Limiting Emissions and Trade: Some Basic Ideas

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April 20, 2010

1 Introduction

On June 26, 2009 the American Clean Energy and Security Act (or the Waxman-Markey Bill after its authors) was approved by the US House of Representatives. It has (in April 2010) yet to clear the Senate. This event marked the first time either house approved a law meant to limit emissions to combat climate change and has resulted in a flurry of work in the area. The bill would essentially create cap-and-trade programs for greenhouse-gas emissions and specifies reductions in total emissions of 17% starting from 2012. See CBO (2009a) for a good summary of the bill and its implications. Recently, there have been indications[1] that the Senate version of the Bill will be weaker, with utilities being subject to caps by 2012 but with manufacturers being phased in only by 2016. In addition, there are likely to be floor and ceiling prices of $10 and $30 per ton that will be adjusted for inflation[2], and import taxes (border tax adjustments or BTAs) on countries that do not limit their emissions.

Existing studies suggested that the size of BTAs needed to level the playing field would likely be quite small for most products. This is why, as currently drafted, US legislation envisages BTAs mainly for producers in energy-

[1] See the Reuters article, March 15, 2010, entitled "Senate climate bill to set utitlities cap-trade".

[2] The price ceiling would insure that businesses do not face too high a cost of permits as these are part of their costs. The floor protects them from the risk of investing in technology to reduce emisssions only to find it was not worth their while ex post.

intensive sectors. These include chemicals, paper, ferrous metals, non-ferrous metals, and mineral products. However, there is wide variation in intensiveness across countries and sectors. Estimates of the effect of the kinds of emissions limits being discussed vary quite a bit. For example, Atkinson et. al. (2009), which was a background paper for World Development Report 2010, uses a partial equilibrium GTAP model to estimate that if carbon is taxed at $50 per ton of CO2, Chinese exports to the US would face an average tariff rate of 10.3%.

Mattoo et. al. (2009) employ a multi country computable general equilibrium framework (the Environmental Impact and Sustainability Applied General Equilibrium Model, or ENVISAGE model) to compare outcomes under different scenarios for BTAs of a carbon tax that reduces emissions by 17% relative to 2005 by all OECD countries. Their work suggests considerable room for leakage, especially without appropriate BTAs. They calculate that a 17% reduction in emissions in energy intensive goods only (which is what the US is proposing) would lead to total emissions in 2025 relative to 2005 rising by about 54% for the world: the 17% reduction in emissions by the OECD countries is more than undone by low and middle income countries raising their emissions by about 120% in the absence of BTAs. The effect of BTAs on emissions and exports is shown to be sensitive to the way that BTAs are implemented.

What does all of this mean for trade and trade policy? What are the key issues in the implementation of emissions controls, especially BTA, and what does past experience and economics say about them?

I will argue that we can learn a fair bit from history here: in particular, from the implementation of the Multi Fibre Arrangement (MFA) where a number of analogous issues arose. Next, I lay out a simple model that will let us think about the issues more clearly. I use a simpler version of the widely used setup in Copeland and Taylor (2003).[3]

1.1 A Model in the Classical Tradition

There are two final goods, x and Y, and a non traded intermediate good, X. Assume that the final good x, is the "dirty" good that creates emissions while Y is the clean one. The dirty good is made using the intermediate good, X,

[3]I keep to their assumptions as far as possible but drop the joint production and functional form assumptions made there.

and emissions, Z. Its production function is given by $x = F^x(X, Z)$, where the non traded intermediate good X is produced using capital (K) and labor (L) according to $X = F^X(K, L)$. The clean good Y is made using capital and labor: $Y = F^Y(K, L)$. Assume X is intensive in K relative to Y, $k_X > k_Y$. The associated unit cost functions for X, x and Y are denoted by $c^X(w, r)$, $c^x(c^X(w, r), \tau)$, and $c^Y(w, r)$ respectively, where w and r are the price of labor and capital and τ is the price of a unit of emissions.

1.2 The Solution Given p, τ.

Let us consider how the model can be solved and explore its properties given a price for the good x, denoted by p, and the price of emissions, τ. Comparative statics on this problem will show what determines the shape of the demand for emissions and how this demand function will shift as policies change.

If both final goods are made and emissions permits are purchased on an open market, we have

$$p = p^* + t + \alpha\tau = c^x(p^X, \tau) \quad (1)$$

$$1 = c^Y(w, r). \quad (2)$$

where p^* is the world price of x, t is the border tax adjustment (BTA) or *import tariff* on x, α is the allotment of emissions permits per unit of output, and p^X is the price of the intermediate good. In the presence of a production tax/subsidy like $\alpha\tau$, the producer price will differ from the consumer price. In such cases we will use p as the producer price and define p^c is the domestic consumer price if needed, ($p^c = p^* + t$).

