related to the fate of humanity. In order to jointly address climate change, the international community has signed three important climate agreements since the 20th century. The first is the United Nations Framework Convention on Climate Change, which establishes the basic principles for countries around the world to address climate change, including the principle of "common but differentiated responsibilities", the principle of fairness, the principle of individual capabilities, and the principle of sustainable development. The second is the Kyoto Protocol, which stipulates that 39 developed countries agree to reduce greenhouse gas emissions and commit to a 5.2% reduction in emissions from 2018 to 2012 compared to 1990. The third is the Paris Agreement, where 178 contracting parties worldwide are committed to controlling the increase in global average temperature from pre industrial periods to within 2 degrees Celsius and striving to limit the temperature increase to within 1.5 degrees Celsius. In addition to jointly negotiating climate policies, various countries are also introducing their own emission reduction policies. China upgraded "dual carbon" to a national strategy in 2021, and gradually established regional carbon emission trading pilot projects in Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, and Shenzhen. The national carbon trading market was officially launched in July 2021. At present, the European Union has shown a positive attitude in implementing carbon reduction processes internationally, in order to take the lead in solving global climate issues. The EU is implementing a carbon border regulation mechanism, and plans to adjust the carbon price of carbon intensive products entering Europe based on their carbon emission intensity starting from 2026, in order to enable importers and EU enterprises to bear the same carbon reduction costs.

Although scholars at home and abroad have conducted extensive research and exploration on how the imposition of carbon tariffs in developed countries affects developing countries, most of the existing literature uses the general equilibrium model and its sub models for quantitative analysis, with little theoretical basis. Even if a theoretical model is constructed, the model setting is based on the fact that all products produced by developing countries are used for export, which is not in line with reality. Therefore, this article makes the following innovation: setting a portion of developing countries' products for export and a portion for domestic sales, and considering factors such as carbon emissions reduction and production cost differences between developed and developing countries, studying how developing countries like China should face carbon tariffs? How to determine the optimal carbon tax after initiating a domestic carbon tax?

What impact will the imposition of carbon tariffs have on social welfare, corporate profits, and environmental pollution in developing countries? Conducting in-depth and systematic research on these issues not only benefits developing countries in setting optimal carbon taxes, but also enables them to occupy an advantageous position in international competition for low-carbon industries in the post pandemic era.

In view of this, this article constructs a two-stage oligopoly competition model, considering that some of the products produced by developing countries are used for export and some are used for domestic sales. Factors such as carbon emissions reduction and the difference in production costs between developed and developing countries are included in the same theoretical framework to conduct in-depth theoretical analysis of the above issues.

2. Literature Review

2.1. Research on Policies and Effects of Climate Warming

On environmental issues, Pigou was the first to put forward the concept of Pigou tax. He pointed out that polluters should be taxed according to the degree of harm caused by pollution, and taxes should be used to make up the gap between the private costs and social costs of polluters' production (Pigou, 1947). However, there are no mandatory international uniform rules to limit the country's pollution discharge behavior. Some countries adopt loose domestic policies to enhance national welfare, while others control carbon emissions through strict regulatory policies (Carraro & Siniscalco, 1993). Compulsory emission reduction for enterprises will invisibly increase their production costs and weaken their ability to participate in domestic and international market competition. Many developed countries are unwilling to adopt strict environmental control measures to weaken the competitiveness of domestic enterprises. Therefore, the United States took a tough stance during Trump's presidency and withdrew from the Paris Agreement.

