Trade, Policy Substitution, and International Carbon Tax Agreements

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Abstract

This paper uses a simple general equilibrium trade model to study the viability of a global carbon tax agreement when governments have multiple policy instruments (tariffs and subsidies) available that can dampen the effects of the carbon tax on affected industries, a possibility that is sometimes referred to as "fiscal cushioning." Similar issues arise in the international trade literature because an agreement to reduce tariffs creates incentives for protectionist governments to use domestic policies as imperfect substitutes for a tariff. The paper explores the extent to which strategies to deal with policy substitution from the international trade agreement literature can be used to support international carbon tax agreements.

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1. Introduction

The current approach to negotiating international climate change agreements has been to focus on country-specific commitments (quotas) on greenhouse gas emissions. This has met with only limited success. An alternative strategy is to negotiate an international agreement under which each participating country would impose a common carbon tax. A carbon tax has a number of advantages over quotas.[2] Developing countries are unlikely to accept emission caps (even with cash transfers) because of concerns that this would constrain their growth. A carbon tax would not cap emissions in any given economy and so would allow changes in relative GDP and comparative advantage to alter carbon emissions across countries via standard market mechanisms. In addition a carbon tax would alleviate concerns about abatement costs because it would cap marginal compliance costs for firms. Motivated by the uncertainty about both compliance costs and damages from carbon emissions, Pizer (2002) applied the Weitzman (1974) prices vs. quantities analysis to climate change and argued that a price instrument (taxes) would be more efficient than quotas.

However, a carbon tax agreement may be much more difficult to enforce than an agreement on quotas. Both are subject to the usual verification and monitoring issues. But suppose that countries stick to their commitments and enforce the agreed-upon tax or quota. Then, governments could use domestic policies to neutralize the effects of a carbon tax on domestic emission reductions, but they cannot do so under a quota regime. This was first pointed out by Hoel (1991) who argued that a carbon tax agreement could be undermined by policy substitution. Countries could comply with the agreement and impose and enforce the agreed-upon carbon tax, but use other domestic policies (such as consumption or production subsidies) to prop up sectors adversely affected by the tax and thereby undermine its effectiveness. This concern has also been discussed by Stavins (1997), Wiener (1999), Victor (2001), Aldy et al. (2008) and others in the climate policy literature.[3] In contrast, in a quota regime if countries adhere to their emission targets,

[2] For good discussions of the merits of a carbon tax agreement, see for example: Nordhaus (2007), Cooper (2008) and Aldy et al. (2008).

[3] Wiener (1999) refers to the undermining of the carbon tax as "fiscal cushioning." Throughout this paper, I will follow the trade literature and use the term "policy substitution."

then any adjustment of domestic policies that increases carbon emissions would have to be offset by other policies that reduce emissions. Policy substitution can undermine a carbon tax agreement but not a quota agreement.[4]

A similar issue arises in international trade agreements. Countries sign agreements to reduce overt trade barriers (such as tariffs), but the pressure to protect favoured industries remains and so governments have incentives to use domestic policies (such as subsidies, tax incentives, and regulatory policy) to help out industries that have lost tariff protection. Hence policy substitution has been a key issue in the design of trade agreements. In the international trade literature, a number of papers analyze the implications of policy substitution for the international trade regime [see for example: Copeland (1990), Bagwell and Staiger (2001), and Horn, Maggi and Staiger (2010)].

This paper draws on the literature on the design of trade agreements in the presence of policy substitution and considers its implications for a potential carbon tax agreement. I develop a simple model in which governments negotiate agreements on trade barriers and carbon taxes. Each country agrees to implement a carbon tax and administers it internally. It is assumed that governments implement (and enforce) the tariff and carbon tax packages as agreed, but they also have domestic policies (subsidies) available that are not bound by the agreement. I first analyze the incentives to use domestic policy to undermine trade and carbon tax agreements, and then consider the implications of these incentives for the design of such agreements.

I obtain several results. I show that existing trade agreements contain provisions (such as for countervailing duties) that can mitigate but not eliminate some of the incentives to

[4] This paper considers only carbon tax agreements under which each country agrees to implement and enforce its own carbon tax. This type of carbon tax agreement has been the focus of most recent policy discussions. Hoel (1993) refers to this as a harmonized domestic carbon tax agreement. An alternative global carbon tax system would have an international agency tax *countries* based on their overall carbon emissions. Revenue could be reimbursed based on some fixed parameters that might reflect international equity considerations. Hoel (1992) shows that such a system would not be vulnerable to policy substitution because in the end whatever domestic policies are used, countries are taxed based on their overall emissions. However such a system is unlikely to be politically feasible and would require an international bureaucracy to deal with tax collection and reimbursement, etc.

undermine a carbon tax agreement. Bagwell and Staiger (2001) showed that in the absence of global pollution, the policy substitution motive would be eliminated if trade agreements were interpreted as market access agreements. I show that their result can be extended to the case of global pollution if such agreements were augmented to also include an agreement on access to the global commons. However, I note that enforcement of such provisions would be problematic; indeed there is evidence of policy substitution in response to trade agreements (Gawande, 1999; Limao and Tovar, 2009). I then consider two stage games in which governments commit to tariffs and carbon taxes in the first stage and anticipate that there will be policy substitution in the second stage. The second best efficient global carbon tax need not be uniform across countries and will be higher than global marginal damage.

As discussed earlier, the policy literature has recognized the potential for policy substitution as one of the challenges for a global carbon tax regime. However, there has been relatively little formal modelling.

Hoel (1992) argues that a carbon tax targetting polluters and administered by national governments would be undermined by policy substitution.[5] He therefore develops a simple model in which a global carbon tax is imposed on countries collected by an external global agency. Revenues would be reimbursed to countries in lump sum according to some agreed-upon formula that might take into account equity concerns. If governments maximize national welfare, then such a policy would lead to global efficiency. Hoel notes that a global tax collection agency might meet with political resistance.

Rohling (2013) develops a simple model in which governments have varying abilities to charge an "effective carbon tax" lower than the agreed-upon tax, but are subject to audit. He studies optimal auditing policies for a global regulator. Rohling and Ohndorf (2012) apply Montero's (2002) analysis of taxes vs. quotas when there is imperfect enforcement. They model policy substitution by simply assuming that the probability of detecting

[5] Hoel (1993) analyzes the choice of a harmonized domestic carbon tax when governments have revenue constraints.

noncompliance in a tax regime is lower than in a quota regime. They show that this increases the attractiveness of global quotas relative to global taxes.

This paper differs from the above work by developing a simple general equilibrium trade model with pollution in which governments have multiple policy instruments (tariffs, emission taxes and output subsidies) available. This provides a simple framework for analyzing the incentives for policy substitution. It also extends previous work on international trade agreements. In the standard analysis of international trade agreements Bagwell and Staiger (1999, 2001), countries are linked via price spillover effects (one country's trade policy affects the terms of trade of other countries). In the present analysis, the price spillover effect is present, but countries are also affected by international emission spillovers.

