"Competitiveness, Carbon Leakage, and Border Tax Adjustments:

Might Imperfect Competition Matter?"

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Abstract

In this paper, analysis is presented relating to the impact of border tax adjustments for climate policy on the international competitiveness of energy-intensive industries, and the related problem of carbon leakage. While many of the economic and legal issues are not particularly new, climate policy does present some possible twists to the analysis of border tax adjustments when vertically-related markets can be characterized as a successive oligopoly. Specifically, an appropriate border tax adjustment will depend on the incidence of a domestic carbon tax, the nature of competition in upstream and downstream sectors, as well as the basis for assessing the trade neutrality of any border tax adjustment. If trade neutrality is defined in terms of market volume, even though carbon leakage is reduced, domestic firm competitiveness cannot be maintained. This compares to defining trade neutrality in terms of market share, which results in domestic competitiveness being maintained and global carbon emissions being reduced.

Keywords: climate policy, carbon leakage, border tax adjustments, imperfect competition

JEL Codes: H87, Q38

Introduction

In the past decade, it has become increasingly obvious to many observers that even though negotiation of the Kyoto Protocol on Global Climate Change in 1997 was a useful first step, further efforts to develop a comprehensive multilateral agreement for reducing carbon emissions will be necessary if global climate change is to be properly addressed (Frankel, 2009). However, irrespective of the logic supporting a multilateral approach to dealing with a global public bad, many countries such as the United States and the European Union (EU) have been actively pursuing national efforts to reduce carbon emissions.

During the 110th US Congress, at least half of the twelve climate change bills introduced by legislators called for some type of border measure to be targeted at energy-intensive imports, based upon the carbon emissions embodied in those imports (Frankel, 2009). More specifically, at the beginning of 2008, separate bills sponsored by Senators Bingaman and Specter, and Senators Liebermann and Warner respectively, were being discussed in the US Congress, both of which called for a domestic cap-and-trade system targeted at carbon emissions, along with a requirement that importers acquire emissions allowances based on the embedded carbon in their goods (Houser *et al*., 2008).

More recently, in the last session of Congress, The American Clean Energy and Security Act [H.R. 2454] sponsored by Representatives Waxman and Markey, was passed by the US House of Representatives in June 2009.[1] Like the earlier bills, the Waxman-Markey bill contained provisions relating to border adjustments for US domestic climate policy. Specifically, if no multilateral climate agreement existed by 2018, the President was mandated to implement an international emissions allowance program, requirements being imposed on non-exempt

[1] A companion bill, sponsored by Senators Kerry and Boxer, was also under consideration by the US Senate in 2009 until it was dropped in 2010 in favor of an alternative bill, sponsored by Senators Kerry and Lieberman. The latter bill was never put to the vote due to lack of Republican support.

importers no earlier than January 2020. Specifically, importers in eligible industries would have been required to purchase an appropriate amount of emission allowances as a condition of entry into the United States, the border price of allowances being based on the mean of the daily US market price for emission allowances.[2]

While comprehensive climate change legislation may not come out of the current session of Congress, the United States itself could potentially be subject to border tax adjustments by the EU. In determining its carbon emissions targets for the post-Kyoto period, the European Commission reached agreement in 2009 on revising its previous Directive 2003/87/EC, and which contained the following language:

> "… Energy-intensive industries which are determined to be exposed to significant risk of carbon leakage could receive up to 100% of allowances free of charge or an effective carbon equalization system could be introduced with a view to putting installations from the Community which are at a significant risk of carbon leakage and those from third countries on a comparable footing. Such a system could apply requirements to importers that would be no less favorable than those applicable to installations within the EU, for example by requiring the surrender of allowances…" [2008/013 COD, p.8] [3]

Frankel (2009) notes that the term "carbon equalization" is consistent with the kind of language spelled out in the Bingaman-Specter and Lieberman-Warner bills, and matches the several calls made by French President Nicolas Sarkozy for a carbon tax on imports, "…A carbon tax at the border is the natural complement to a domestic carbon tax. More importantly, a carbon tax at the border is vital for our industries and our jobs. This has nothing to do with protectionism…This is about fair play…" (*Financial Times*, September 10, 2009).

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[2] Importers in eligible industries would have been exempt from having to purchase allowances if it were established that 85 percent or more of US imports of covered goods were produced in countries that met at least one of two criteria: (i) the country, along with the United States, were party to an international agreement to reduce GHG emissions, where the GHG reduction requirement were at least as stringent as those applied in the United States; (ii) the country had implemented domestic climate policies that increased production costs in the eligible industry by at least 80 percent of the cost of complying with US legislation.

[3] Directive of the European Parliament and of the COUNCIL amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading system of the Community. (http://ec.europa.eu/environment/climat/emission/pdf/com_2008_16_en.pdf)

While the principle of using border adjustments for domestic environmental policy is not a particularly new regulatory issue, there are potentially new challenges for economic analysis. Specifically, in setting appropriate border adjustments, it is important to account for the incidence of climate policies targeted at upstream energy production, on downstream production of energy-intensive goods. Incidence of the carbon tax will be a function of factors such as vertical market structure, the shape of the demand curve for the final good, industry technology, and the nature of competition among firms producing the energy and final goods.

In analyzing this problem, the current paper is organized as follows: in section 1, the existing literature on the connection between trade and climate policy is briefly reviewed, followed in section 2 by a discussion of current trade law as it relates to border tax adjustments; in section 3, some stylized facts are presented about the type of vertically-related market most likely to be affected by climate policy, followed in section 4 by description of a model of successive oligopoly, which is then used in section 5 to analyze border tax adjustments for domestic climate policy; finally, a summary of the paper and some conclusions are presented.

1. Trade and Climate Policy

The inclusion of border measures in climate change legislation is predicated on two concerns: first, there will be a reduction in *competitiveness* of firms in industries most affected by domestic climate policies; second, there will be *carbon leakage*, i.e., production by energy-intensive industries will relocate to countries with less restrictive climate policies, thereby creating *carbon havens* and generating globally inefficient production of a global bad (WTO/UNEP 2009).[4]

[4] In the both US and the EU, the issues of competitiveness and carbon leakage have been explicitly linked in relation to the use of border measures (van Asselt and Brewer, 2010).

