Social welfare, climate change and strategy selections for developing countries

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Abstract

This paper introduces external effect of carbon emission in social welfare function, constructs two-stage trade game among three countries, analyzes partially equilibrium output of the three countries and then discusses the influences of different carbon tax policies on social welfare in each country. The study shows it is more effective for developing countries to adopt strategies about founding free trade area and domestic carbon tax collection, up to a higher social total welfare lever, when they face carbon border tax adjustments(BTAs) from developed countries under Nash game conditions. By further studying, the efficiency of domestic carbon tax policy depends on the carbon intensity relation of each country; a higher relative intensity of carbon abroad decreases the negative external effect value caused by the carbon emissions.

Keywords: border tax adjustments, social welfare function, game theory

1 Introduction

In order to limit global warming, the Intergovernmental Panel on Climate Change (IPCC) noted that worldwide annual carbon emissions need to be cut approximately in half by 2050. As an essential part of post-Kyoto international climate negotiations, carbon-based border tax adjustments (BTAs) have been proposed to “level the playing field” by the US, EU and other OECD countries against countries without compatible emissions-reduction commitments, including China [1-2]. The US House of Representatives (2009) passed the American Clean Energy and Security Act of 2009 (HR2998) on June 26, 2009, in which a carbon-based border-adjustment provision was proposed to protect the competitive advantages of American producers against their competitors in countries without comparable emissions-reduction commitments. In the EU, the EC-commissioned High Level Group on Competitiveness, Energy and Environmental Policies proposed the BTA issue in its second report early in 2006. Moreover, BTAs have been recommended as useful policy tools to protect the competitiveness of domestic industries in the EU [3-5].

Such border tax adjustments by participating countries are driven by two related objectives. One is to provide competitiveness (of energy-intensive industries) offsets for domestic producers since the added costs for domestic producers involved with domestic carbon pricing impose a competitive disadvantage on them [6]. The other is carbon leakage, that the reductions of carbon emissions in participating countries such as the EU, US and other OECD countries [7-8]. Alexeeva-Talebi utilized CGE model to analyze the effects of carbon tariff on importing and exporting countries and considered carbon tariff could effectively protect domestic competitiveness of importing countries [9]. Weber and Peters drew the conclusion that carbon tariff neither violates WTO agreement nor influenced on international industrial competitions through analysis of America implementing carbon tariff policy [2]. Based on GTAP data, Hubler analysis drew the conclusion that carbon tariff policy does not only contribute to global emission reduction, but also worsened social welfare of developing countries [10]. Manders and Veenendaal found implementation of carbon tariff policy could effectively reduce carbon leakage, which would be beneficial to EU but damage the welfare of other countries, under EU emission system [11]. Siqueira applied a two-country model to analyze the effects of domestic politics on international externality [12]. He also investigated two kinds of countries which are cooperated with carbon emission or not.

A number of researchers have examined the impacts of BTAs and related policies. Most of the researchers have focused on the effectiveness of BTAs for protecting competitiveness and avoiding carbon leakage. But no general agreement has been found to date. Gros found that BTAs would increase global welfare [13]. Dissou and Eyland found that competitiveness would be hindered by BTAs in Canada [14]. Fischer and Fox suggested that border carbon adjustments would be beneficial for domestic production but not be effective to reduce global emissions [15]. Kuik and Hofkes focused on the carbon leakage-avoidance effects of the EU Emissions Trading System and suggested that BTAs might reduce the sector leakage rate of the iron and steel industry, but the overall leakage-reduction effect was modest [16].

Most of the existing studies focused on the effects of BTAs in developed countries, only a few studies examine the international trade impacts of a carbon border tax adjustments and none seems to look at the welfare implications from a developing country point of view, the country that BTAs mainly target, either implicitly or

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explicitly. This paper focus on how the developing countries international trade patterns could be used, for the fulfillment of climate policy and social welfare objectives. While this paper focus on the strategies selected by the developing countries to maximize the social welfare that are heavily export-oriented, the developing countries trading partners (notably the developing country and the developed country) are clearly also important subjects of discussion and are discussed where relevant.