The next section sets up the model. The global non-cooperative equilibrium in studied in Section 3. Section 4 considers international agreements and the potential for policy substitution. Section 5 analyzes the potential for existing trade remedy procedures to prevent policy substitution. Section 6 generalizes the market access agreements of Bagwell and Staiger (2001) to include global commons access agreements, and section 7 considers cooperative agreements when commons access agreements are not feasible. Section 8 concludes.

2. The Model

I use a very simple model that allows us to clearly focus on policy substitution issues. There are two countries; Home and Foreign. Foreign variables are denoted with an asterisk (*). Each country produces 4 goods, and there are four primary factors of production. I work with a 4 good model because it is convenient to have a numeraire good, a non-traded good, and an import and export good for each country.

Labour is mobile across sectors (but not countries) and is used as an input in all four goods. The endowments of labour are L and L* in Home and Foreign, respectively. In addition, there are three specific factors with endowments K_1, K_2 and K_3 at home (and

K_i*) in Foreign. Each specific factor i can only be employed in sector i - that is, specific factors are not mobile across sectors.

2.1. Technology

The numeraire good, x_0, is produced with constant returns to scale from labour only. I set $p_0 = 1$. The production functions are:

$$\begin{aligned} x_0 &= L_0 \\ x_0^* &= \alpha^* L_0^* \end{aligned} \tag{1}$$

Assume that the endowment of labour is large enough in each country so that each country always produces some of the numeraire good even when there is free trade. The zero profit condition in the numeraire sector will then ensure that the wage in each country is fixed ($w = 1$ and $w^* = \alpha^*$).

The other 3 goods are produced using labour and a specific factor, and pollution is generated during production. The production function for (non-numeraire) good i at Home is given by:

$$x_i = F^i(K_i, L_i, Z_i) \tag{2}$$

where Z_i is the level of carbon emissions from sector i, and where $F^i_{L_i Z_i} > 0$. For convenience (and in common with much of the literature) I have modeled emissions as an input – think of emissions as being environmental services needed for production. With some restrictions on technology, this is equivalent to emissions and the final good being joint products.[6]

It is convenient to represent technology with the implied profit functions:

$$\pi^i(q_i, \tau) = \max_{\{L_i, Z_i\}} \left\{ q_i F^i(K_i, L_i, Z_i) - wL_i - \tau Z_i \right\} \tag{3}$$

[6] See for example Copeland and Taylor (2003).

where q_i is the producer price of good i, and τ is an emission tax (or permit price). I have suppressed the role of w and K_i in π_i because they are fixed. Foreign technology is specified analogously.

The full employment conditions require that each specific factor be fully employed in its relevant sector and that labour be fully employed:

$$\sum_{i=0}^{3} L_i = L \tag{4}$$

Aggregate income accruing to the private sector can be summarized by the GDP function, defined as follows:

$$G(\boldsymbol{q},\tau,\boldsymbol{v}) = wL + \sum_{i=1}^{3} \pi^i(q_i,\tau) \tag{5}$$

where **q** is the vector of producer prices and **v** is the vector of factor endowments. Note that G does not include government revenue - we will assume that any such revenue is rebated in lump sum to consumers so that aggregate national income will be given by the sum of G and net government revenue.

2.2. Preferences

I assume a simple preference structure that rules out cross price effects in demand (to keep things simple). There is a representative domestic consumer with utility function given by:

$$U = x_0^c + \sum_{i=1}^{3} u_i(x_i^c) - \gamma Z^w \tag{6}$$

where the u_i are increasing and concave, and where Z^W is world pollution, which is the sum of emissions from all domestic and foreign production.[7] It is assumed that

[7] The structure of this utility function implies that the marginal damage from pollution is constant (γ) and therefore independent of income. Because income differences across countries do not play a role in the analysis of this paper, the structure in (6) was adopted for clarity and simplicity. For an analysis of the interaction between trade and the environment in cases where marginal damage does vary with income see for example Copeland and Taylor (2003).

consumers treat world pollution as given when choosing goods consumption levels. Given consumer prices p_i, the above utility function implies that the demand for each non-numeraire good depends only on its own price - there are no income or cross price effects. Let $D^i(p_i)$ denote domestic demand for good i.

The corresponding indirect utility function is

$$V(\boldsymbol{p}, I, Z^w) = I + CS(\boldsymbol{p}) - \gamma Z^w \tag{7}$$

where **p** is the consumer price vector and CS is consumer surplus:

$$CS(\boldsymbol{p}) = \sum_{i=1}^{3}\left[u^i\left(D^i(p_i)\right) - p_i D^i(p_i)\right]. \tag{8}$$

2.3. Trade Pattern

I assume that endowments and parameters are such that Good 1 is imported by Home (and exported by Foreign) and Good 2 is imported by Foreign (and exported by Home). Good 3 is a non-traded good in each country. The numeraire good may be imported or exported by either country - its pattern of trade is determined by the condition that overall trade be balanced across the 3 tradable goods for the two countries.

2.4. Policy Instruments

Governments are assumed to choose policy to maximize the welfare of the representative agent. The model could be extended to encompass political economy motivations for intervention. However, the key issues of policy substitution will arise regardless of the weight governments place on special interests, and so the simpler welfare-maximizing approach is sufficient for our purposes. In the context of trade policy (without environmental problems), Bagwell and Staiger (1999) have shown how their key results hold for a wide variety of government objective functions.

There are three motivations for policy intervention in this model. There is a domestic pollution distortion (domestic pollution harms domestic consumers); there is an international pollution distortion (each country's pollution harms consumers in the other country), and there are terms of trade motives for trade protection (using one's monopsony power to reduce import demand can lead to terms of trade improvements). To analyze policy, I proceed in three stages. First I note that unilateral policy actions by governments lead to global inefficiencies. Then I consider the structure of efficient international policy agreements. And finally (the main objective of this paper) I consider international agreements that are incomplete contracts in the sense that not all policy instruments are covered by the agreement).

I need to specify the set of policy instruments available to governments. In common with all papers in this literature, I restrict the policy space by assuming that governments have only a few key instruments available. To explore the policy substitution issue, we need a set of instruments that is sufficient to achieve an efficient outcome - trade and pollution policy instruments - and we need another set of domestic policy instruments that might not normally be needed to achieve the first best, but which may be tempting to use if other instruments are constrained. Consequently I assume that each government has import tariff and export taxes (t) available. To deal with pollution, there is a carbon tax (τ). And in addition, each government has available a vector of production subsidies (s_1, s_2, s_3) that can be used to target production of goods x_1, x_2, and x_3, respectively. Pollution could also be targeted with quotas perhaps implemented with a cap and trade system. I will discuss quotas from time to time; however, the focus of this paper is on the design of an international carbon tax system. Production subsidies are just one example of the many potential instruments in addition to trade barriers that governments can use to support local production. In a later section of the paper, I discuss the implications of considering a broader range of such instruments; in particular I allow governments to use both production subsidies and consumption subsidies in Section 5.

3. Unilateral policy

I first consider a non-cooperative Nash equilibrium. To illustrate the results, I focus on the Home government's problem. The Home government chooses the levels of its policy instrument to maximize the welfare of its representative consumer given the policy of the foreign government. Consumer welfare is given by:

$$V(p_1 + t_1, p_2 - t_2, p_3, I, Z^w) \tag{9}$$

where t_1 is an import tariff, t_2 is an export tax, and p_1 and p_2 should be though of as the "world" prices - these are the prices that foreigners would pay if their government did not impose its own taxes and subsidies.