In terms of competitiveness, if a country such as the United States unilaterally implements a carbon tax or some type of emissions trading scheme, this will impact negatively the relative costs of domestic firms, which in turn will constrain their ability to compete with imports from other countries with less stringent climate policies. While competitiveness of firms is a difficult concept to define, it would typically be thought of in terms of their ability either to maintain market share and/or profits. As the WTO/UNEP (2009) report notes, the competitiveness of industries subject to domestic climate policies will be a function of multiple factors, including: first, the specific characteristics of an industry such as market structure, industry technology, the extent of import competition, and the incidence of any explicit/implicit carbon price; and, second, the exact design of the domestic climate policy; and the design of other countries' climate policies.

Related to the expected impact of domestic climate policies on competitiveness is the issue of carbon leakage, which can be thought of as the possibility that output of energy-intensive industries will either increase in, or production will relocate to countries that have less restrictive climate policies. Essentially, a wedge will exist between the price of carbon in countries, that either do not implement domestic climate policy or impose lower caps on carbon emissions, and countries that implement considerably tougher climate policies. This lack of an international carbon price is expected to have two effects: first, carbon havens may develop in those countries where less restrictive climate policies will attract carbon-intensive industries, resulting in globally inefficient production of a public bad; second, the possibility of capital flight through relocation of industries to countries with a lower carbon price will result in job losses in countries with a higher carbon price.

Despite these two issues coming to the forefront of the debate on implementation of domestic climate policy, they are not particularly new, both issues having been analyzed in the literature on trade and the environment. Since the early-1990s, the connection between trade and environmental policy has been the subject of considerable debate between the trade policy community and environmentalists. This debate was given much prominence during negotiations over the North American Free Trade Agreement (NAFTA) (Esty, 1994), and became more intense with completion of the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) and subsequent formation of the WTO (Copeland and Taylor, 2004). A defining characteristic of this debate has been the oft-expressed concern of environmentalists that additional competitive pressures come with the process of international economic integration. These pressures will result in lobbying for less stringent environmental policies, and thereby "regulatory chill" (Bagwell and Staiger, 2001a). This argument is typically applied to developed countries where international competition may be expected to hurt domestic industries either through loss of market share or movement of those industries from developed countries with tough environmental standards to less developed countries with weaker environmental standards, i.e., a pollution haven effect (Copeland and Taylor, 2004).

While the issues of competitiveness and carbon leakage are closely connected, they have typically been addressed separately in the environmental and international economics literatures. In the former, the focus is on how trade policy instruments might be used to prevent carbon leakage when one group of countries commits to cooperation over climate policy, while a second group free-rides by not implementing climate policy (Hoel, 1994, 1996; and Mæstad, 1997, 2001). For example, Hoel (1994) shows a social optimum can be obtained if cooperating countries set common carbon taxes, and at the same time use import tariffs (export subsidies) on all traded goods, the objective being to shift the terms of trade against free-riding countries, thereby reducing carbon leakage. While this literature does not explicitly address competiveness, it seems reasonable to assume that it will be affected via the use of trade instruments in the cooperating countries. However, several authors in this literature argue that use of trade policy instruments could be constrained by existing WTO/GATT rules (Hoel, 1996; Mæstad, 1997).

In the international economics literature, Bagwell and Staiger (2001b) offer an explicit solution to the problem of reduced competitiveness due to tougher environmental policy. Suppose the WTO/GATT consists of a two-stage tariff negotiation game, where, before negotiations begin, existing environmental policies of countries are noted.[5] At the first stage of the game, bound tariffs are negotiated, implying a set of market access commitments by the set of countries. At the second stage of the game, countries can make unilateral changes to their mix of policies, providing that tariffs do not exceed their bound level, implied market access commitments being maintained.

What happens if the preferred choice of environmental policy in a sub-set of countries negatively affects their competitiveness, resulting in increases in the other sub-set of countries' market access in energy-intensive goods? In order to maintain its negotiated market access commitments, the first set of countries would need to raise tariffs on these products above their bound level, which they are unable to do under WTO/GATT rules. Bagwell and Staiger (2001b) argue that resolution of this problem lies in providing more flexibility to the current rules by allowing countries to renegotiate their bound tariffs if unilateral changes in their environmental policies increase market access. While the problem of pollution havens is not addressed

[5] While climate policy is not explicitly mentioned by Bagwell and Staiger (2001b), their key results can easily be adapted to include it.

explicitly by Bagwell and Staiger (2001b), allowing countries to renegotiate their bound tariffs while maintaining their market access commitments, would necessarily mitigate carbon leakage.

2. Border Tax Adjustments and Trade Law

The preceding discussion indicates that the potential for climate policies to increase carbon leakage/negatively affect competitiveness is well-understood in the extant environmental and international economics literatures. Importantly, there are theoretical arguments for the use of trade policy instruments in the presence of domestic climate policies. Yet both literatures raise the concern that existing trade rules will prevent the use of such instruments targeted at preventing carbon leakage/maintaining competitiveness. However, the basic principle is already applied with respect to competitiveness in existing WTO/GATT rules relating to border tax adjustments (BTAs) for domestic excise taxes.

According to WTO/UNEP (2009), a *border tax* (or tariff) is imposed on imported goods while a *border tax adjustment* is the imposition of a domestically imposed excise tax on *like* imported goods. Essentially GATT Article II: 2(a) allows members of the WTO to place on the imports of any good, a border tax equivalent to an internal tax on the like good. However, under GATT Article III: 2, the BTA cannot be applied *in excess* of that applied directly or indirectly to the like domestic good, i.e., they have to be *neutral* in terms of their impact on trade, their objective being to preserve *competitive equality* between domestic and imported goods (WTO, 1997). As a consequence, any country imposing a BTA in excess of the domestic tax would be in contravention of GATT Article III.[6] Importantly, WTO/GATT rules on BTAs are not motivated

[6] With respect to exported goods, WTO/GATT rules allow remission of the domestic tax on the exported good. As long as the border adjustment does not exceed the level of the domestic tax, it is not regarded as an export subsidy under the GATT Subsidies Code (WTO, 1997).

by environmental concerns, but instead are supposed to ensure trade neutrality (Demaret and Stewardson, 1994).

Initial discussion of the legal status of BTAs arose in the late-1960s when the US expressed concern that its exports to the then European Economic Community (EEC) were subject to an adjustment at the border for value-added tax (VAT), while at the same time VAT-free exports from the EEC were receiving an export subsidy. In the event, no dispute settlement case was initiated through GATT by the US, and there was no negotiation over the issue in the Tokyo Round. In synthesizing analysis of this issue, Lockwood, de Meza and Myles (1994) have shown that movement between an origin and a destination base for VAT would have no real effects on trade, production and consumption.