If the BTA is set so that it equals the cost of permits used by domestic producers, as we will assume here, then $t = c^x_\tau(p^X, \tau)\tau = a_{Zx}(.)\tau$.[4] It is worth pointing out that it is not clear what level the tax should be set at. One option would be to have emissions of firm's from non complying countries be certified (much as meeting rules of origin is certified) and have them pay the cost of these emissions. This would have the advantage of providing the right *incentives* for exporters to reduce emissions. However, the costs of this are likely to be prohibitive. Recent work suggests that such documentation costs are large and significantly restrict trade through their impact on entry. See Cherkashin et. al. (2010).

[4]If the BTA is set at a level corresponing to home permit prices and the level of emissions abroad where there are no emissions controls, then $t = c^x_\tau(c^X(w^*, r^*), 0)\tau$.

So the only feasible way to implement a BTA is to base such taxes on some norm for emissions created in production. This norm could be that for domestic firms or that for the exporting firms. If the tax is set at the home price of emissions (τ) times the level of emissions that would have occurred if the product had been produced at home (where there are emissions controls in place) then the tax would be lower than if the tax is set at the cost of the level of actual emissions from producing the good as the technique used abroad is likely to be more emissions intensive than that at home.[5] Note *neither* will provide the right incentive effects for foreign producers to reduce their emissions.

The term $\alpha\tau$ in equation 1 would capture the fact that emissions permits are allocated to producers at the rate of α per unit of output in our static model. This makes such a policy equivalent to a *production subsidy*. Moreover, note that if all permits are allocated to producers on the basis of previous output, $\alpha x = \bar{Z}$, where $\bar{Z}$ equals the total available permits which implies $\alpha = a_{Zx}(.)$. In this event, producers would get the same price whether they were allocated permits or given a production subsidy (or tariff) equal to their use of emissions permits.

Lemma 1 *In our static setting, producers will be indifferent between a BTA equal to their current expenditure on emissions permits and being allocated permits on the basis of their past output, while consumers will prefer the latter.*

Since X is non traded, as long as x is produced domestically, so is X. Thus,

$$p^X = c^X(w, r). \tag{3}$$

Now the demand for X comes only from x so

$$a_{Xx}\left(\frac{c^X(w, r)}{\tau}\right)x = X, \tag{4}$$

where $a_{Xx}(\frac{c^X(w,r)}{\tau})$ is the unit input requirement of the intermediate good X in x. It depends on the price of X (which equals its cost) relative to the price of an emissions permit.

[5]Work by Mattoo et al(2009) and McKiben and Wilcoxen (2008) among others, suggests that whether developing country emissions or developed country ones are used as a basis for the BTA makes a substantial difference to developing country exports and world emissions.

Even at this preliminary stage a number of points are clear. Giving emissions permits to producers is not just a transfer of rents. To the extent that they are conditional on production (and in practice they always are) they act like a production subsidy and limit the movement of production abroad. While a border tax adjustment on imports (exports) from (to) countries that do not restrict emissions would level the playing field for domestic firms, allocating permits to producers (with permits contingent on production) in addition to such a BTA would amount to overcompensation and create an *additional* distortion.

All of this is true in partial and general equilibrium. However, in general equilibrium, w, r, p^X, as well as x, X, and y are endogenous. We turn to the general equilibrium next. Totally differentiating equation (1) reveals that for a given τ, the slope of the curve is the capital labor ratio in good X, k_X. If both goods are made, this will give factor prices (w, r) given $p = p^* + t + \alpha\tau$ to be at the intersection of the two curves depicting equations (1) and (2). Giving permits worth $\alpha\tau$ for every unit produced, or putting a tariff on imports, raises the attractiveness of the sector and the equilibrium output levels.[6] Note that both the terms $\alpha\tau$ and t affect the equilibrium levels of factor prices in the same way: they both shift the curve depicting equation (1) outwards, reducing w and raising r in equilibrium (i.e. at the intersection point). This is depicted in Figure 1. In contrast, keeping p fixed $(p = p^* + t + \alpha\tau)$ and increasing τ on the right hand side reduces the ability to pay other factors so that the combinations of w and r that are consistent with zero profits given by (1) shifts inwards towards the origin.