In addition to leading to a lack of competitiveness for enterprises, production enterprises tend to choose countries or regions with lower environmental regulations to invest and build factories, leading to the transfer of pollution to these countries, which is known as the Pollution Shelter Hypothesis (PHH). Markusen (1975) compared unilateral implementation of environmental measures with bilateral implementation of carbon taxes, tariffs, or subsidies on carbon intensive imported products, and found that the results contradicted the pollution shelter hypothesis. A concept closely related to the pollution shelter hypothesis is carbon leakage, which refers to the increase in emissions caused by the transfer of high carbon emitting enterprises from developed countries to developing countries due to emissions reduction in developed countries. Scholars from various countries are seeking solutions to protect companies with impaired competitiveness. One option is to feed back tax revenue to severely damaged companies, and the other is to allocate carbon emissions based on output. Although these

solutions protect companies to some extent, they will bring greater welfare losses (Dissou, 2006).

In addition to the above solutions, strict trade policies can also be used to address the lack of competitiveness of enterprises, and can also enable non participating countries to join policy alliances (Barrett, 2003; Kemfert, 2004). In theoretical research, it has been repeatedly mentioned that border tax adjustments can be used to restrict the import of energy intensive products from high emission countries. Hoel (1996) established a more general model based on Markusen's model, analyzing that if everyone's emissions are also included in the cost of environmental damage, carbon tariffs or differentiated domestic carbon taxes must be implemented to reduce competitive losses caused by carbon leakage and achieve maximum national welfare.

In the face of carbon tariff collection, domestic scholars have also made corresponding countermeasures and research. Huang (2010) proposed that the Chinese government and enterprises should take the initiative to address the negative impact of carbon tariffs through measures such as adjusting industrial structure and innovating technology. Lan et al. (2018) pointed out through research that in order to address the impact of carbon tariffs, China can achieve carbon emissions reduction by promoting low-carbon development of its industrial structure. Fan (2009) proposed that instead of allowing the United States to impose carbon tariffs, it would be better for us to take the lead in imposing carbon taxes domestically and use the taxes to subsidize enterprises in order to promote the transformation and upgrading of industrial structure. Cui et al. (2013) pointed out that carbon taxes can be levied domestically in China based on the principle of cost fairness and independent emission reduction to address the threat of carbon tariffs. Han and Li (2021) proposed to accelerate the promotion of domestic carbon emissions trading legislation, so as to align China's carbon emissions trading system with international standards.

2.2. Different Research Methods on Carbon Tariffs

In foreign studies, Burniaux, Chateau and Duval (2008) used the CGE model to find that carbon tariffs can more effectively control Carbon leakage only when the EU achieves its carbon emission reduction goals. Gros (2009) found that the welfare changes of carbon tariff implementing countries and regulated countries are uncertain by establishing a Partial equilibrium model. Baker used a computable general equilibrium model of the multi regional world economy and found that China would suffer huge losses if carbon tariffs were imposed. Dong and Whalley (2011) constructed CGE models including the United States, China, the European Union, and other countries around the world, and simulated the environmental impact of carbon tariffs imposed by the United States and Europe on goods imported from China. Research shows that the positive impact of carbon tariffs on the global environment is not significant. Warwick and Peter (2008) established a multi-sectoral, multinational model to analyze the economic

and environmental effects of carbon tariffs. The results showed that the welfare effects of carbon tariffs were not significant and could not even offset their adverse effects on international trade. Eyland and Zaccur (2012) hypothesized that there are differences in production costs and emission reduction technologies between developing and developed countries, and constructed a game model for developed countries to impose carbon tariffs. They found that only when the carbon tariff coefficient is set at 0.5 can global total welfare reach its maximum.