There is however debate among legal observers as to whether WTO/GATT rules will allow BTAs on specific final goods that embody energy inputs, much of the discussion focusing on the precise interpretation of the relevant GATT Articles (WTO/UNEP, 2009). The language contained in GATT Article II.2 (a) is interpreted as restricting BTAs to inputs that are *physically incorporated* into the final good, thereby precluding their application to imported energy-intensive final goods. In contrast, the language contained in GATT Article III.2 is interpreted as allowing BTAs to be applied to *inputs* such as energy used in the production process of the final good. Claims of legal precedent for the latter appeal to the 1987 *Superfund* case involving the US, where a GATT Panel ruled that a BTA levied on imported substances that were the end-products of certain chemicals taxed in the US, was equivalent to the tax borne by like domestic substances, and therefore consistent with GATT Article III.2 (GATT, 1987).[7]

[7] In 1989/90, a tax was imposed in the US of a range of chlorofluorocarbons (CFCs), and a BTA was also applied to the import of such chemicals, as well as the import of manufactured products that either contain CFCs or use them in their production process (Barthold, 1994). To date no WTO ruling has been rendered on this BTA.

It should be noted that even if a border tax adjustment for domestic climate policy is deemed inconsistent with GATT Article III: 2, there has been extensive legal several discussion of whether it may still be possible to justify it under the environmental exceptions of GATT Article XX (General Exceptions).[8] Ultimately while legal clarity on this issue can only be settled by a WTO Dispute Settlement Panel, the remainder of the paper proceeds upon the assumption that BTAs applied to energy-intensive imports will be allowed under the WTO/GATT rules.

3. Climate Policy and Energy-Intensive Industries

The burden of domestic climate policy is expected to fall mostly on import-competing, energy-intensive manufacturing industries in the developed countries. Consequently, an important part of figuring out any appropriate border adjustments involves establishing those industries that are most vulnerable to the unilateral implementation of climate policy. In the case of the US, Houser *et al*. (2009) identify five energy-intensive industries most likely to be affected by domestic climate policy: steel, aluminum, chemicals, paper and cement, with net imports accounting for 19, 59, 6, 10 and 25 percent of domestic demand respectively.[9] A similar set of industries have been discussed with respect to EU concerns about carbon leakage (Monjon and Quirion, 2010).

How should BTAs be applied to this particular set of industries? If both energy and carbon-intensive final goods markets are perfectly competitive, then the appropriate treatment of imports of a energy-intensive good such as aluminum is relatively straightforward (see Poterba and Rotemberg, 1995): an import tax on imported aluminum equal to the level of the carbon tax times the extent to which energy enters the cost function for domestically produced aluminum,

[8] For example, see Goh (2004) and Pauwelyn (2007).

[9] Interestingly, Canada is the largest source of US imports for all of these industries, with the exception of chemicals, and China is only a major import competitor in the case of cement. It should be noted, however, that over the past fifteen years, the share of energy-intensive US imports from developing countries has been increasing Houser *et al*. (2009).

would raise marginal costs for the importer of aluminum by the same amount, and consequently will have a neutral effect on imports of aluminum, and thereby be WTO/GATT-consistent.

It may be more appropriate, however, to assume that both the energy and energy-intensive final goods markets are oligopolistic. In the case of electricity markets, with increased deregulation it is now quite commonplace to characterize generating firms in terms of their oligopolistic interaction (Ventosa *et al*., 2005). For example, Borenstein and Bushnell (1999), and Fowlie (2009) both model the Californian electricity market as a Cournot game, while Bolle (1992), Green and Newberry (1992), and Green (1996) all model the UK electricity market as a supply function equilibrium, the upper bound to which is the static Cournot outcome.[10] With respect to the set of energy-intensive industries, several authors analyzing the competitiveness/carbon leakage issue have already modeled firm behavior as oligopolistic, e.g., steel (Demailly and Quirion, 2008; Ritz, 2009) and cement (Ponssard and Walker, 2008), and there is also empirical evidence that firms in these industries may behave less than competitively, e.g., steel (Gallett, 1996); aluminum (Yang, 2001); paper (Mei and Sun, 2008); and cement (Azzam and Rosenbaum, 2001).

Consequently, if the vertical market structure of these industries is best described as one of successive oligopoly, then taxing imports of energy-intensive goods at the same level as the carbon tax imposed on energy production may not have a non-neutral impact. In order to analyze this possibility, the remainder of the paper consists of the adaptation and use of a model developed in two earlier papers by McCorriston and Sheldon (2005a; 2005b).

[10] Other examples include Andersson and Bergman (1995), Chen and Hobbs (2005), Puller (2007), Bushnell, Mansur and Saravia (2008), and Hortaçsu and Puller (2008).

4. A Model of Successive Oligopoly

Assumptions

The model introduced here is one of successive oligopoly, i.e., both the upstream (intermediate) and downstream (final) sectors are imperfectly competitive, and one that is standard when dealing with policy issues in vertically-related markets (for example, Sleuwaegen *et al*., 1998; Ishikawa and Spencer, 1999). In the downstream sector, the domestic firm competes with a foreign exporter of the energy-intensive good. In both domestic and foreign upstream sectors, two firms produce a non-traded intermediate input, electricity, which is homogenous once generated and supplied to the electricity transmission system. Production of electricity generates carbon emissions e via the function $e_j = g(x_j^U)$, where x_j^U is total upstream electricity production in countries j =1, 2, where 1 refers to the home country and 2 the foreign country, $g'(x_j^U) > 0$ and we can allow for $g'(x_2^U) > g'(x_1^U)$, capturing the idea that the foreign country's electricity production generates more carbon emissions e_j for a given level of output. A domestic carbon tax will raise domestic intermediate firms' costs subsequently raising the domestic downstream firm's costs due to the increased price of electricity. The technology linking each sector is one of fixed proportions. Formally, $x_j = \phi x_j^U$, j = 1, 2, where x_j and x_j^U represent output in both the domestic and foreign downstream and upstream sectors respectively, where superscript U denotes the upstream sector, and where ϕ is the constant coefficient of production. To ease the exposition, ϕ is set equal to one in the framework outlined below. Like much of the previous literature on vertical markets, arm's length pricing between the downstream and upstream sectors is also assumed, i.e., the downstream sector takes electricity prices as given (Abiru, 1988; Salinger, 1988).[11]

Following Ishikawa and Spencer (1999), the model consists of a three-stage game. At the first stage, the domestic government commits to a carbon tax and a BTA, while the second and third stages consist of Nash equilibria in the upstream and downstream sectors. The timing of the firm's strategy choice goes from upstream to downstream. Specifically, given costs and the derived demand curve facing the upstream sector, upstream firms simultaneously choose output to maximize profits, which generates Nash equilibrium in the upstream sector. The intermediate input prices are taken as given by the domestic downstream firm which, simultaneously with their foreign competitor, chooses their output to maximize profits, thus giving Nash equilibrium in the downstream sector. In terms of solving the model, equilibrium in the downstream sector is derived first and then the upstream sector. In addition, all equilibria are sub-game perfect.