It is argued that the social welfare of free trade area agreements and domestic carbon tax strategies are higher than the strategy of passive coping. By increasing focus on the efficiency of domestic carbon tax policy, a higher relative intensity of carbon abroad increases the desirability of high import tariff imposed by the home country because a border tax shifts production to the importing country, which in this case leads to lower environmental costs.

2 Model assumption and description

On the basis of analytic framework of traditional international trade theory, this paper blends in influencing factors of carbon tariff and constructs a partial equilibrium model considering climate changes to analyze the effects of importing countries collecting carbon tariff on welfare of importing and exporting countries and analyze the countermeasures of importing countries.

2.1 FUNDAMENTAL ASSUMPTION

Consider a reciprocal market model of intra-industry trade in homogeneous goods. There are three countries (G1, G2 and G3), and each country has a manufacturer which can be regarded as the aggregation of domestic enterprises to produce the same commodity which is both sold in domestic market and exported. The developed country imports goods from developing countries but does not export goods to other countries. The market of the goods in each country is segmented and three-oligarch by Home firm and two foreign firms. A static representation of a Cournot game is useful to map equilibrium options of various tax schemes. Without loss of generality, one unit of labor produces one unit of the goods, so that the wage rate is internationally fixed to unity. Production of the goods is nationally monopolized under a constant marginal cost $c \geq 0$, and emits a proportional emission. Letting means the product quantity provided to Country j by the manufacturer of Country i. Suppose international trade transportation cost is 0; the market of each country is completely divided effectively; the information among governments, between governments and enterprises as well as among enterprises is complete. Utility maximization under the budget constraint yields linear inverse demand functions:

$P_j = P_j(Q_j) = A - Q_j$, where $Q_j = \sum_{i=1}^{3} q_j^i$

Without loss of generality, we suppose that G1 is a developed country and the pure importing country; G2 and G3 are developing countries with both import and export trade. As the representative of developing countries, China is expressed as G2. Assume all countries carry out non-discriminatory special tariff for the imported products from the countries which do not sign trade agreement with the country. (i≠j) means special import tariff collected from the manufacturer in Country i by Country j. The importing countries collect extra carbon tariff (is used to express carbon tariff collected from Country i by G1) from the countries which do not take emission reduction obligation while collecting emission tax (expressed as) domestically so as to reach the purpose of limiting emission reduction of exporting countries and relieving climatic variations.

2.2 ENTERPRISE PROFIT FUNCTION AND CONSUMER SURPLUS

On each market, manufacturers' products face competetions against other manufacturers. All manufacturers make decisions simultaneously and confirm their own output in the condition of the other manufacturers is given to maximize the profit. Enterprise profit function of the importing country (G1) is:

$$\pi_1 = q_1^1 (A - c - \sum_{i=1}^{3} q_1^i - \varepsilon) \quad . \tag{1}$$

Enterprise profit functions of the importing countries (G2 and G3) are:

$$\pi_2 = \sum_{j=1}^{3} q_j^2 (A - c - \sum_{i=1}^{3} q_j^i - t_j^2) - \beta_1^2 q_1^2 \quad , \tag{2}$$

$$\pi_3 = \sum_{j=1}^{3} q_j^3 (A - c - \sum_{i=1}^{3} q_j^i - t_j^3) - \beta_1^3 q_1^3 \quad . \tag{3}$$

To simplify the formula, make $B = A - c$.

$$CS_j = \frac{1}{2} (Q_j^d)^2 \quad . \tag{4}$$

Consumer surplus of Country j is the function of market product demand; product demand of Country j is $Q_j^d = \sum_{i=1}^{3} q_j^i$.