National income is income accruing to producers, plus net government revenue, which is pollution tax revenue and tariff and export tax revenue, less the cost of production subsidies:

$$I = G(p_1 + t_1 + s_1, p_2 - t_2 + s_2, p_3 + s_3, \tau, v) - \sum_{i=1}^{3} s_i x_i + \tau \sum_{i=1}^{3} Z_i + t_1 M_1 + t_2 E_2 \tag{10}$$

where M_1 is Home imports of good 1 and E_2 is Home exports of good 2. Imports of good i are the difference between domestic demand and supply:

$$M_i = D^i - x_i \tag{11}$$

where x_i is the domestic output of good i. Using Hotelling's Lemma, this can be recovered from the GDP functions or profit functions:

$$x_i = \frac{\partial G}{\partial q_i} = \frac{\partial \pi^i}{\partial q_i} \tag{12}$$

Referring to (11), note that if $M_i < 0$, then good i is exported. For clarity, we have denoted exports as $E_i \equiv -M_i$.

Goods prices p_i are determined by market clearing conditions. In the market for good 1, p_1 is determined by the condition that Home imports equal Foreign exports.

$$M_1(p_1, t_1, s_1) = E_1^*(p_1, t_1^*, s_1*) \tag{13}$$

In the market for good 2, we require that Home exports equal Foreign imports:

$$E_2(p_2, t_2 s_2) = M_2^*(p_2, t_2^*, s_2*) \tag{14}$$

And in the markets for good 3, which is non-traded, the market clearing conditions are that domestic demand and supply are equal in each country, or equivalently that net imports are zero in each country:

$$M_3(p_3, s_3) = M_3*(p_3*, s_3*) = 0 \tag{15}$$

We can now solve the Home government's policy problem. It chooses the pollution tax, trade taxes and production subsidies to maximize welfare (9) subject to the consumer budget constraint (10) and market clearing conditions (13) - (15) treating foreign policy variables as given. The solution is standard. The home government internalizes the domestic pollution externality (but ignores the effect of its pollution on foreigners). Hence:

$$\tau = \gamma \tag{16}$$

In addition, the government wants to influence its terms of trade and foreign pollution. The only way to influence either is by affecting world prices, and the most efficient way to target world prices is via trade taxes. Hence the optimal policy is to impose trade taxes in sectors 1 and 2, and to set production subsidies equal to zero:

$$t_1 = \frac{1}{\varepsilon^*_{E_1^* p_1}}\left(1 + \frac{MD \bullet Z*}{p_1 E_1^*}\varepsilon^*_{Z* p_1}\right) \tag{17}$$

$$t_2 = -\frac{1}{\varepsilon^*_{M_2^* p_2}}\left(1 - \frac{MD \bullet Z*}{p_2 E_2}\varepsilon^*_{Z* p_2}\right) \tag{18}$$

$$s_1 = s_2 = s_3 = 0\,. \tag{19}$$

where $\varepsilon^*_{E_1^* p_1} > 0$ is the elasticity of the foreign export supply curve for good 1; $\varepsilon^*_{M_2^* p_2} < 0$ is the elasticity of the foreign import demand for good 2; and $\varepsilon^*_{Z* p_i} > 0$ is the elasticity of foreign pollution emissions with respect to the price of good i.

The import tariff (17) has two components, both of which are positive - the first term reflects the incentive to improve the terms of trade; the second reflects an incentive to reduce foreign pollution. In each case, the home country benefits by pushing the world price down; hence taxing imports is optimal. The export tax (18) also has two components, but in this case they are of opposite sign. The first term reflects the terms of trade motive - a positive tax on exports reduces supply of the export good and pushes up its price. The second term reflects the incentive to reduce foreign pollution in this sector; this may be accomplished by pushing down the world price and hence an export subsidy is called for. The net effect may be positive or negative depending on how damaging pollution is.

The foreign country has similar motives to intervene and as is well known, the Nash equilibrium is inefficient - trade barriers are excessively high because trade barriers both transfer income between countries and introduce distortions; and pollution taxes are too low because neither country takes into account the effects of its pollution on the welfare of the other country.

4. International agreements

I now consider an efficient negotiated agreement that covers all policy variables. It is simplest to suppose that a lump sum transfer is available to deal with the international distribution of income.[8] In that case given the form of our utility functions, the efficient policy can be obtained by maximizing the sum of utilities across countries. The result is standard - trade taxes and production subsidies are all eliminated, and the carbon tax is set equal to the sum of marginal damages across countries:

$$t_1 = t_2 = t_1^* = t_2^* = 0\,; \tag{20}$$

$$s_i = s_i^* = 0, \qquad i = 1,2,3\,; \tag{21}$$

$$\tau = \tau^* = \gamma + \gamma^*\,. \tag{22}$$

[8] If lump sum transfers are ruled out, then the optimal policy is more complicated because policy variables play a dual role of minimizing distortions and redistributing income across countries. In some cases, efficiency can be obtained if a positive trade tax in one country is offset by a negative trade tax in the other country (see Mayer, 1981). However, even if lump sum transfers are ruled out, the policy substitution issues analyzed in the next section will continue to arise.

4.1. Incomplete International Agreement

International trade agreements constrain only a subset of the policy instruments available to governments. Governments have a multitude of potential domestic policy instruments available that can affect trade flows by either restricting imports via non-tariff barriers or promoting favoured domestic production through subsidies or preferential tax and regulatory treatment. Most of these policy instruments are not specifically targetted by trade agreements. To capture this feature of international agreements, I now assume that while governments can negotiate binding agreements on tariffs and on domestic carbon taxes, they are not able to negotiate an agreement on subsidies. I first show how a free trade and carbon tax agreement can be undermined by the use of subsidies; I then consider possible remedies.

Suppose that governments have agreed to free trade and that they have also agreed to impose a carbon tax τ. The carbon tax is administered internally by each government, and I assume that it is fully enforced. The carbon tax need not be set at the efficient levels - the key assumption that we need is that the carbon tax is set higher than any government would choose on its own; that is we assume that $\tau > \gamma$. Similarly, we do not need countries to be in free trade - the key assumption needed is that trade taxes are below levels that governments would choose unilaterally. However, the analysis is simpler if we assume that we have free trade and so I will assume this, since our focus is on a carbon tax agreement.