In domestic research, Shen and Li (2010) used a dynamic computable general equilibrium model to study the potential impact of carbon tariffs on China's industrial production, exports, and employment, based on the 2002 input-output table and analyzing the implicit carbon emissions of China's industrial exports. Qu and Wu (2011) analyzed the impact of carbon tariffs on importing and exporting countries by building a Partial equilibrium carbon tariff model between the two countries. The conclusion indicates that imposing carbon tariffs on importing countries can improve their own welfare level and reduce the welfare level of exporting countries, but the specific degree of welfare change depends on the domestic carbon tax of the importing country, whether the exporting country levies a carbon tax, and the level of carbon intensity in the importing and exporting countries. Wang (2013) constructed a general equilibrium model and calculated that under a carbon tariff rate of $30 or $60, China's exports to the United States can decrease by 1.38% to 6.44% in the short term. In the long run, the impact will intensify, and the decline in China's exports to the United States will reach 8.69% to 40.54%. Wang et al. (2010) hypothesized that there were differences in production costs between countries and constructed a game model of the United States imposing carbon tariffs on developing countries and implementing export subsidies on developing countries. They found that imposing carbon tariffs on developing countries would reduce US imports from developing countries and increase imports from developed countries. Li (2013) hypothesized that there is a difference in carbon emissions per unit product between two countries and constructed a game model where they impose carbon tariffs on each other. He found that, compared to not imposing carbon tariffs, imposing carbon tariffs increases the profits of enterprises in the domestic market, but at the same time reduces profits in foreign markets, causing damage to the overall welfare of the country. Yang and Wei (2014) considered the differences in production costs and carbon emissions intensity between developing and developed countries, and constructed a multi-stage game model of whether and when developing countries implement trade policies under the background of carbon tariffs imposed by developed countries. They found that whether developing countries can improve national welfare by implementing trade policies depends on the size of model parameters, but regardless of the policy choices of developing countries, For developed countries, implementing this policy after imposing carbon tariffs can improve national welfare. Yang and Weng (2013) introduced the dynamic changes in carbon emissions and constructed a diffe-

rential game model for the selection of carbon taxes and tariffs in two identical countries. They found that imposing carbon taxes on both countries can maximize the reduction of global carbon emissions and improve global welfare levels.

In summary, domestic and foreign scholars have conducted extensive research on environmental regulation policies, among which different research methods have been used to achieve fruitful results on the impact of carbon tariffs imposed by developed countries on developing countries. However, existing research still has some shortcomings: 1) Most of them use quantitative analysis and lack a theoretical basis. 2) Even if a theoretical model is constructed, it still does not match the actual situation. The main contributions of this article are reflected in two aspects: on the one hand, constructing a dynamic oligopoly competition model, specifically analyzing the factors that affect the optimal carbon tax setting in developing countries, as well as the impact of carbon tariff collection on social welfare, trade effects, and environmental pollution in developing countries. On the other hand, by introducing the comparative advantage of developing countries in furniture trade (lower production costs), the products produced by developing countries are divided into export and domestic sales, making the assumptions more realistic.

3. Duopoly Model

There are two countries in an open economy: developing country (s country) and developed country (n country), with corresponding enterprises called a developing country enterprise (enterprise s) and a developed country enterprise (enterprise n), respectively. The marginal production cost of enterprise i ($i = s, n$) is c_i. Two enterprises produce homogeneous products. The products produced by developing country enterprise s are divided into two categories: one is used for exporting to the developed country, and the other is used for sales in the domestic market; The products produced by enterprise n in the developed country are only sold in developed country markets. Denote by q_n the quantity produced by the developed enterprise n, by q_x the quantity produced by the developed enterprise n for exporting to the developed country and q_s the quantity produced by the developed enterprise n for sales in the domestic market.

According to Singh and Vives (1984) heterogeneous product demand function, simplifying the market size of the developed country and the developing country to 2, the linear-inverse demand function for homogeneous products in the developed country can be given by $p_n = 2 - q_n - q_x$, the linear-inverse demand function for homogeneous products in the developing country can be given by $p_d = 2 - q_d$.

Consumer surplus in the developed country is $CS_n = \left(q_n + q_x\right)^2 / 2$, Consumer surplus in the developing country is $CS_s = q_d^2 / 2$.

Due to the consumption of fossil fuels in the production of products, accompanied by carbon dioxide emissions, assume per unit product generate unit car-

bon emissions. To reduce carbon emissions, enterprises can invest in carbon reduction funds. The cost function of carbon reduction for enterprise i is $CA_i = a_i^2/2$, where $a_i > 0$, a_i is the carbon reduction of the enterprise.