Equilibrium in the Energy-Intensive Sector

Let x_1 equal the output choice of the domestic downstream firm and x_2 the output choice of its foreign competitor. The revenue functions can be written as:

$$R_1(x_1, x_2) \tag{1}$$

$$R_2(x_1, x_2)\,. \tag{2}$$

We assume downward sloping demands and substitute final goods.

Given (1) and (2), the relevant profit functions downstream are given as:

$$\pi_1 = R_1\,(x_1, x_2) - c_1 x_1 \tag{3}$$

$$\pi_2 = R_2\,(x_1, x_2) - c_2 x_2, \tag{4}$$

[11] It should be noted that we assume that there is no bargaining over upstream prices. This is a common assumption in models of successive oligopoly. Adapting a rationale for this provided by Ishikawa and Spencer (1999) it is assumed that the upstream electricity-producing firms sell to a large number of different downstream sectors, reducing any monopsony power one individual downstream sector may have.

where c_1 and c_2 are the domestic and foreign firms' respective costs. Firms' costs relate to the purchase of the intermediate input electricity, other costs being omitted as arguments.

The first-order conditions for profit maximization are given as:

$$R_{1,1} = c_1 \tag{5}$$

$$R_{2,2} = c_2 , \tag{6}$$

Equilibrium in the downstream sector can be derived by totally differentiating the first-order conditions (5) and (6):

$$\begin{bmatrix} R_{1,11} & R_{1,12} \\ R_{2,21} & R_{2,22} \end{bmatrix} \begin{bmatrix} dx_1 \\ dx_2 \end{bmatrix} = \begin{bmatrix} dc_1 \\ dc_2 \end{bmatrix}. \tag{7}$$

The slopes of the reaction functions are found by implicitly differentiating the firms' first-order conditions:

$$\frac{dx_1}{dx_2} = r_1 = -\frac{R_{1,12}}{R_{1,11}} \tag{8}$$

$$\frac{dx_2}{dx_1} = r_2 = -\frac{R_{2,21}}{R_{2,22}} . \tag{9}$$

With this set-up, we can deal with both strategic substitutes and strategic complements where the variable of interest is the cross-partial effect on marginal profitability, i.e., $\text{sign}\, r_i = \text{sign}\, R_{i,ij}$. Consequently, with reference to equation (8) and (9), if $R_{i,ij} < 0$, then $r_i < 0$. In this case, we have the case of strategic substitutes, and the reaction functions are downward sloping. However, if $R_{i,ij} > 0$, the reaction functions are upward sloping and we have strategic complements. The distinction between strategic substitutes/complements relates to the "aggressiveness" of firm's strategies (Bulow *et al*. 1985). With strategic substitutes, firms' strategies are less aggressive than those associated with strategic complements, i.e., with strategic substitutes (complements), an increase in the output of firm 1 would be met by a decrease (increase) in that of firm 2.[12]

Given (7), the solution to the system is found by re-arranging in terms of dx_i and inverting where Δ is the determinant of the left-hand side of (7):

$$\begin{bmatrix} dx_1 \\ dx_2 \end{bmatrix} = \Delta^{-1} \begin{bmatrix} R_{2,22} & -R_{1,12} \\ -R_{2,21} & R_{1,11} \end{bmatrix} \begin{bmatrix} dc_1 \\ dc_2 \end{bmatrix}. \tag{10}$$

To simplify the notation re-write (10) as:

$$\begin{bmatrix} dx_1 \\ dx_2 \end{bmatrix} = \Delta^{-1} \begin{bmatrix} a_2 & b_1 \\ b_2 & a_1 \end{bmatrix} \begin{bmatrix} dc_1 \\ dc_2 \end{bmatrix}, \tag{11}$$

where: $a_1 = R_{1,11}$ $a_2 = R_{2,22}$, and $b_1 = R_{1,12}$ $b_2 = R_{2,21}$.

For stability of the duopoly equilibrium, the diagonal of the matrix has to be negative, i.e., $a_i < 0$, and the determinant positive, i.e., $\Delta = a_1 a_2 (1 - r_1 r_2) > 0$. Given these conditions, further comments can be made about the reaction functions. $r_i = -(b_i)/a_i$ from (8) and (9). Hence, if $a_i < 0$, then for strategic substitutes, $b_i < 0$, in order to satisfy $r_i < 0$, and $b_i > 0$ in order to satisfy $r_i > 0$ for strategic complements. The expression for r_i can be substituted into (11) in order to make the comparative statics easier to follow:

$$\begin{bmatrix} dx_1 \\ dx_2 \end{bmatrix} = \Delta^{-1} \begin{bmatrix} a_2 & a_1 r_1 \\ a_2 r_2 & a_1 \end{bmatrix} \begin{bmatrix} dc_1 \\ dc_2 \end{bmatrix}. \tag{12}$$

[12] Whether we have strategic substitutes or complements in quantity space depends on the second derivatives of the demand function (see Ishikawa and Spencer 1999; and Leahy and Neary 2001).

Equilibrium in the Electricity Generating Sector

Given the fixed proportions technology and $\phi = 1$, total output in either the domestic or foreign electricity generating sectors is given by $x_j^U \left(= x_j\right)$. The latter also implies that upstream emissions can be written directly as function of the downstream firm's output, i.e., $e_j = g(x_j^U) \equiv g(x_j)$. It is assumed that in each country there are two upstream firms (*A* and *B*) whose combined output of electricity equals x_j^U, i.e., $x_j^A + x_j^B = x_j^U$. Due to the intermediate good electricity being assumed homogeneous once supplied to the transmission system, the downstream firms are therefore indifferent about the relative proportions of x_j^A and x_j^B used in its production process. Assuming that the downstream firms face no costs other than the price paid for electricity, the inverse derived demand function facing firms in the upstream sector can be found by substituting p_i^U for c_i in (5) and (6) respectively. In countries *j* = 1, 2, firms' profits in the upstream sector are, therefore, given by:

$$\pi_j^A = R_j^A(x_j^A, x_j^B) - c_j^A x_j^A \tag{13}$$

$$\pi_j^B = R_j^B(x_j^A, x_j^B) - c_j^B x_j^B , \tag{14}$$

where c_j^A and c_j^B are the upstream firms' costs respectively in country *j*.