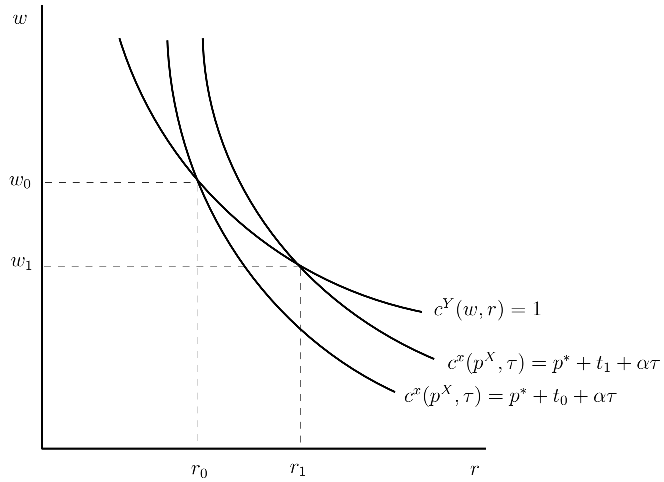
It is easy to verify that the slope of the curve defined by equation (1) in w, r space is the same as that of (3) and is steeper than that defined by equation (2) as $k_X > k_Y$. If allocation is a fixed fraction, α, of output, then totally differentiating equation (1) shows that

$$\begin{aligned} p^* + t + \alpha\tau &= c^x(p^X, \tau) \\ dp^* + dt + \left[\alpha - c^x_\tau(p^X, \tau)\right] d\tau &= \left[c^x_{p^X}(.)\right] \left[c^X_w(.)dw + c^X_r(.)dr\right] \end{aligned}$$

If the unit emissions requirement, $c^x_\tau(.)$, is more than α, i.e., firms are net buyers of permits, $\frac{dw}{d\tau} = \frac{\left[\alpha - c^x_\tau(p^X, \tau)\right]}{c^x_{p^X}(.)c^X_w(.)} < 0$. An increase in τ reduces the ability to pay other factors shifting the curve represented by equation (1) inwards.

[6] This is the equivalent of inducing entry in monopolistic competition models as firm size/number are indeterminate in competitive settings.

Figure 1: Effect of an increase in t on equilibrium factor prices



If the opposite is true, which could be the case if the country is a net seller of emission permits, then this shift would be outward.[7]

If all firms are allocated exactly the level of permits they use in equilibrium, then $c^x_\tau(c^X(w,r),\tau) = \alpha$ and α is *not* exogenous. Totally differentiating equation (1) gives

$$dp^* + dt + [\tau c^x_{\tau\tau}]\, d\tau = \left[c^x_{p^X}(.) + \tau c^x_{\tau p^X}\right] \left[c^X_w(.)dw + c^X_r(.)dr\right]$$

In this case,

$$\frac{dw}{d\tau} = \frac{\tau c^x_{\tau\tau}}{\left[c^x_{p^X}(.) + \tau c^x_{\tau p^X}\right] c^X_w(.)} < 0.$$

While the direct effect $\left[\alpha - c^x_\tau(p^X,\tau)\right]$ is zero, an increase in τ reduces the allocation of permits and this effect shifts the curve given by (1) inwards. If the government allocates all permits to producers on a historical basis, this would be the relevant case in our static setting. Thus we can say :

Lemma 2 *A small increase in τ shifts equation (1) inwards if firms are allocated emissions permits on a historical basis. An increase in τ will raise w and reduce r in this case as well.*

[7]Giving developing countries more permits than they will use has been suggested as one way of compensating them for the emissions produced in the past by developed countries.

Factor prices give the unit input requirements of factors ($a_{ij}(.)$) and so

$$a_{LX}(\frac{w}{r})X + a_{LY}(\frac{w}{r})Y = L \quad (5)$$

$$a_{KX}(\frac{w}{r})X + a_{KY}(\frac{w}{r})Y = K. \quad (6)$$

Substituting for X gives

$$a_{LX}(\frac{w}{r})a_{Xx}(\frac{c^X(w,r)}{\tau})x + a_{LY}(\frac{w}{r})Y = L \quad (7)$$

$$a_{KX}(\frac{w}{r})a_{Xx}(\frac{c^X(w,r)}{\tau})x + a_{KY}(\frac{w}{r})Y = K. \quad (8)$$

Thus, the system solves out in the usual manner: given p, τ we will get a w, r from equations (1) and (2). Knowing w and r we get the price of the non traded input, p^X, from equation (3). These in turn give the unit input requirements in the above which allows us to solve for x, and Y from equations (7) and (8) and X from equation (4).

How is the level of τ determined? So far we have kept τ fixed. It comes from setting the demand for emissions equal to the supply, $\bar{Z}$. This gives

$$a_{Zx}(\frac{c^X(w,r)}{\tau})x(.) = \bar{Z}. \quad (9)$$

so that the price for a pollution permit equates demand to the supply of permits. If τ is fixed, $\bar{Z}$ will be endogenously determined in this way, while if $\bar{Z}$ is fixed, τ will be endogenously determined from equation (9). This would give the required permits for every given τ, taking as given p, K, L. Inverting this (assuming invertibility which is yet to be looked at) will give τ for a given p, Z, K, L.

We are interested in understanding how the system responds to changes in the exogenous variables. We are predominantly interested in the effects of emissions controls in one country on world emissions. So we need to incorporate the rest of the world that is not instituting emissions controls into the model.