Therefore, the net carbon emissions of enterprise i is $e_i = q_i - a_i$. Drawing on the research of Breton, Sbragia, and Zaccour (2010), the environmental damage caused by carbon emissions in the developed country is $ED_n = q_n - a_n$, in the developing country is $ED_s = q_x + q_d - a_s$. The developed country enterprise is subject to a per-unit BTA, which is given by $BTA = \tau * q_x$, where $\tau \in (0,1)$ is a given constant. Since the production cost of the developing country is relatively low, in order to simplify the calculation, without loss of generality, it is assumed that $c_s = 0$, $c_n = c > 0$.

4. The Game

The game is played in two stages and a Nash equilibrium is sought. In the first stage, the developed country set the optimal carbon tax rate and carbon tariff, while the developing country set the optimal carbon tax rate; In the second stage, enterprises from various countries determine the optimal production volume. To obtain a subgame-perfect equilibrium, the game is solved, as usual, in the reverse order.

4.1. Second-Stage Equilibrium

The profit functions of enterprises in various countries are as follows:

$$\pi_s = (2 - q_d) q_d + (2 - q_n - q_x) q_x - t_s (q_x + q_d - a_s) - \frac{1}{2} a_s^2 - \tau q_x \tag{1}$$

$$\pi_n = (2 - q_n - q_x) q_n - c q_n - t_n (q_n - a_n) - \frac{1}{2} a_n^2 \tag{2}$$

The developing country enterprise and the developed country enterprise respectively determine the optimal production level with the goal of maximizing their own profits. The first order conditions for maximizing profits for each enterprise are:

$$\begin{aligned} q_d &= \frac{1}{2}(2 - t_s) \\ q_x &= \frac{1}{3}(2 + c + t_n - 2t_s - 2\tau) \\ q_n &= \frac{1}{3}(2 - 2c - 2t_n + t_s + \tau) \\ a_s &= t_s; a_n = t_n \end{aligned} \tag{3}$$

4.2. First-Stage Equilibrium

Let's look at the first stage again. At this point, the developing and the developed country respectively choose the optimal carbon tax rate to maximize their national welfare functions as follows:

$$W_s = \pi_s + \frac{1}{2} q_d^2 + t_s (q_x + q_d - a_s) - (q_x + q_d - a_s) \tag{4}$$

$$W_n = \pi_n + \frac{1}{2}(q_x + q_n)^2 + t_n(q_n - a_n) + \tau q_x - (q_n - a_n) \tag{5}$$

The developing and the developed country determine the optimal carbon tax rate based on maximizing their own welfare, and the first-order conditions for maximizing their respective welfare are:

$$\begin{aligned} t_s &= \frac{1}{4}(4 - 2c + \tau) \\ t_n &= c + \tau \end{aligned} \tag{6}$$

From Equation (6), it can be seen that the optimal carbon tax for developed and developing countries is related to enterprise production costs and carbon tariff coefficients. Among them, the setting of the optimal carbon tax for developing countries is negatively correlated with the production costs of developed countries, and positively correlated with carbon tariffs. The lower the production cost in developed countries, the higher the carbon tariff, and the larger the carbon tax set by developing countries themselves.

Therefore, in the developed country where carbon taxes and tariffs are imposed, and in the developing country where carbon taxes are imposed, some goods are exported and some are sold domestically, the optimal production for both developed and developing countries is

$$\begin{aligned} q_x^* &= c - \frac{1}{2}\tau \\ q_d^* &= \frac{1}{8}(4 + 2c - \tau) \\ q_n^* &= \frac{1}{4}(4 - 6c - \tau) \end{aligned} \tag{7}$$

To ensure that the model has an interior solution, it is required that the output of enterprises in the developing and developed country be positive, i.e. $0.5\tau < c < 0.6667 - 0.1667\tau$.