Given this, following the outline above, equilibrium in the upstream market, *j* = 1, 2, is:

$$\begin{bmatrix} dx_j^A \\ dx_j^B \end{bmatrix} = (\Delta_j^U)^{-1} \begin{bmatrix} a_j^B & a_j^A r_j^A \\ a_j^B r_j^B & a_j^A \end{bmatrix} \begin{bmatrix} dc_j^A \\ dc_j^B \end{bmatrix}, \tag{15}$$

where $a_j^A, a_j^B < 0$, and $(\Delta_j^U)^{-1} > 0$ for stability.

5. Carbon Taxes, Border Tax Adjustments and Neutrality

Carbon Taxes and Leakage

Assume initially that the domestic government can only target a carbon tax t^e at its electricity producers.[13] The imposition of the carbon tax t^e on domestic electricity producers raises both c_1^A and c_1^B. In turn, this raises the price of electricity, i.e., the costs to the domestic downstream firm c_1. The cost increase to the domestic downstream firm also affects imports of the energy-intensive final good, given by dx_2 / dc_1. Following Ritz (2009) and Karp (2010), and assuming that domestic electricity producers do not respond to the carbon tax t^e by reducing their intensity of carbon emissions via cleaner technology, carbon leakage *l* is given as:

$$l = \frac{de_2}{-de_1} \equiv \left[\frac{g'(x_2^U)}{g'(x_1^U)} . \frac{dx_2^U}{-dx_1^U} \right], \tag{16}$$

i.e., even if intensity of carbon emissions is the same in the domestic and foreign upstream sectors, $g'(x_2^U) = g'(x_1^U)$ there will be positive carbon leakage, l >0, if there is positive output leakage, $dx_2^U / -dx_1^U > 0$. Given that $x_j^U \left(= x_j\right)$, (12) can be used to re-write (16) as:

$$l = \frac{de_2}{-de_1} \equiv \left[\frac{g'(x_2^U)}{g'(x_1^U)} . \frac{\Delta^{-1} a_2 r_2 dc_1}{-(\Delta^{-1} a_2 dc_1)} \right]. \tag{17}$$

If $l > 0$, there is positive carbon leakage, and if $l < 0$, there is negative carbon leakage in the sense that foreign carbon emissions actually decrease after implementation of the policy. Given $\Delta^{-1} > 0$ and $a_2 < 0$, such that $dx_1 = \Delta^{-1} a_2 dc_1 < 0$, the direction of carbon leakage is given by the sign of r_2, and the extent by the size of $g'(x_2^U)$ relative to $g'(x_1^U)$: if $g'(x_2^U) = g'(x_1^U)$ and $r_2 < 0$ (>

[13] While an optimal carbon tax could be derived explicitly, it is treated as exogenous in this paper.

0), then $dx_2 = \Delta^{-1} a_2 r_2 dc_1 > 0 (< 0)$ and $l > 0$ (< 0), i.e., there is positive (negative) carbon leakage if final goods are strategic substitutes (complements); and if $g'(x_2^U) > g'(x_1^U)$, given $|r_2| < 1$, the extent of positive (negative) carbon leakage depends on the intensity of foreign relative to domestic carbon emissions.

LEMMA 1: *With strategic substitutes, a carbon tax causes positive carbon leakage. With strategic complements, a carbon tax causes negative carbon leakage. The extent of positive or negative carbon leakage is determined by the relative intensity of foreign to domestic carbon emissions.*

Border Tax Adjustments and Neutrality

Now assume a BTA t^b can be targeted at imports of the energy-intensive final good, thereby raising the costs of the downstream firm's foreign competitor which, in turn affects the level of imports. This is given by dx_2 / dc_2, which given the assumption of fixed proportions, also feeds back into foreign electricity production, $dx_2 / dc_2 = dx_2^U / dc_2 = d\left(x_2^A + x_2^B\right) / dc_2$, which in turn affects foreign carbon emissions e_2, and thereby carbon leakage *l*. Since the WTO/GATT guidelines are not specific in defining 'competitive equality', we consider the cases where the neutral BTA (*neutral BTA*) is defined as *either* the change in c_2 that keeps the *volume* of final good imports constant given the environmental tax t^e, *or* as the change in c_2 that keeps the domestic *market share* of final good imports constant given t^e.

Import-Volume Neutrality

If neutrality is defined in terms of import volume, the appropriate BTA is given as:

$$neutral\ BTA = \frac{(dx_2 / dc_1)\ t^e}{-(dx_2 / dc_2)}. \tag{18}$$

When markets are competitive, then $|dx_2 / dc_2| = |dx_2 / dc_1|$, the net effect being such that $dx_2 = 0$, there being no carbon leakage, i.e., the appropriate BTA should be set equal to the domestic carbon tax. Specifically, with a domestic carbon tax t^e, the BTA is effectively based on the carbon embodied in the domestically produced final good. This, rules out the domestic policymaker setting $t^b > t^e$ when $g'(x_2^U) > g'(x_1^U)$, i.e., given binding WTO/GATT rules, the appropriate BTA cannot be based on the carbon embodied in the foreign produced final good.[14]

In contrast, when markets are imperfectly competitive, setting the BTA equal to the domestic carbon tax will lead to a non-neutral outcome, $dx_2 \neq 0$.

LEMMA 2: *With strategic substitutes, the appropriate import policy to ensure neutrality is an import tax. With strategic complements, import volume neutrality requires an import subsidy.*

Consider first of all the effect of the import tax on the imports of the final good. Using (12), $dx_2 = \Delta^{-1} a_1 dc_2$, since $\Delta^{-1} > 0$ and $a_1 < 0$, the border tax (as expected) reduces the level of imports, i.e., $dx_2 < 0$. From the previous section, the effect of the domestic carbon tax on imports $dx_2 = \Delta^{-1} a_2 r_2 dc_1$ depends on the sign of r_2. In the case of strategic substitutes, $r_2 < 0$, which results in $dx_2 / dc_1 > 0$, i.e., import volume neutrality requires an import tax. Necessarily, if $dx_2 = 0$ there will be no carbon leakage.

In the case of strategic complements $r_2 > 0$, so that $dx_2 / dc_1 < 0$, suggesting that the carbon tax has a non-neutral impact on imports of the final good, as it further reduces imports.