2.3 EXTERNAL EFFECT OF CARBON EMISSION

This paper adopts the processing method of Daniel Gros (2009) to set negative externality of CO_2 as invariant parameter σ . In order to account for potential differences in carbon technologies and intensities in each country, it is not assumed that the production of each unit leads to the same negative external effect. Instead production abroad takes place with a potentially different carbon intensity, which relative to country j is denoted by γ_j . Furthermore there is

α_j households at Country j. Global social welfare of carbon emission is thus given by:

$(\alpha_1+\alpha_2+\alpha_3)\sigma(\gamma_1 q_1^s+\gamma_2 q_2^s+\gamma_3 q_3^s)$.

External effects of carbon emission for country j should be the function of the total supply (q_j^s) of the country:

$$W_j^{carbon}=(\alpha_1+\alpha_2+\alpha_3)\sigma\gamma_j q_j^s = M\gamma_j q_j^s \quad , \tag{5}$$

$M=(\alpha_1+\alpha_2+\alpha_3)\sigma$ for simplicity.

2.4 SOCIAL TOTAL WELFARE FUNCTION

The gain of a country as the game player is social total welfare they care for. It is composed of four parts: consumer surplus (CS), domestic enterprise profit (π); government tax revenue (TR) and subtract the external effect of carbon emission (W^{carbon}):

$$W_j = CS_j+\pi_j+TR_j-W_j^{carbon} . \tag{6}$$

3 Carbon tax policies under non-cooperative and ccooperative game equilibrium

3.1 SITUATION OF EXPORTING COUNTRIES ARE CONFRONTED WITH BTAS OF IMPORTING COUNTRIES

G1 collects carbon emission tax at home and collects carbon border tax adjustments (BTAs) for imported products of the countries which do not adopt emission reduction measures. G2 and G3 adopt Nash equilibrium of negative coping. Manufacturers of each country are equal competitive relations and take actions simultaneously when seeing carbon emission tax and BTAs policies of each government. The game sequence is that each government first formulates their own tax policy and manufacturers of each country meanwhile maximize their won profits. To solve this game with backward induction, we have:

The optimal tax policy schemes of each government are:

$$\begin{aligned} &\varepsilon = 3M\gamma_1 - B \\ &t\beta_1^2 = t\beta_1^3 = \frac{1}{2}M\gamma_1 , \\ &t_3^2 = \frac{1}{130}(50B+30M\gamma_1+24M\gamma_2-54M\gamma_3) \\ &t_2^3 = \frac{1}{130}(50B+30M\gamma_1-54M\gamma_2+24M\gamma_3) \end{aligned} \tag{7}$$

Where, $B=A-c$. Since the collecting objects and coefficients of tariff t_j^i and carbon border tax adjustments β_j^i of G1 are the same, let $t\beta_1^2=t_1^2+\beta_1^2$ and $t\beta_1^3=t_1^3+\beta_1^3$ for simplicity. Substitute the optimal tax policies confirmed by the governments into the social welfare and gain the optimal outputs of manufactures of each country are:

$$\begin{aligned} &q_1^1 = B-2M\gamma_1 \quad q_1^2=q_1^3=\frac{1}{2}M\gamma_1 \\ &q_2^2=\frac{1}{3}(B+t_2^3) \quad q_2^3=\frac{1}{3}(B-2t_2^3) \\ &q_3^2=\frac{1}{3}(B-2t_3^2) \quad q_3^3=\frac{1}{3}(B+t_3^2) \end{aligned} \tag{8}$$

3.2 SITUATION OF EXPORTING COUNTRIES SET UP FTA TO COPE WITH BTAS IMPORTING COUNTRIES

When G2 and G3 form a free trade area (FTA), internal tariff among the member countries is 0, so $t_2^3=t_3^2=0$. Each member country selects external optimal tariff to make the social welfare maximize. The game sequence is that each government first formulates their own tax policy and meanwhile manufacturers of each country maximize their won profits after seeing the tax policies.