I now wish to investigate the optimal (non-cooperative) choice of subsidies given that there is free trade and a carbon tax agreement in place. Let us focus on the Home country. The government has three subsidies available; its problem is to choose levels of these subsidies to maximize utility (7) subject to the budget constraint (10) and market clearing conditions (13) - (15) with all trade taxes set equal to zero and with the carbon tax given. Rather than writing down the full solution to this optimization problem, it is instructive to consider the welfare effects of a small increase in subsidies, starting from the point where the subsidy is zero. Starting with the non-traded good, I consider the effect on welfare of imposing a small production subsidy:

$$\frac{\partial V}{\partial s_3} = -M_3 \frac{dp_3}{ds_3} - s_3 \frac{dx_3}{ds_s} + (\tau - \gamma)\frac{dz_3}{ds_3} - \gamma \sum_{i=1}^{3} \frac{dz_i^*}{ds_3} \tag{23}$$

The subsidy potentially has several effects - it stimulates the output of good 3 and this affects p_3. However because good 3 is non-traded ($M_3 = 0$), this price change does not generate a terms of trade effect and so the first term in (23) is zero. The second term in (23) measures the distortionary effect of the subsidy. The third term measures the welfare effect of the increased pollution caused by the expansion of good 3 output - I will come back to this below. And the last term in (23) measures the effect on domestic welfare of any induced change in foreign pollution. However, foreign pollution will change only if the domestic subsidy affects prices in the foreign market. Since good 3 is not traded and since there are no income effects or cross price effects (due to the structure imposed), foreign prices do not change and hence the last term is zero. Hence we are left with only the distortionary effect of the subsidy and its effect on domestic pollution. To consider the effect of a small subsidy, we have:

$$\left.\frac{\partial V}{\partial s_3}\right|_{s_3=0} = (\tau - \gamma)\frac{dz_3}{ds_3} > 0 \tag{24}$$

A small subsidy is unambiguously welfare-enhancing for the Home country. Of course the subsidy harms the foreign country since it increases world pollution:

$$\left.\frac{\partial V^*}{\partial s_3}\right|_{s_3=0} = -\gamma^* \frac{dz_3}{ds_3} < 0\,. \tag{25}$$

This is the mechanism originally discussed by Hoel (1991). From the perspective of the domestic government, the carbon tax has pushed output of pollution-intensive activities below the level that is domestic welfare maximizing. Hence there is an incentive to choose policies that offset the tax. A production subsidy will do this. In short, the net marginal benefit of increasing access to the global commons is positive from the domestic government's perspective (because it ignores the effect on Foreign countries) and there is an incentive to use domestic policy to increase access to the commons. Note that in the extreme case where pollution is directly proportional to output (z = x), the domestic production subsidy will completely undo the effect of the tax.

Let us now turn to the tradable goods. First consider Home's import-competing sector (good 1). Because good 1 is tradable, a subsidy in sector 1 will now generate terms of trade effects, and hence the welfare effect of the subsidy is more complex. Consider the effect of a small subsidy:

$$\left.\frac{\partial V}{\partial s_1}\right|_{s_1=0} = -M_1 \frac{dp_1}{ds_1} + (\tau - \gamma)\frac{dz_1}{ds_1} - \gamma \frac{\partial z_1^*}{\partial p_1}\frac{dp_1}{ds_1} \qquad (26)$$

$$(+)(-) \qquad (+) \quad (+) \qquad (+)(-)$$

The middle term in (26) has the same interpretation as in the case of the non-traded good in (24). The government has an incentive to subsidize output of good 1 since the carbon tax has pushed output in that sector below the level that is privately optimal for the Home country (for given levels of foreign output). That is the subsidy provides a loophole in the carbon tax agreement.

In addition, the subsidy has two other effects that operate via its effect on international goods prices. The subsidy reduces p_1 and since Home imports good 1, this leads to a terms of trade improvement for home; that is, the first term in (26) is positive. This result is familiar from the trade literature (Copeland, 1990; Bagwell and Staiger, 2001). The opportunity to use domestic subsidies provides a loophole in trade agreements because subsidies can act as a second best trade policy instrument. In the present model, the subsidy can play a dual role of undermining both the trade agreement and the carbon tax agreement. Finally the third term in (26) is also positive. By pushing down the world price, Home's subsidy leads to a fall in the output of good 1 in the Foreign country. This reduces Foreign pollution, which benefits Home. Hence (26) is unambiguously positive and Home has strong incentives to subsidize import-competing production in response to either a trade agreement, a carbon tax agreement, or both.

Now let us consider the export sector. This differs from the import competing sector in that a subsidy will now worsen Home's terms of trade. Consider the effect of a small subsidy for good 2 production:

$$\left.\frac{\partial V}{\partial s_2}\right|_{s_2=0} = E_2 \frac{dp_2}{ds_2} + (\tau-\gamma)\frac{dz_2}{ds_2} - \gamma \frac{\partial z_2^*}{\partial p_2}\frac{dp_2}{ds_2} \tag{27}$$

$$(+)(-) \qquad (+) \quad (+) \qquad (+)(-)$$

The second two terms in (27) are both positive for the same reasons noted above for the case of the import-competing sector. The middle term reflects the incentive to undermine the carbon tax agreement by subsidizing a polluting sector. The third term measures the benefits of the induced fall in foreign pollution caused by the subsidy-induced decline in the price of good 2. The first term in (27) is, however, negative. The subsidy reduces the price of the country's export good and this worsens the terms of trade. Hence in the case of the export-competing sector the benefits of attempting to undermine the carbon tax agreement can be mitigated by the potential terms of trade loss. The sign of (27) is ambiguous and depends on the strength of the terms trade effect relative to the other effects.

Finally, it is worth briefly considering a small country where terms of trade effects are negligible. Because we have assumed a welfare maximizing government, the optimal trade policy is free trade, and so a small country would have no incentive to use subsidies to undermine a trade agreement. However, the incentive to undermine the carbon tax agreement remains. For a small country with no terms of trade effects induced by its subsidy, the effects of a small subsidy in any sector is unambiguously positive:

$$\left.\frac{\partial V}{\partial s_i}\right|_{s_i=0} = (\tau-\gamma)\frac{dz_i}{ds_i} > 0, \quad i = 1,2,3. \tag{28}$$

All countries – whether they be large or small – have an incentive to free ride on access to the global commons, and hence a carbon tax agreement is potentially quite vulnerable to the policy substitution incentive.

5. Countervailing duties and market access commitments

Policy substitution has been anticipated by governments when negotiating trade agreements, and presumably would also be anticipated when negotiating a carbon tax agreement. In our simple model, the solution seems straightforward – governments could negotiate subsidies as well as the carbon and trade taxes and achieve the first best. However, as noted above governments potentially have a huge policy arsenal at their disposal and so signing agreements on some domestic policies would just create an incentive to substitute to other policies. Loopholes would only be fully closed when all domestic policy is constrained. Assuming that this is neither feasible nor desirable,[9] we want to consider other options available when some domestic policy is unconstrained by an agreement. To capture this, we therefore continue to assume that the subsidies represent a set of policies that are non-contractible.

In the context of trade agreements, the General Agreement on Tariffs and Trade and the WTO have several mechanisms in place to constrain policy substitution. The WTO prohibits export subsidies and allows countries to impose countervailing import duties to offset the effects of export subsidies. Subsidies that protect import-competing industries may also be actionable under WTO rules especially if they undermine the benefits a trading partner would reasonably have been expected to receive as a result of an agreement to reduce tariffs.[10]

To see how the WTO rules would affect the incentives to subsidize carbon intensive industries, let us first consider countervailing duties. Countervailing duties are an instrument that under some conditions can be used to offset the effects of a foreign export subsidy (or policies that are de facto export subsidies such as production subsidies targetting goods that are exported). The use of both export subsidies and countervailing duties have been a subject of some debate among economists since it is difficult to come up with scenarios under which either policy is welfare improving for the country implementing a policy. The producers receiving an export subsidy do get a benefit, but this is more than offset by the other effects of the subsidy: it worsens a country's terms of trade (by lowering the price of exports) and transfers income to foreign consumers. The imposition of a countervailing duty is meant to provide incentives for the trading partner

[9] Horn et al. (2010) study the extent to which constraints on domestic policy instruments are desirable in the context of trade agreements. There is a tradeoff between the benefits of allowing domestic governments flexibility to adjust their domestic policy to meet domestic needs, and the potential for this flexibility to be exploited to restrict trade.