[14] Mattoo *et al*. (2009) have provided some empirical estimates of the likely impact of BTAs by OECD countries, given a carbon tax designed to reduce emissions by 17% by 2020. Key to their analysis is the assumption concerning the basis for BTAs on final goods, with two choices being modeled: BTAs based *either* on (i) the carbon content embodied in final goods produced in the importing country, *or* (ii) the carbon content embodied in the imported goods, the latter option broadly matching provisions of the Waxman-Markey Bill. Given production in countries such as China is more carbon-intensive than in OECD countries, choice (ii) implies BTAs of up to 25%, with China's exports of energy-intensive goods forecast to fall by 43%. By contrast, choice (i) implies border tax adjustments ranging up to 8%, with China's exports of energy-intensive goods forecast to fall by 6%.

Specifically, the carbon tax imposed on domestic electricity production reduces domestic output in the downstream sector *and* imports of the final good. In principle, from (18) this implies that with strategic complements, since $dx_2 / dc_1 < 0$, to restore neutrality, the appropriate policy is an import *subsidy* rather than an import tax. However, this result can probably best be regarded as a theoretical *curiosum* due to the fact that an import subsidy would likely be politically infeasible. Of course, in terms of carbon leakage, an import subsidy is actually unnecessary due to the fact that the domestic carbon tax, by causing the foreign downstream firm to reduce their output, generates negative carbon leakage.

The appropriate border tax adjustment for a domestic carbon tax that ensures import volume neutrality is summarized in the following proposition:

PROPOSITION 1: *The BTA required to ensure import volume neutrality depends on (a) whether the nature of competition is strategic substitutes or complements; (b) the effect of a change in costs in the final market; and (c) the extent to which the domestic carbon tax, t^e, is transmitted into an increase in domestic downstream firm's costs.*

Part (a) of Proposition 1 follows directly from Lemma 2. Relating to parts (b) and (c), whether the expansion of imports matches the contraction due to the BTA depends on two factors: the effect of the change in costs on the downstream sector, and the extent to which the domestic carbon tax, t^e, is transmitted into an increase in the downstream firm's costs, dc_1. Focusing, first of all, on the former, even if $dc_1 = dc_2$, the impact of the domestic carbon tax will likely be less than the BTA. For example, if $a_1 \approx a_2$, as $|r_2| < 1$, then $a_2 r_2 < a_1$. Second, consider the likelihood of $dc_1 = dc_2$. This depends on the incidence of the carbon tax on the downstream firm's cost function, i.e., $dp_{1,1}^U / (dc_1^A + dc_1^B)$ the extent to which the price of domestic energy rises as a result of the domestic carbon tax. Since electricity is homogenous at the point of consumption downstream, then:

$$dp_1^U = p_{1,1}^U(dx_1^A + dx_1^B). \tag{19}$$

Using (15):

$$dp_1^U = p_{1,1}^U\left\{(\Delta^U)^{-1}[dc_1^A a_1^B(1+r_1^B) + dc_1^B a_1^A(1+r_1^A)]\right\} = \{p_{1,1}^U D\}t^e, \tag{20}$$

where $p_{1,1}^U < 0$, and $D = (\Delta^U)^{-1}[a_1^B(1+r_1^B) + a_1^A(1+r_1^A)] < 0$. Therefore, domestic downstream costs will increase with imposition of a carbon tax upstream, i.e., $dc_1 = dp_1^U > 0$. For reasonable characterizations of the demand function, there will be under-shifting of the carbon tax $\{p_{1,1}^U D\}t^e < 1$.[15]

Using (12), and (18)-(20), the appropriate BTA implied by Proposition 1 can generally be given as (assuming $a_1 \approx a_2$):

$$neutral\ BTA = -r_2\{p_{1,1}^U D\}t^e = -r_2\, dc_1. \tag{21}$$

It is clear that the form of the BTA, i.e., whether it is an import tax or subsidy, depends on the nature of competition in the downstream sector.[16] Further, the size of the appropriate BTA depends on the nature of competition in both the downstream and upstream sectors. Also, note that if the appropriate BTA is set, i.e., $dx_2 = 0$, there will be no carbon leakage. As noted earlier, the BTA cannot be used to target foreign production when $g'(x_2^U) > g'(x_1^U)$ as this would violate the import-volume neutrality constraint.

Import-Share Neutrality

In the case of import-share neutrality, the appropriate BTA is defined as one where the net effect of the carbon tax t^e on x_1 and x_2 must equal the net effect of the BTA on x_1 and x_2. In this case, the neutral BTA is defined as:

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[15] For example, a linear, or more generally a weakly convex demand function will generate under-shifting.

[16] Note that including the upstream sector generalizes the impact of the domestic carbon tax and hence what the appropriate BTA should be. If the upstream sector were perfectly competitive, then the incidence of the carbon tax in the upstream sector would not matter**.** In this case $dc_1 = 1$ the *neutral BTA* being equal to $-r_2$.

$$neutral\ BTA = \frac{t^e[(dx_2/dc_1)+(dx_1/dc_1)]}{[(dx_1/dc_2)+(dx_2/dc_2)]}, \quad (22)$$

PROPOSITION 2: *Defining competitive equality in terms of market share leads to a policy that does not depend on the existence of strategic substitutes or complements. However, the BTA required will be lower in the strategic complement case compared to that required for the strategic substitute case.*

Using (23) and assuming $a_1 \approx a_2$, the neutral *BTA* can be re-written as:

$$neutral\ BTA = \frac{(r_2+1)t^e}{(r_1+1)} = \frac{(r_2+1)\,dc_1}{(r_1+1)}. \quad (23)$$

It is clear from (23) that defining 'competitive equality' in terms of market shares does not lead to the 'sign' of the policy. However, the magnitude of the BTA is still dependent on the nature of competition between the downstream firms. Specifically, in the case of strategic substitutes, $r_i < 0$, and given that $|r_1| > |r_2|$, the appropriate BTA exceeds that for the case of import-volume neutrality as given in (21).[17] For strategic complements, $r_i > 0$, and given that $|r_1| > |r_2|$, the neutral *BTA* is lower than in the strategic substitutes case. However, whether final goods are strategic substitutes or complements, the domestic carbon tax combined with the BTA "facilitates" collusion, a result similar to that when import restrictions are defined in terms of market share (Denicolo and Garella, 1999). As a result, global carbon emissions are actually reduced below that prior to implementation of the domestic carbon tax.