5. Analysis of the Effect of the Developing Country Imposing Carbon Taxes under Carbon Tariff Conditions

5.1. Welfare Effect

Substituting Equations (6) and (7) into Equation (4) yields the welfare function for the developing country as

$$W_s^* = \frac{7}{8} + \frac{c}{8} + \frac{11}{32}c^2 - \frac{\tau}{16} - \frac{11}{32}c\tau + \frac{11}{128}\tau^2 \tag{8}$$

Calculate the first derivative of the social welfare function to the production cost c, and get:

$$\frac{\partial W_s^*}{\partial c} = \frac{1}{32}(4 + 22c - 11\tau) \tag{9}$$

It is easy to prove that when $0.5\tau < c < 0.6667 - 0.1667\tau$, there is always $\partial W_s^* / \partial c > 0$.

When the production costs of developed countries increase, they will consider transferring production to developing countries. For developing countries or regions, accepting industrial transfer from developed countries accelerates the industrialization process. Domestic enterprises have expanded their production with low production costs, increased their profits, and improved the overall welfare of society. In addition, in the face of carbon tariffs imposed by foreign countries, China will adopt a carbon tax to increase its tax revenue; More products have shifted from exports to domestic sales, resulting in an increase in domestic consumer surplus. In summary, the overall social welfare of developing countries has improved.

Then the social welfare function of the developing country is derived from carbon tariff coefficient τ, and the results are as follows:

$$\frac{\partial W_s^*}{\partial \tau} = \frac{1}{64}\left(-4 - 22c + 11\tau\right) \tag{10}$$

When $0 < \tau < 0.3636 + 2c$, $\partial W_s^* / \partial \tau < 0$; When $0.3636 + 2c < \tau < 1$ and $0 < c < 0.4545$, $\partial W_s^* / \partial \tau > 0$.

Under the condition of mixed duopoly competition, the social welfare of the developing country shows a U-shaped relationship with carbon tariffs. The social welfare of developing countries first decreases with the increase of carbon tariffs, and when $0.3636 + 2c < \tau < 4 - 6c$, it increases with the increase of carbon tariffs.

Due to the imposition of carbon tariffs, on the one hand, the export costs of developing country enterprises have increased, their competitiveness in the international market has decreased, and they have to reduce product production and exports, leading to a decrease in corporate profits and a decrease in national welfare. On the other hand, with the expansion of trade advantages for developing countries, they are facing increasingly high carbon tariff rates, making it increasingly difficult to improve national welfare. However, with the increase in carbon tariffs imposed by developed countries, developing countries will also levy carbon taxes accordingly. The introduction of carbon taxes by developing countries prevents their domestic export enterprises from being subject to carbon tariffs imposed by developed countries, and this portion of tax revenue can be retained domestically. In addition, with the improvement of emission reduction technologies in developing countries, environmental pollution will also decrease, thereby enhancing its welfare effect.

***Conclusion* 1:** *In developed countries where carbon tariffs are imposed, carbon taxes are implemented domestically, and carbon taxes are implemented domestically in developing countries, the social welfare of developing countries increases with the increase in production costs in developed countries. The social welfare of developing countries shows a U-shaped relationship with the carbon tariff collection in developed countries, that is, as the carbon tariff collection in developed countries increases, the social welfare of developing countries first decreases and then increases.*

5.2. Trade Effect

Substituting Equations (6) and (7) into Equation (1) yields the profit function for the developing country as

$$\pi_s^* = \frac{1}{64}\left[48-16c+76c^2+(8-76c)\tau+19\tau^2\right] \tag{11}$$

Calculate the first derivative of the profit function to the production cost c, and get:

$$\frac{\partial \pi_s^*}{\partial c} = \frac{1}{16}(-4+38c-19\tau) \tag{12}$$

When $0.5\tau < c < 0.1053+0.5\tau$, $\partial \pi_s^* / \partial c < 0$; When $0.1053+0.5\tau < c < 0.6667-0.1667\tau$, $0 < c < 0.4545$, $\partial \pi_s^* / \partial c > 0$.