[10] See Sykes (2005)

to avoid export subsidies; however it seems somewhat paradoxical that countries would want to use a policy aimed at convincing their trading partner to *increase* the price they are charging for their exports. Nevertheless countervailing duties have in fact been used to protect producer interests.

The introduction of a carbon tax changes the welfare effects of both export subsidies and countervailing duties. In our model a subsidy for good 2 production in the Home country would be treated as an export subsidy under WTO rules since good 2 is exported by Home. The welfare effect of a subsidy to this sector are given by (27) which we reproduce here for convenience:

$$\left.\frac{\partial V}{\partial s_2}\right|_{s_2=0} = \underset{(+)(-)}{E_2 \frac{dp_2}{ds_2}} + \underset{(+)}{(\tau-\gamma)}\underset{(+)}{\frac{dz_2}{ds_2}} - \gamma \underset{(+)(-)}{\frac{\partial z_2^*}{\partial p_2}\frac{dp_2}{ds_2}}$$

Note that if there were no pollution, the second and third terms would disappear and we would be left with only the first term, which is negative - this is the standard result that in the absence of other distortions, subsidies to the export sector are welfare-decreasing. However, in the presence of pollution and an internationally imposed carbon tax, then this result can be overturned. If terms of trade effects are small and if the carbon tax is higher than domestic marginal damage, then the middle term (which is positive) dominates - the country can gain by subsidizing a polluting sector to partially offset the competitiveness-reducing effects of the carbon tax. That is, in the presence of a carbon tax agreement, an export subsidy can be welfare-improving. Moreover, the case for using countervailing duties is also strengthened, since the countervailing duty would be aimed at reducing carbon emissions from the trading partner in addition to the standard strategy of helping producer interests.

Let us now consider the effectiveness of a countervailing duty as a tool for combatting export subsidies in the presence of carbon emissions. The WTO puts a ceiling on the level of the countervailing duty - it is meant to offset the effects of the export subsidy. So we will assume that when the Home country introduces a subsidy s_2, the Foreign country responds with a tariff $t_2* = s_2$. Again we consider the welfare effects on Home of a small subsidy.

$$\left.\frac{\partial V}{\partial s_2}\right|_{s_2=0} = E_2 \frac{dp_2}{ds_2} + (\tau - \gamma)\frac{dz_2}{ds_2} - \gamma \frac{\partial z_2^*}{\partial p_2}\left(\frac{dp_2}{ds_2} + 1\right) \qquad (29)$$

$$(+)(-) \quad (+) \quad (+) \quad (+) \quad (+)$$

This is similar to (27); it differs in two ways. First the magnitude of the fall in p_2 is greater because Foreign import tariff reduces import demand. Second, the final term has an additional component - the retaliatory foreign tariff (which matches the subsidy) causes a net increase in the domestic foreign price (we will demonstrate this below) and this causes foreign pollution to rise.

To find the change in p_2 (which is needed to sign the middle and last terms in (29)), we use the equilibrium condition that Home export supply equal Foreign import demand:

$$E(p_2, s_2) = M^*(p_2 + t_2^*) \qquad (30)$$

Differentiating and noting that $dt_2* = ds_2$ yields:

$$\frac{dp_2}{ds_2} = -\frac{E_{s_2} - M_{p_2}^*}{E_{p_2} - M_{p_2}^*} = -\frac{G_{p_2 p_2} - M_{p_2}^*}{G_{p_2 p_2} - D_{p_2}^2 - M_{p_2}^*} > -1 \qquad (31)$$

where recall that the domestic supply of good 2 can be recovered from the GDP function as G_{p_2} and domestic exports are the difference between domestic supply and demand for good 2. Home's subsidy causes a fall in p_2 because export supply shifts out. The countervailing tariff causes a further reduction in p_2 because it shifts in import demand. The key result in (31) is that even with the countervailing duty, p_2 falls by less than the full amount of the subsidy. This is because while the foreign tariff affects both foreign supply and demand, the Home production subsidy affects only Home supply (but not demand) - hence the Home export supply curve does not shift down by the full amount of the subsidy. Home producers care about what happens to $p_2 + s$, and (31) implies that $p_2 + s$ rises. Hence even with the countervailing duty, the subsidy causes an expansion of good 2 production at home:

$$\frac{dx_2}{ds_s} = \frac{\partial x_2}{\partial p_2}\left(\frac{dp_2}{ds_s} + 1\right) > 0 \tag{32}$$

where we have used (31) to sign the expression above. The reason for this is that while the foreign countervailing duty more than offsets the effects of the subsidy on exports (one can show that exports actually fall), the subsidy also expands production in the Home market and the decline in the price of good 2 induced by the foreign tariff is not sufficient to fully offset this. And since the output of good 2 expands, we also have an increase in pollution from sector 2.

Because the middle term in (29) is positive, the overall net welfare effect of the subsidy is ambiguous. However, the countervailing duty does have environmental benefits in that it reduces the incentive for Home to use an subsidy to undermine the carbon tax - the terms of trade decline is greater (term 1 in (29) is larger than in the absence of the countervailing duty) and Foreign production of the polluting good rises, increasing global pollution and harming domestic welfare via the term in (29). And the subsidy-induced expansion of good 2 output is muted (although completely eliminated) by the countervailing duty.

Consequently, the mechanism provided by existing trade agreements to deter export subsidies can also be used to reduce the incentive to undermine the carbon tax agreement in export industries. Moreover, note that this mechanism is different than the border taxes that are usually discussed in the context of climate change - the standard border tax argument is a proposal that they be used to target countries that do not impose a carbon tax or meet their Kyoto targets. Whether or not this is legal under WTO rules has been the subject of some debate. However, the countervailing duty discussed above is a border tax that is entirely consistent with WTO rules - a production subsidy in the export sector is a clear violation of WTO rules.

Now let us turn to subsidies targetting the import-competing sector. Bagwell and Staiger (2001) have considered this issue in the context of trade agreements (without global pollution externalities). They argue that when governments negotiate trade agreements, they are really negotiating agreements on market access - in the context of this model, Home agrees to reduce its trade barriers restricting Foreign imports of good 1 in return for an agreement by the Foreign government to reduce its trade barriers to allow Home producers of good 2 increased access to the Foreign market. If Home subsequently subsidizes good 1 production to undermine a carbon tax agreement, this will increase Home output and reduce Foreign imports. Hence Home's production subsidy would reduce Foreign access to Home's market and undermine the implicit market access agreement. Under the GATT/WTO framework, countries can bring "non-violation" complaints against a country that uses domestic policy to undermine market access commitments. A key result in Bagwell and Staiger (2001) is that if we think of the market access commitments as binding, then countries have no incentive to manipulate domestic policy to undermine trade agreements. The attractiveness of this approach is that the market access commitments constrain governments from introducing domestic policies that have international spillover effects (via the terms of trade channel) without explicitly negotiating agreements on individual domestic policies.