Border Tax Adjustments and Competitiveness

While appropriate BTAs that ensure trade neutrality can be defined in the presence of imperfect competition, thereby ensuring no carbon leakage, the downstream output and profit

[17] This assumption relates to the relative slopes of the reaction functions, implying that firm 1's reaction function is steeper, in absolute terms than that of firm 1, which is necessary to ensure stability of equilibrium.

(competitiveness) effects of the two definitions of neutrality are quite different.[18] This is important since even though the appropriate BTA will keep imports of the final good at the same level, re-distribution of output and profits between domestic and foreign downstream firms can still occur. This can be summarized in the following proposition.

PROPOSITION 3*: With import volume neutrality, an appropriate BTA for a domestic carbon tax has the potential to reduce output and profits of the domestic downstream firm, thereby reducing its competitiveness, while increasing the profits of the foreign downstream firm. With the import share rule, the domestic downstream firm maintains its competitiveness in terms of market share, and both domestic and foreign downstream firms gain additional profits.*

Specifically, under *import-volume neutrality*, and for either strategic substitutes or complements, the combination of domestic carbon tax and BTA reduces output and profits of the domestic downstream firm, and raises profits of the foreign downstream firm. Under the rule that $dx_2 = 0$, the change in output of the domestic downstream firm is derived from (12), and assuming $a = a_1 \approx a_2$:

$$dx_1 = \Delta^{-1} a(dc_1 + r_1 dc_2). \tag{24}$$

Given $\Delta^{-1} > 0, a < 0, dc_1 > dc_2$, and $|r_1| < 1$, then $dx_1 < 0$ for both $r_1 < 0$ and $r_1 > 0$, i.e., even if the BTA is trade neutral, the domestic firm still reduces its output with a carbon tax. In the case of profits, totally differentiate (3) and (4):

$$d\pi_1 = R_{1,1} dx_1 + R_{1,2}\, dx_2 - c_1 dx_1 + \pi_{1,c_1} dc_1 \tag{25}$$

$$d\pi_2 = R_{2,2} dx_2 + R_{2,1}\, dx_1 - c_2 dx_2 + \pi_{2,c_2} dc_2 \tag{26}$$

[18] While this discussion is concerned only with output/profit-shifting as a by-product of border tax adjustments in the presence of carbon taxes, there is a literature on the explicit use of environmental policy as strategic trade policy, e.g., Conrad (1993), Barrett (1994), Kennedy (1994) and Ulph (1996).

Again, based on the rule that $dx_2 = 0$, and $\pi_{1,c_1} dc_1 = -x_1 dc_1$ from (3), it is easy to see that $d\pi_1 < 0$, i.e., domestic downstream firm profits fall. For the foreign downstream firm, and assuming, $a = a_1 \approx a_2$, (26) can be re-written as:

$$d\pi_2 = R_{2,1}\, dx_1 + \pi_{2,c_2} dc_2 = x_2 [\, \Delta^{-1}\, p_{2,1}\, a\, (\, dc_1 + r_1 dc_2) - dc_2 \,]. \tag{27}$$

Given $\Delta^{-1} > 0, p_{2,1} < 0, a < 0,$ and $r_1 < 0,$ as long as $[.] > 0$, then $d\pi_2 > 0$, i.e., foreign downstream firm profits increase. The reason for this is that the BTA has been set appropriately and is less than the domestic carbon tax. If $r_1 > 0$, and an import subsidy is used, as can be seen from (25), $d\pi_1 < 0$, i.e., the domestic downstream firm's profits still decline. In the case of the foreign downstream firm, from (27), as long as $dc_1 > |r_1 dc_2|$, and $[.] > 0$, then $d\pi_2 > 0$, i.e., the downstream foreign firm's profits increase. In the case where an import subsidy is not used due to its political infeasibility, from (25) and (27), it can be seen that these profit effects are reinforced.

In the case of *import-share neutrality*, the combination of the carbon tax and BTA increases the profits of both the domestic and foreign downstream firms in both the strategic substitutes and complements cases. In order to see this, first derive dx_1 and dx_2 from (12), assuming $a = a_1 \approx a_2$, and substituting in for dx_2 from (23):

$$dx_1 = \Delta^{-1} \left[\; a\, dc_1 \left(1 + r_1 \left\{ \frac{(r_2+1)}{(r_1+1)} \right\} \right) \right] \tag{28}$$

$$dx_2 = \Delta^{-1} \left[a\, dc_1 \left(r_2 + \left\{ \frac{(r_2+1)}{(r_1+1)} \right\} \right) \right]. \tag{29}$$

As $\Delta^{-1} > 0, a < 0, dc_1 > 0$, and for strategic substitutes, $r_i < 0$, then $dx_1 < 0$ and $dx_2 < 0$. For strategic complements, $r_i > 0$, so again, $dx_1 < 0$ and $dx_2 < 0$.

Substituting (28) and (29) into (25) and (26):

$$d\pi_1 = x_1 dc_1 \left\{ p_{1,2}\Delta^{-1} a \left[r_2 + \left(\frac{r_2+1}{r_1+1} \right) \right] - 1 \right\} \tag{30}$$

$$d\pi_2 = x_2 \left\{ p_{2,1}\Delta^{-1} adc_1 \left[1 + (1+r_1)\left(\frac{r_2+1}{r_1+1} \right) \right] - dc_2 \right\}. \tag{31}$$

For strategic substitutes, $r_i < 0$, and in addition, in (30), $p_{1,2} < 0, \Delta^{-1} > 0, a < 0,$ and $[.] > 0$, while in (31), $p_{2,1} < 0, \Delta^{-1} > 0, a < 0,$ and $[.] > 0,$. Therefore, as long as $p_{1,2}\Delta^{-1}a[.] > 1$ in (30), and also that $p_{2,1}\Delta^{-1}adc_1[.] > dc_2$ in (31), then it follows that $d\pi_1 > 0$, and $d\pi_2 > 0$. The same holds for strategic complements.

These output and profit effects are illustrated in figure 1 for the case of final goods being strategic substitutes, where the initial Nash equilibrium is *N*. With a domestic carbon tax t^e upstream being passed through to downstream as dc_1, the new Nash equilibrium at *N** results in the foreign downstream firm increasing both its output and profits at the expense of the domestic downstream firm, i.e., there is a loss in the latter's competitiveness. However, in the case of *import-volume neutrality*, the combination of dc_1 and the BTA $t^{b\prime}$ shifts less output and profits away from the domestic to the foreign downstream firm. The pass-through of the carbon tax in dc_1 shifts the domestic downstream firm's reaction function from F_1 to F_1', output falling to x_1', and the BTA shifts the foreign downstream firm's reaction function from F_2 to F_2', the new Nash equilibrium being N', such that the foreign downstream firm's output remains at $x_2 = x_2'$. However, even with a trade neutral BTA, the domestic downstream firm still loses market share, and its profits fall to π_1', while the foreign downstream firm's profits increase to π_2'. As per Proposition 1, the BTA is less than the domestic carbon tax, due to the carbon tax not being fully passed through by the domestic electricity generating firm in terms of an increase in the energy costs of the domestic firm producing the final good.