Under the condition of mixed duopoly competition, there is a U-shaped relationship between the profits of the developing country and the production costs of the developed country. With the increase in production costs in the developed country, profits in the developing country first decrease and then increase.

When the production cost of developed countries increases and is less than $0.1053+0.5\tau$, under the imposition of carbon tariffs, developing country enterprises' exports decrease and their profits decrease; When the production costs of developed countries are large enough and exceed $0.1053+0.5\tau$, developed countries will consider transferring production to developing countries, bringing new opportunities to them. Developing countries rely on production factors such as low labor and low land costs to increase corporate profits. Then the profit function of the developing country is derived from carbon tariff coefficient τ, and the results are as follows:

$$\frac{\partial \pi_s^*}{\partial \tau} = \frac{1}{32}(4-38c+19\tau) \tag{13}$$

Obviously, when $0 < c < 0.5263$, there is always $\partial \pi_s^* / \partial \tau > 0$. This means that the higher the carbon tariffs in the developed country, the greater the profits for the developing country.

The conclusion drawn in this article contradicts the mainstream research findings, and the possible explanations are as follows: as carbon tariffs imposed by developed countries increase, developing countries' exports to developed countries decrease, while domestic sales increase. In the context of strong domestic demand in developing countries, the introduction of carbon tariffs will promote domestic demand, increase internal circulation, and thus increase corporate profits. In addition, the increase in carbon tariffs will force domestic enterprises to upgrade their industries, leading to a shift towards high-end, energy-saving, and intelligent products. High value-added products will bring more profits to enterprises.

***Conclusion* 2:** *In developed countries where carbon tariffs are imposed, carbon taxes are implemented domestically, and carbon taxes are implemented domestically in developing countries, there is a U-shaped relationship between*

the profits of developing country enterprises and the production costs of developed countries. That is, as the production costs of developed countries increase, the profits of developing country enterprises first decrease and then increase. The increase in carbon tariffs imposed by developed countries will result in higher profits for developing country enterprises.

5.3. Environmental Effect

Substituting Equations (6) and (7) into equation $ED_s = q_x + q_d - a_s$ yields the environmental pollution function for the developing country as

$$ED_s^* = \frac{1}{8}\left(-4 + 14c - 7\tau\right) \tag{14}$$

Calculate the first derivative of the environmental pollution function to the production cost c, and get:

$$\frac{\partial ED_s^*}{\partial c} = \frac{7}{4} \tag{15}$$

When $0.5\tau < c < 0.6667 - 0.1667\tau$, $\partial ED_s^* / \partial c > 0$. This means that environmental pollution in the developing country increases with the increase in production costs in the developed country.

Developed countries, considering the high production costs caused by high land costs, high labor costs, and high environmental governance costs in their own countries, will shift the production of low value-added products to developing countries as the production costs of developed countries increase. Due to the low profit and high pollution characteristics of low value-added products, this will burden the environment of developing countries, increase carbon emissions and intensify environmental pollution.

Then the environmental pollution function of the developing country is derived from carbon tariff coefficient τ, and the results are as follows:

$$\frac{\partial ED_s^*}{\partial \tau} = -\frac{7}{8} \tag{16}$$

It is obviously that $\partial ED_s^* / \partial \tau < 0$. This means that environmental pollution in the developing country decreases with the increase of carbon tariffs in the developed country.

With the increase in carbon tariffs imposed by developed countries, the cost of exporting products from developing countries will increase; In order to meet the carbon emission standards of developed countries, developing country enterprises will also increase their technology research and development costs. In the context of increased carbon tariffs, developing country enterprises have reduced product production on the one hand, improved their technological research and development level and promoted green upgrading of products on the other hand. Furthermore, the introduction of carbon taxes in developing countries has strengthened the awareness of carbon reduction among enterprises. Driven by three factors, environmental pollution in developing countries will

also decrease accordingly.