Enterprise profit target function of G1 is the same with Formula (1). Enterprise profit target functions of G2 and G3 changes.In the second stage, enterprises of the three countries maximize their own profit through selecting the optimal output. The solving process is the same with that in Section 3.1. The optimal outputs of manufacturers of each country are:

$$\begin{aligned} &q_1^1=\frac{1}{4}(B-3\varepsilon+t_1^2+\beta_1^2+t_1^3+\beta_1^3) \\ &q_1^2=\frac{1}{4}(B+\varepsilon-3t_1^2-3\beta_1^2+t_1^3+\beta_1^3) \\ &q_1^3=\frac{1}{4}(B+\varepsilon+t_1^2+\beta_1^2-3t_1^3-3\beta_1^3) \\ &q_2^2=q_2^3=q_3^2=q_3^3=\frac{1}{3}B \end{aligned} \quad . \tag{9}$$

In the first stage, each government selects tax policies to maximize social welfare function (6). The tax policies of the governments are:

$$\varepsilon = 3M\gamma_1 - B \quad t\beta_1^2=t\beta_1^3=\frac{1}{2}M\gamma_1 \quad . \tag{10}$$

From here we can see that domestic carbon tax and BTAs of G1 are not influenced by FTA set up by G2 and G3. The optimal social welfare function of G1 is the same with that in Section 3.1.

3.3 SITUATION WHERE G2 ADOPTS CARBON TAX

COLLECTION AT HOME TO COPE WITH BTAS

When G3 does not take any measure, but G2 collects carbon tariff at home to cope with carbon border tax adjustments of G1, what different from setting up free trade area is that the two exporting countries select the optimal tariff by themselves to maximize their own welfare. The same batch of commodities should pay both carbon tax collected by exporting countries and BTAs collected by importing countries. According to the principle of avoidance of double taxation, G2 collects carbon tax for domestically produced products, and G1 does not collect extra carbon tariff any more for the products imported from G2.

Enterprise profit target function of G1 is the same with Formula (1). Enterprise profit target functions of G2 and G3 change. Adopting backward induction method to solve tax policies of each country and the optimal outputs of manufacturers of each country are as follows:

$$\begin{aligned} &q_1^1 = B - 2M\gamma_1 + \frac{1}{7}\varepsilon^* \quad q_1^2 = \frac{1}{2}M\gamma_1 - \frac{3}{7}\varepsilon^* \\ &q_1^3 = \frac{1}{2}M\gamma_1 + \frac{1}{7}\varepsilon^* \quad q_2^2 = \frac{1}{3}(B - 2\varepsilon^* + t_2^3) \\ &q_2^3 = \frac{1}{3}(B + \varepsilon^* - 2t_2^3) \quad q_3^2 = \frac{1}{3}(B - 2\varepsilon^* - 2t_3^2) \\ &q_3^3 = \frac{1}{3}(B + \varepsilon^* + t_3^2) \end{aligned} \quad . \tag{11}$$

Domestic carbon tax of G1 $\varepsilon = 3M\gamma_1 - B$ keeps unchanged; the tariff collected from G2 by G1 is $t_1^2 = \frac{1}{2}M\gamma_1 - \frac{3}{7}\varepsilon^*$; tariff policy of G1 for G3 is the same with the situation in Section 3.1.

4 Contrastive analysis and discussion

4.1 COMPARISON OF SOCIAL TOTAL WELFARE OF G2 UNDER 3 GAME CONDITIONS

When developed country G1 adopts import carbon tariff collection policy, we compare the social welfare about developing country G2 under three different strategies. The first is the situation adopting negative coping, the second is set up free area with G3 and the third is collecting carbon tax at home.

$$W_2^2 - W_2^1 = \frac{1}{6}t_2^3(\frac{4}{3}B - \frac{1}{3}t_2^3) + (\frac{2}{3}t_3^2 - \frac{1}{3}t_2^3)(M\gamma_1 + \frac{4}{3}B - M\gamma_2 - \frac{2}{3}t_3^2 + \frac{1}{3}t_2^3) > 0$$