To see how this works, suppose that there is a free trade agreement and an agreement to impose a carbon tax τ. Then in the absence of any domestic policy manipulation, this would imply a level of imports of good 1 in the Home country of $\bar{M}$, defined as

$$\bar{M} \equiv D_1(p_1) - x_1(p_1, \tau) \tag{33}$$

where p_1 is the world price that prevails under free trade, no production subsidies, and a carbon tax τ.

If Home takes the market access agreement seriously, then once the trade and carbon tax agreement is in place the choice of domestic subsidies is constrained by the condition that imports do not fall below $\bar{M}$:

$$M(p_1, s_1, \tau) = D_1(p_1) - x_1(p_1 + s_1, \tau) \geq \bar{M} \tag{34}$$

Since $dM/ds_1 < 0$, then the market access commitment would be sufficient to prevent the use of production subsidies to undermine the carbon tax agreement. Again, as in the case of countervailing duties, this illustrates how provisions in existing trade agreements can be used to provide incentives for countries to avoid the use of policy substitution to undermine a carbon tax agreement.

However, in practice, governments have a range of policy instruments available. If we expand the policy space, then it will be possible for the Home government to both meet its market access commitment and stimulate the polluting sector. To see this suppose that Home can use a consumption subsidy s^c in addition to the production subsidy s. Assuming that it binds, the market access commitment is now:

$$M(p_1, s_1, s_1^c, \tau) = D_1(p_1 - s_1^c) - x_1(p_1 + s_1, \tau) = \bar{M} \tag{35}$$

And since markets have to clear, we also have

$$E^*(p_1) = x_1^*(p_1, \tau) - D_1^*(p_1) \tag{36}$$

Combining (35) and (36), we see that the market access constraint requires that Home choose s_1 and s_1^c such that p_1 stays fixed. That is, (35) and (36) imply that the market access constraint requires

$$\frac{ds_1^c}{ds_1} = -\frac{\partial x_1 / \partial p_1}{dD_1 / dp_1} > 0 \tag{37}$$

Let us now consider the welfare effect on Home of introducing a package of subsidies that satisfy (37). We have:

$$dV = -Mdp_1 - s_1^c dD_1 - s_1 dx_1 + (\tau - \gamma)dz - \gamma dz^* \tag{38}$$

Since the market access constraint requires that p_1 stay fixed, the first and last terms in (38) are zero (there are no terms of trade effects and foreign output does not change, so foreign pollution is unchanged. Hence using the constraint (37) - that is, treating s_1^c as a function of s_1, we have

$$\left.\frac{\partial V}{\partial s_1}\right|_{s_1=0} = (\tau - \gamma)\frac{dz_1}{ds_1} > 0. \tag{39}$$

The idea here is that the home government has an incentive to promote industry 1 to offset the effects of the carbon tax. To avoid violating the market access agreement it simultaneously subsidizes domestic consumers so that they are willing to absorb all of the extra production. Both the production and consumption subsidies are distortionary, but the first order effect of small subsidies is close to zero, leaving welfare-improving policy substitution effect to dominate as shown in (28).

This example shows that the market access commitments made via trade agreements, even if these were enforceable,[11] would not be enough to prevent the carbon tax agreement from being undermined. The market access commitments are not irrelevant, however, because they raise the marginal cost to governments of intervening - in the example above, a simple production subsidy was not enough - the market access agreement required the government to introduce an additional domestic distortion to promote the carbon-intensive industry. So as we also saw in the case of export markets, existing international trade rules can play some role in dampening the incentive to undermine carbon tax agreements.

Finally, let us briefly turn to the non-tradable sector. In this case, global trade agreements would play at most a peripheral role in preventing policy substitution to undermine a carbon tax agreement. Since nontradable goods and service are by definition not traded, they are not covered by WTO market access commitments or subsidy codes. Hence there is no mechanism to offset the incentive to subsidize carbon-intensive nontradables as we saw in (24). One potential mechanism (not modelled here) is that nontradable goods and services are used as intermediate inputs into the production of tradable goods and so there may be some limited opportunities to use trade agreements as an enforcement mechanism via that channel.

6. Market access and access to the commons

A key insight from the Bagwell and Staiger (1999) paper on the GATT that was exploited in their (2001) paper on policy substitution was that (even in the presence of political economy motivations for policy intervention), the only way that the policy actions of one country affected another was via the terms of trade effect. And this was a zero sum game

[11] We will discuss enforceability of market access commitments below.

- an improvement in one set of countries' terms of trade must be balanced by a loss in other countries. Consequently they argue that the role of trade agreements is to neutralize this externality by negotiating market access agreements, which they essentially interpret as agreements under which countries can manipulate domestic policy subject to the constraint that it have a neutral effect on the terms of trade.

In this paper we are considering a scenario where there are two channels through which countries' actions can affect each other - terms of trade effects and international pollution externalities. An efficient international agreement must target both channels. Consequently, we consider an agreement that includes both market access commitments and global commons access commitments. That is, we consider an agreement that fixes both trade taxes and an international carbon tax, but also includes access commitments to constrain the use of domestic policy.

Referring to (20) - (22), we assume that the agreement specifies free trade (20) and an efficient carbon tax (22). However, subsidies are not constrained by the agreement. Instead we calculate the level of market access and commons access implied by (20)-(22) and consider an agreement under which governments commit to those levels of access.

Consider the Home country. Let (p_1,p_2,p_3) be the price vector implied by (20)-(22) and its foreign analogue and the market clearing conditions. The level of market access implied by (20)-(22) is

$$\bar{M} \equiv D_1(p_1) - x_1(p_1, \tau) \tag{40}$$

$$\bar{E} \equiv x_2(p_2, \tau) - D_2(p_2) \tag{41}$$

The definition of import market access is the same as in (33). For exports, the commitment would be that the Home country not use domestic policy to promote exports beyond the level implied by (33). The level of commons access implied by (20)-(22) is given by

$$\bar{Z} = -\sum_{i=1}^{3} \partial \pi_i(p_i, \tau) / \partial \tau \tag{42}$$

where recall that $-\partial\pi_i / \partial\tau$ is the emissions of sector i.

As in the previous section we allow governments to use both consumption subsidies (or taxes) and production subsidies (or taxes) because we want to capture the idea that they have many instruments to draw upon if they want to try to exploit loopholes in the agreement. We assume that the market and commons access commitments are as follows:

$$M(p_1, s_1, s_1^c, \tau) = D_1(p_1 - s_1^c) - x_1(p_1 + s_1, \tau) \geq \bar{M} \tag{43}$$

$$E(p_2, s_2, s_2^c, \tau) = x_2(p_2 + s_2, \tau) - D_2(p_2 - s_2^c) \leq \bar{E} \tag{44}$$

$$-\sum_{i=1}^{3} \partial\pi_i(p_i + s_i, \tau) / \partial\tau \leq \bar{Z} \tag{45}$$

That is, governments may use domestic policies provided that they do not violate their market and commons access commitments. Once the agreement is in place (and assuming it is enforced), the Home government's problem is to choose its domestic policy instruments to maximize welfare subject to market clearing and the access constraints (43)-(45).