***Conclusion* 3:** *In developed countries where carbon tariffs are imposed, carbon taxes are implemented domestically, and carbon taxes are implemented domestically in developing countries, environmental pollution in developing countries will increase with the increase in production costs in developed countries and decrease with the increase in carbon tariffs.*

6. Main Conclusion

To study the relevant issues of developing countries' optimal carbon tax setting for carbon tariffs imposed by developed countries, this paper establishes a dynamic oligopoly model and analyzes its derivation. The results show that: 1) the optimal carbon tax setting for developing countries is related to the production costs and carbon tariff coefficients of developed countries. There is a negative correlation with production costs in developed countries and a positive correlation with carbon tariff coefficients. 2) The social welfare of developing countries increases with the increase of production costs in developed countries; With the increase in carbon tariffs imposed by developed countries, the social welfare of developing countries first decreases and then increases. 3) The profits of enterprises in developing countries first decrease and then increase with the increase of production costs in developed countries; With the increase in carbon tariffs imposed by developed countries. 4) The environmental pollution of developing countries will increase with the increase of production costs in developed countries, and decrease with the increase of carbon tariffs.

7. Policy Recommendations

Based on the research results, this article proposes three suggestions for developing countries, especially China: 1) Accelerate the improvement of China's carbon emission trading system. Up to now, China has initially established a national carbon emission trading system, but only the power industry is allowed to trade in the market. For high emission industries such as steel, cement and fertilizer, which are the focus of the EU, it has not yet entered the carbon emission trading market. China should gradually include industries such as electrolytic aluminum, cement, and fertilizers to achieve full coverage of the eight high energy consuming industries. In addition to enriching trading varieties, trading methods should also be improved, for example, increasing the benchmark for carbon emission quota issuance, introducing auction mechanisms for quota issuance, and introducing third-party investment institutions to enter the carbon market for trading, etc. If the domestic carbon emission trading market can be improved before the EU implements carbon tariffs, the negative effects of the EU's carbon border regulation mechanism will gradually weaken. 2) Continue to expand the comparative advantage of trade. Due to the widespread lack of capital and technology in developing countries, labor-intensive products have become important export products for developing countries. Therefore, as labor costs in developing

countries rise and their trade comparative advantages weaken, domestic enterprises should actively improve their product production processes, reduce labor input in the production process, further reduce production costs, continue to maintain or expand their trade comparative advantages, and enhance their international competitiveness. 3) Strengthen technological innovation and promote the green transformation of high energy consuming industries. The country should provide preferential policies to encourage enterprises to develop low-carbon technologies, vigorously invest in industries such as clean energy, new energy vehicles, and environmentally friendly new materials, build a complete green industry chain, actively promote the export trade of green products and services, and enhance the green competitiveness of Chinese products in the global market. In terms of industrial strategy, expand the export of high value-added and high-tech products, reduce the proportion of high energy consuming industries in exports, and achieve industrial structure adjustment and upgrading.

This article explores the setting of optimal carbon taxes in developing countries and the impact of carbon tariffs on welfare, trade, and environmental effects in developing countries by constructing a two-stage oligopoly competition model. I believe this study will be helpful for the setting of domestic tariffs and the countermeasures taken in the face of imposing carbon tariffs. However, there is still future research to be done. Firstly, in order to simplify the model setting, this article only takes into account the differences in production costs and carbon reduction costs between developed and developing countries. In fact, there are many factors that affect the profit function of the two, such as research and green innovation costs. Future research can expand the model to make it closer to reality. Secondly, the article is limited to mathematical derivation, and whether factual data can be used to support it, making the conclusion more convincing.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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