Conclusion 1: on the condition of Nash game, the strategy of G2 and G3 setting up FTA can achieve higher social total welfare level than adopting negative coping strategy.

$$W_2^3 - W_2^1 = \frac{2787}{882}(\varepsilon^*)^2 + (-\frac{324}{126}B - \frac{92}{126}t_2^3 + \frac{148}{63}t_3^2 - \frac{37}{21}M\gamma_1 + \frac{37}{21}M\gamma_2)\varepsilon^* + \frac{1}{3}t_2^3(B - 2t_2^3)$$

$W_2^3 - W_2^1$ can be regarded as a unitary quadratic function about domestic carbon tax ε^* of G2. Due to $\frac{2787}{882} > 0$ and $t_2^3(B - 2t_2^3) > 0$, the opening of this function is upward and the intercept term is higher than 0. The solving equation $W_2^3 - W_2^1 = 0$ has two solutions greater than zero, i.e. ε_1^* and ε_2^* ($0 < \varepsilon_1^* < \varepsilon_2^*$). When $\varepsilon_1^* < \varepsilon^* < \varepsilon_2^*$, we have $W_2^3 < W_2^1$. Thus, for developing country G2, social welfare resulted from domestic carbon tax collection is lower than that resulted from negative coping strategy. Thus, developing countries would rather show no interest in BTAs policy of developed countries. When $0 < \varepsilon^* < \varepsilon_1^*$ or $\varepsilon^* > \varepsilon_2^*$, we have $W_2^3 > W_2^1$. Developing country G2 can effectively improve social welfare level when collecting carbon tax at home.

Conclusion 2: on the condition of Nash game, G2 which adopts domestic carbon tax collection policy is not strictly superior to negative coping strategy. When carbon tax planted to be collected by developing countries is in $[\varepsilon_1^*, \varepsilon_2^*]$, negative coping strategy can realize higher social welfare level than carbon tax collection strategy.

$$\begin{aligned} W_2^3 - W_2^2 = &\frac{2728}{882}(\varepsilon^*)^2 + (-\frac{324}{126}B - \frac{92}{126}t_2^3 + \frac{148}{63}t_3^2 - \frac{37}{21}M\gamma_1 + \frac{37}{21}M\gamma_2)\varepsilon^* + \frac{1}{3}t_2^3(B - 2t_2^3) \\ &- \frac{1}{6}t_2^3(\frac{4}{3}B - \frac{1}{3}t_2^3) - (\frac{2}{3}t_3^2 - \frac{1}{3}t_2^3)(M\gamma_1 + \frac{4}{3}B - \frac{2}{3}t_3^2 + \frac{1}{3}t_2^3) - M\gamma_2(\frac{1}{3}t_2^3 - \frac{2}{3}t_3^2) \end{aligned}$$

Solve $W_2^3 - W_2^2 = 0$. Since the coefficient of the quadratic term is greater than 0 and the intercept term is less than 0, it is known that this equation has one positive solution and one negative solution according to the function properties, i.e. $\hat{\varepsilon}_1^*$ and $\hat{\varepsilon}_2^*$ ($\hat{\varepsilon}_1^* < 0 < \hat{\varepsilon}_2^*$). When $\varepsilon^* \geq \varepsilon_2^*$, there is $W_2^3 - W_2^2 \geq 0$. For G2, social total welfare resulted from high-level carbon tax collection at home is higher than that brought by G3 setting up free trade area. The government of G2 will choose the coping strategy of carbon tax collection at home. If $\varepsilon^* \in [0, \hat{\varepsilon}_2^*]$, we have $W_2^3 < W_2^2$. For G2, social total welfare resulted from carbon tax collection at home is lower than that brought by G3 setting up free trade area. In this case, the government of G2 will choose to set up free trade area with G3.