Proposition. Suppose there is a free trade agreement, a carbon tax satisfying (22) and that governments respect their market and commons access commitments (43)-(45). Suppose also that governments are free to set domestic production and consumption subsidies or taxes. Then a welfare maximizing government will set domestic production and consumption subsidies/taxes equal to zero.
Proof: See Appendix.

The intuition for this result comes from the targeting principle. The market and commons access constraints essentially give the government two targets that must be met - a terms of trade target and an overall emissions target. The most efficient instruments available to meet these targets are trade taxes and a uniforms emissions tax. Since these have also been set efficiently by the agreement and since there are no other distortions in the economy, that government has no incentive to use other policies.

While market access and commons access commitments solve the problem of governments using domestic policy to undermine either or both trade agreements and carbon tax agreements, there are weaknesses with this approach. The whole point of using an international carbon tax is that it is an alternative to the approach of assigning countries emission targets. Yet on the face if it, the commons access constraint is essentially an emissions target. And a key aspect of trade agreements has been to eliminate import and export quotas and move to trade taxes with a view towards slowly phasing them out. Yet a market access commitment has features that resemble a quota.

A way to think about access commitments is that they are not meant to be hard quotas, but rather they are a reflection of the underlying enforcement system. Governments are aware that if they manipulate domestic policy in a way that has spillover effects on other countries, then those countries have the right to initiate an action against them. For an action to be successful, it would have to be demonstrated that the domestic policy manipulation deprived foreign countries of benefits that they would have reasonably been expected to gain under the agreement. Since there are only two channels through which they may be deprived of such benefits (terms of trade and increased depletion of the global commons), then a government that wants to avoid such actions should choose policies that do not increase market access or access to the commons beyond the level that would have been expected under the agreement and given the current state of the world.

Looked at in this way, however, it becomes clear that enforcement is challenging. Enforcement actions are not driven by violations of explicit quotas, but rather complainants must demonstrate that specific policy manipulations deprive them of implicit access commitments - that is, it must be demonstrated that the introduction of new domestic policies distorts trade or access to the commons in a way that deprives other parties to the agreement benefits they should reasonably have expected. Given the complexity and opaqueness of the domestic policy structure in most countries, this is not easy to do. In the context of trade agreements, while there have been many countervail cases, there have been very few "non-violation" complaints. That is, while in principle the GATT/WTO has allowed countries to initiate actions based on a failure to honour implicit market access commitments, there have been very few such actions. Both Gawande (1999) and Limao and Tovar (2009) have found evidence that trade agreements have indeed induced some policy substitution.

Enforcement of commons access agreements arising from an agreement on carbon taxes would be more difficult than in trade agreements for two reasons. First, there would have to be a method to assess compliance with the commons access agreement. Suggestions have included estimating the shadow price of carbon in countries, having an agency such as the IMF provide a broad assessment of the effects of all government policies on carbon emission (Aldy et al., 2008), or monitoring aggregate emissions. Aldy and Pizer (2016) review methods for measuring and assessing compliance with climate change agreements.

Second, a violation of a trade agreement that reduces market access for one or more countries creates incentives for those countries to seek remedial action. Moreover, there is a natural remedy – the affected countries can retaliate (via a dispute settlement mechanism) by reducing market access for the country whose government is violating the agreement. However the harm when a country violates an agreement on access to the commons would be shared globally, thus creating free rider problems in enforcement. And it is not obvious what the appropriate remedy should be – an in-kind response in which non-violating countries increase their own access to the commons (i.e. increase emissions) would harm all countries, not just the violating country. One possibility would be to respond to violations of a commons access agreement by restricting market access. Limao (2005) considers the merits of linking trade and environmental agreements.

7. Negotiations when countries anticipate a subsidy war

Suppose now that when countries negotiate a carbon tax, they anticipate that this will induce governments to use subsidies to partially undo the effects of the agreement. To keep the analysis clear and simple, I assume that a free trade agreement is already in place and start by assuming that countries are prohibited from using subsidies in the tradable sector (perhaps because they are constrained by a trade agreement). Hence the only available instrument for which each country has discretion is a subsidy on good 3. The advantage of this assumption is that it rules out terms of trade effects so that the only channel through which policy substitution spills across borders is via the international pollution externality. This allows us to focus on incentives to undermine the carbon tax agreement and abstract from incentives to undermine the trade agreement.

I will allow negotiators the flexibility to assign different levels of the international carbon tax across countries if this should turn out to be optimal. And I will also allow for an international lump sum transfer across countries – this is to avoid the use of environmental policy as an instrument to achieve a desired international distribution of income.[12]

We can think of this as a two stage game. In the first stage, the countries commit to levels of the carbon tax (and lump sum transfers). I assume that these commitments are binding and enforceable. In the second stage, countries are free to choose production subsidies. Negotiators will be able to predict the outcome of the subsidy war. Using (23), Home's subsidy is

$$s_3 = (\tau - \gamma)\frac{dz_3 / ds_3}{dx_3 / ds_3} \tag{46}$$

This implies that we can write s_3 as a function of the carbon tax τ and Home's factor endowment vector v (it also depends on p_3 but this is endogenous and depends on τ and v):

$$s_3 = s_3(\tau, v) \tag{47}$$

Because the utility functions (6) are quasi-linear, then in the presence of lump sum transfers, an efficient bargain will maximize the sum of the two countries' utilities:

[12] It is well known that in the absence of lump sum transfers an efficient agreement may involve differences in the second best optimal carbon tax across countries. Here we wish to remove this motive for generating unequal carbon taxes to focus on the pure effect of the incentive to undermine the agreement with subsidies.

$$V(p_1,p_2,p_3,I,Z^w)+V^*(p_1,p_2,p_3^*,I^*,Z^w) \tag{48}$$

subject to market clearing for the non traded good, the income constraints:

$$I = G(p_1,p_2,p_3+s_3,\tau,v)-s_3x_3+\tau\sum_{i=1}^{3}z_i - T \tag{49}$$

$$I^* = G^*(p_1,p_2,p_3^*+s_3^*,\tau^*,v^*)-s_3^*x_3^*+\tau^*\sum_{i=1}^{3}z_i^* + T \tag{50}$$

and the endogenous subsidy response (47) and its foreign analogue.

One can show that the first order conditions for the choice of the carbon taxes imply:

$$\tau = \gamma+\gamma^* + s_3(\tau,v)\underset{(+)}{\left[\frac{dx_3/d\tau}{dz_3/d\tau}\right]} \tag{52}$$

$$\tau^* = \gamma+\gamma^* + s_3^*(\tau,v)\underset{(+)}{\left[\frac{dx_3^*/d\tau^*}{dz_3^*/d\tau^*}\right]} \tag{53}$$

First note that if the countries were somehow able to ensure that subsidies were constrained to be zero (that is, if there were no loophole in the agreement), then (52) and (53) would yield the standard result that carbon taxes should be the same across countries and equal to the sum of marginal damages across countries.