For *import-share neutrality*, the new Nash equilibrium is N'', the combination of dc_1 and the BTA $t^{b''}$ results in profits of the domestic downstream firm increasing to π_1'', and the profits of the foreign downstream firm increasing to π_2'', their market shares remaining constant along $x_2/(1-x_2)$. In terms of political economy, the domestic downstream firm will lobby for trade neutrality to be defined in terms of market-share as it maintains both its competitiveness measured by market share, and increases its profits by moving into the Pareto-superior profit set bounded by the iso-profit contours π_1 and π_2. In contrast, its foreign competitor would prefer trade neutrality to be defined in terms of market-volume where it maintains its exports, and earns higher profits, moving the domestic downstream firm outside of the Pareto-superior profit set. Of course, in either case, even though trade neutrality and no carbon leakage are ensured, the aggregate reduction in output of the final good generates a deadweight loss to consumers. Minimizing the costs of the latter distortion would necessarily have to be taken into account if the carbon tax were being set optimally.[19]

5. Summary and Conclusions

In this paper, analysis has been presented relating to the impact of border tax adjustments for climate policy on the international competitiveness of energy-intensive industries, and the related problem of carbon leakage. While many of the economic and legal issues are not particularly new, climate policy does present some possible twists to the analysis of border tax adjustments when vertically-related markets can be characterized as a successive oligopoly. Specifically, an appropriate border tax adjustment will depend on the incidence of a domestic carbon tax, the

[19] For example, see Conrad (1996) for a discussion of optimal environmental taxes in an oligopoly setting with a global public bad.

nature of competition in upstream and downstream sectors, as well as the basis for assessing the trade neutrality of any border tax adjustment. If trade neutrality is defined in terms of market volume, even though carbon leakage is avoided, domestic firm competitiveness cannot be maintained. This compares to defining trade neutrality in terms of market share, which results in both domestic competitiveness being maintained and global carbon emissions being reduced. Given these results, incorporating an explicit political economy dimension into the model would be an interesting extension of the analysis.

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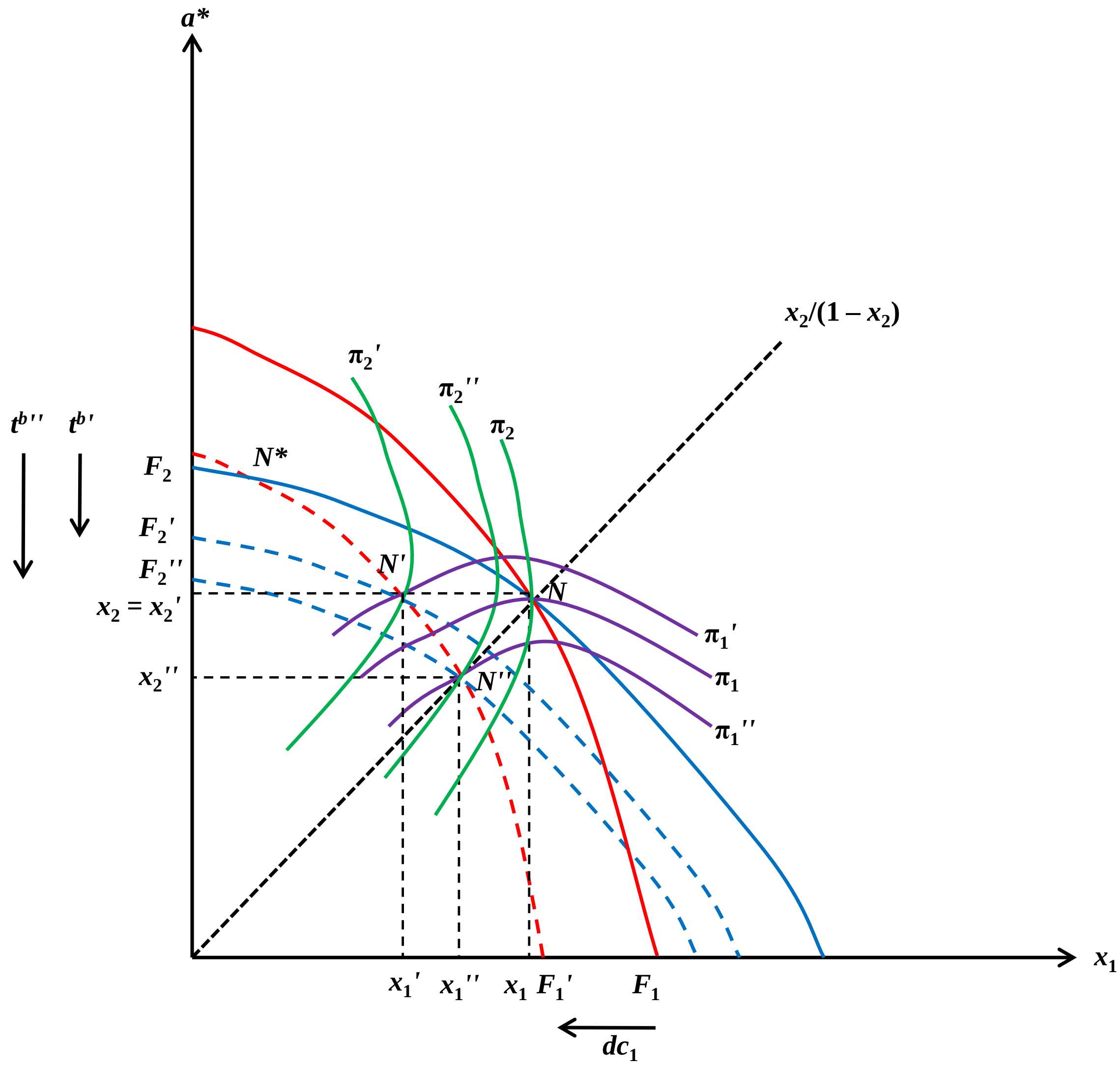

Figure 1. Neutral BTAs