Conclusion 3: under the objective of pursuing maximization of social total welfare, if the carbon tax G2 plants to collect is in $[0, \hat{\varepsilon}_2^*]$, social total welfare resulted from carbon tax collection at home is lower than that brought by G3 setting up free trade area. For G2, carbon tax collection at home is not the optimal selection.

4.2 COMPARISON OF EXTERNAL EFFECTS OF CARBON EMISSION UNDER 3 GAME CONDITIONS

Under the k^{th} game situation, external effect of global carbon emission is the function of aggregate supply of each country:

$$WW^k_{carbon} = \sum_{j=1}^{3} M\gamma_j q_j^s \ . \tag{12}$$

The D-value between global carbon emission externality brought by G2 and G3 setting up free trade area and global carbon emission externality brought by negative coping strategy is:

$$WW^2_{carbon} - WW^1_{carbon} = \frac{1}{3}M\gamma_2(2t_3^2 - t_2^3) + \frac{1}{3}M\gamma_3(2t_2^3 - t_3^2) \ . \tag{13}$$

Since carbon intensity y_j of unit product of each country is constant greater than 0, the optimal tariff between G2 and G3 (see Section 3.1) has $2t_3^2 > t_2^3$ and $2t_2^3 > t_3^2$. In this case we have $WW^2_{carbon} - WW^1_{carbon} > 0$.

Conclusion 4: the strategy of G2 and G3 setting up free trade area are results in greater negative external effect of carbon emission than negative coping strategy.

$$WW^3_{carbon} - WW^1_{carbon} = \frac{1}{21}M\varepsilon^*(3\gamma_1 - 16\gamma_2 + 17\gamma_3) \ . \tag{14}$$

The influence of carbon tariff strategy of G2 collecting domestic carbon tax depends on the relations of carbon intensity of each country. When $16\gamma_2 \geq 3\gamma_1 + 17\gamma_3$, $WW^3_{carbon} \leq WW^1_{carbon}$. G2 collecting carbon tax at home brings less negative external effect of carbon emission than negative coping strategy. In other words, this strategy has promotion effect on reduction of global carbon emission externality. When $16\gamma_2 < 3\gamma_1 + 17\gamma_3$, we have $WW^3_{carbon} > WW^1_{carbon}$. G2 collecting carbon tax at home brings larger negative external effect of carbon emission than negative coping strategy. In other words, this strategy is not beneficial to reduction of global carbon emission externality.

Conclusion 5: the influences of G2 collecting carbon tax at home on environment depends on carbon intensity relations of each country. Higher carbon intensity of developing countries means carbon tax collection is more beneficial to reduction of external effect of carbon emission.

Conclusions

This paper analyzes how developing countries dynamically choose and confirm the optimal strategy in international trade competitions when faced with BTAs and considering negative external effect of carbon emission and strategy selection of other developing countries so as to realize maximization of social total welfare level. This paper depicts the process of carbon emission externality influencing government decision-making through introducing the influence of carbon emission on environment into social total welfare function, analyzes how manufacturers of various countries dynamically decide their outputs and corresponding strategies to gain the maximum profits.

The results show when developing countries are faced with developed countries collecting carbon tax, it is more superior for them to choose free trade area strategy than negative coping strategy, but domestic carbon tax collection strategy is not strictly superior to negative coping strategy. This conclusion is different from that Dieter et al. (2009) consider carbon policy is sub-game perfect Nash equilibrium solution. Social total welfare level caused by setting up free trade area and collecting carbon tax domestically is influenced by domestic carbon tax. When the carbon tax level developing countries plan to collect is in a certain interval, it is more superior for developing countries to choose free trade area strategy than the other strategies. In terms of the influences of carbon emission on external environment, the strategy of setting up free trade area is beneficial to enterprises in developing countries expanding market to gain larger profits and meanwhile causes more negative external effects of carbon emission. The effects of domestic carbon tax collection on environment depend on the carbon intensity relation of each country. Higher carbon intensity of developing countries means carbon tax collection is more beneficial to reduction of external effect of carbon emission.

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