If countries cannot constrain subsidies, then (52) and (53) yield two interesting results. First, carbon taxes should be set higher than marginal damage.

$$\tau > \gamma+\gamma^* \quad and \quad \tau^* > \gamma+\gamma^* \tag{54}$$

This is because negotiators anticipate that any carbon tax will be undermined by subsidies – that is, it is useful to distinguish between the *nominal* carbon tax (the τ and τ^*) and the *effective* carbon tax, which is the net effect of the carbon tax and the offsetting production subsidy. The negotiators set the nominal carbon high so that the effective carbon tax will be closer to the desired target.

Second, note that (55) implies that the second best optimal carbon taxes need not be equal across countries. This is because the deviation of the carbon tax from marginal damage depends on the strength of the subsidy response in each country. Since this depends on the technology, endowments, and preferences of each country, there is no reason for these responses to be the same across countries.

That is, the presence of an anticipated subsidy response undermines two of the key principles that underlie the setting of pollution taxes – they do not equal marginal damage, and different sources face different taxes despite there being a uniformly mixed pollutant.

Using (46) in (52) allows us to gain further insight into the structure of the second best carbon tax. Consider the tax for the home country:

$$\tau = \gamma + \frac{\gamma *}{\left[1 - \left(\frac{dz_3 / ds_3}{dx_3 / ds_3}\right)\left(\frac{dx_3 / d\tau}{dz_3 / d\tau}\right)\right]} . \tag{55}$$

Each country's carbon tax fully internalizes the effects of its own pollution on itself, but it more than offsets the marginal damage caused to other countries because it is anticipated that this effect will be undermined by the subsidy.

Finally note that if pollution is directly proportional to the output of good x, then a pollution tax is a tax on good x and the production subsidy fully offsets the effect of the tax. This means that the environmental agreement is essentially irrelevant – in (55) the optimal carbon tax is undefined because the denominator of the second term goes to zero – as the subsidy becomes a better substitute for the carbon tax, the magnitude of the second best carbon tax increases (and it the limit it becomes infinite).

8. Conclusion

In principle, international agreements on trade and climate change could be implemented by negotiating international targets for either quantity or price instruments. However, in practice, price instruments are vulnerable to policy substitution in ways that quantity instruments are not. In the context of trade, an (enforced) agreement to eliminate tariffs can be undermined by the use of domestic subsidies but an (enforced) agreement to allow foreign countries a certain amount of access to one's market (essentially a quantity instrument) cannot be undermined by subsidies. Similar issues would arise if we were to have a carbon tax agreement. Carbon tax agreements can be circumvented by the use of domestic subsidies; while carbon emission quotas cannot be (assuming the quotas are enforced).

This paper has considered the role of policy substitution in the design of a potential carbon tax agreement. It is shown that some of the existing institutions aimed at curtailing policy substitution in the context of trade could be used to mitigate (but not fully eliminate) the incentives to undermine a carbon tax agreement. For example, countervailing duties aimed at offsetting foreign subsidies to carbon-intensive industry would both curtail policy substitution and be consistent with WTO rules.

It is also shown that the anticipation of policy substitution alters some of the key features of a carbon tax agreement - the second best optimal carbon tax is above marginal damage; and it need not be uniform across countries (even if distributional issues are dealt with via lump sum transfers).

Bagwell and Staiger (2001) have argued that GATT and WTO trade agreements can the interpreted as market access agreements and that this can be effective in constraining governments from using policy substitution to undermine tariff-reduction agreements. This paper shows that supplementing a market access agreement with a commons access agreement could in principle prevent governments from using policy substitution to undermine a carbon tax agreement. However, enforcement of a commons access agreement is likely to be more challenging than enforcement of a market access agreement because the harm from violations is shared globally, this creating free rider problems for enforcement.

Another response to policy substitution is to constrain a wider set of instruments - for example, subsidies aimed at carbon intensive activities could be banned. However, there are both benefits and costs of imposing added restrictions on domestic policy, an issue that has been explored in the context of trade agreements by Horn et al. (2010).

Finally, the point that an agreement on carbon taxes is vulnerable to policy substitution while an agreement on carbon quotas is not so vulnerable does not imply that agreements on quotas are necessarily superior to agreements on taxes. There are advantages and disadvantages of each instrument. The potential for policy substitution is simply one more factor that must be considered in the design of international emissions policy.

Appendix

Proof of Proposition. The market and commons access constraints both bind. Given the market clearing constraints, the market access conditions require that changes in domestic policy instruments leave world prices unchanged ($dp_1 = dp_2 = 0$). This requires that consumption and production subsidies must be linked to keep the terms of trade constant. For good 1 this means that (35)-(37) hold. Note that this constraint implies that s_1 and s_1^C both have the same sign, and that we can treat s_1^C as an increasing function of s_1. For good 2, the market access constraint requires that (44) hold with equality since it binds. Hence the market access condition requires that s_2 and s_2^C also both have the same sign, and that we can treat s_2^C as an increasing function of s_2.

$$\frac{ds_2^c}{ds_2} = -\frac{\partial x_2 / \partial p_2}{dD_2 / dp_2} > 0$$

Using the result that $dp_1 = dp_2 = 0$, the first order conditions for the choice of production and consumption subsidies reduce to:

$$-s_i \frac{dx_i}{ds_i} - s_i^c \frac{dD_i}{ds_i^c}\frac{ds_i^c}{ds_i} + (\tau - \lambda)\frac{dz_i}{ds_i} = 0, \qquad i = 1,2 \tag{A1}$$

$$-s_3 \frac{dx_3}{ds_3} + (\tau - \lambda)\frac{dz_3}{ds_3} = 0. \tag{A2}$$

$$-s_3^c \frac{dD_3}{ds_3^c} + (\tau - \lambda)\frac{dz_3}{ds_3^c} = 0. \tag{A3}$$

where λ is the Lagrange multiplier associated with the commons access constraint (45) and where the derivatives in (A2) and (A3) take into account the endogenous change in p_3.

Note that for all i, we have $dz_i / ds_i > 0$, $dx_i / ds_i > 0$, and $\left(dD_i / ds_i^c\right)\left(ds_i^c / ds_i\right) > 0$. Also from above we know that s_1 and s_1^C both have the same sign, and s_2 and s_2^C both have the same sign. Hence by examining (A1) and (A2) we conclude that the s_i should all be of the same sign (or zero) for all i. If $\lambda > \tau$, then the s_i are negative, which would indicate that the market access constrain does not bind – this is a contradiction since $\tau > \gamma$

(the international carbon tax is higher than the domestic government would choose if not constrained by the agreement). If $\lambda < \tau$, then $s_i > 0$ for all i. However summing the conditions in (A1) and (A2) over i yields

$$\sum_{i=1}^{3} s_i \frac{dx_i}{ds_i} + \sum_{i=1}^{2} s_i^c \frac{dD_i}{ds_i^c} \frac{ds_i^c}{ds_i} = 0 \qquad \text{(A4)}$$

because the commons access commitment requires $\sum_{i=1}^{3} dz_i / ds_i = 0$. However, (A4) is inconsistent with $s_i > 0$ for all i. Hence we must have $\lambda = \tau$. This in turn implies that

$$s_i = s_i^c = 0, \qquad i = 1,2,3.$$

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