1.3 Adding the Rest of the World

The rest of the world is incorporated as a country that does not have any emissions controls. The technology is assumed to be the same everywhere:

a standard assumption in this class of models. I will assume that there is a lower limit to how high emissions will go: after all, even if the permits are free, i.e., $\tau^* = 0$, there are limits to how much even a careless producer emits. It is worth emphasizing that this not the case with production functions like the Cobb Douglas one or CES with elasticities of substitution greater than unity. Factor prices are given by the analogue of equations (1) (2), and the price of intermediates by the analogue of (3), while the analogue of (6) (5) and (4) give outputs. Note that factor prices will differ at home and abroad, as will the price of X: w will be higher and r lower if the rest of the world faces international prices for goods.[8]

In addition

$$a_{Zx}(\frac{c^X(w^*, r^*)}{\tau^*})x^* = \bar{Z}^* \tag{10}$$

defines the equilibrium level of emissions in the rest of the world when the emissions price there is τ^* which may be zero.

Product markets for final goods clear jointly. Thus the equilibrium price of x is given by relative demand for x in the world being equal to its relative supply. As usual, relative demand depends only on prices.

$$\frac{x^* + x}{y^* + y} = \frac{D^x}{D^y}(p^* + t + \alpha\tau) \ .$$

It is worth noting that the only way that the rest of the world affects home is via the price of the traded good x. For this reason we will focus on the effects of a reduction in the permitted emissions at home on the world price, and through this, on emissions abroad. We now turn to the effects of a reduction in $\bar{Z}$ on the world equilibrium. But before this we need to understand what drives the demand for emissions.

1.4 The Demand for Emissions

The demand for emissions equals

$$Z^D(\tau, p) = a_{Zx}(\frac{c^X(w(\tau, p), r(\tau, p))}{\tau})x.$$

What does this look like as a function of τ, taking as given p, the price of x?

[8] This can be reconciled with the lower wages per worker in LDCs by having fewer effective units of labor embodied in LDC workers.

Result 1 The demand for emissions is downward sloping in τ for a given p if there is limited substitutability in production between X and z in making x.

This result is easy to see. First $a_{Zx}(.)$ will fall as τ rises given the way w and r are determined in equilibrium whether permits are sold, or given away on a historical basis. An increase in τ shifts the $p = c^x(c^X(w,r),\tau)$ curve inwards so that w rises and r falls. Moreover, to keep the price for X equal to its cost, p^X must fall. Consequently, as τ rises, $\frac{c^X(w,r)}{\tau}$ must fall, so there is substitution towards X away from z in making x, i.e., a *technique effect* that makes $a_{Zx}(.)$ fall as τ rises.

What about the effect on emissions via x? This is a bit trickier. There are two effects on the factor market clearing equations that determine x. First as w rises and r falls, unit labor requirements fall and unit capital requirements rise. Due to this the K line shifts in while the L line shift out so x falls and Y rises. Second, via the technique effect $a_{Xx}(.)$ rises and $a_{zx}(.)$ falls. This additional effect on the factor market clearing equations complicates things as explained below.

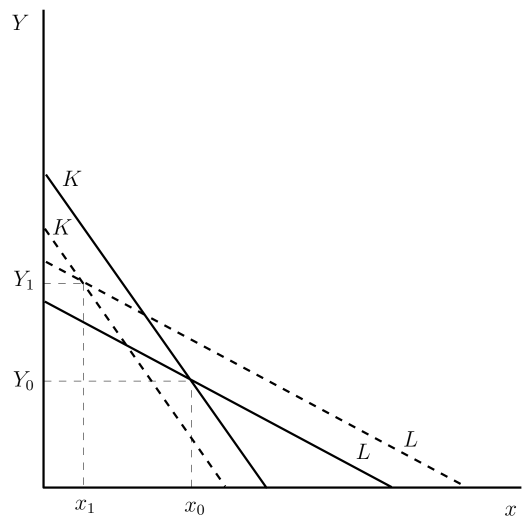
$$\overbrace{a_{LX}(\frac{w}{r})}^{\downarrow}\overbrace{a_{Xx}(\frac{c^X(w,r)}{\tau})}^{\uparrow}x + \overbrace{a_{LY}(\frac{w}{r})}^{\downarrow}Y = L \qquad (11)$$

$$\overbrace{a_{KX}(\frac{w}{r})}^{\uparrow}\overbrace{a_{Xx}(\frac{c^X(w,r)}{\tau})}^{\uparrow}x + \overbrace{a_{KY}(\frac{w}{r})}^{\uparrow}Y = K. \qquad (12)$$

As the unit capital requirement in x and Y rises, the K line shift in. However, the L line moves out only if L and K are more substitutable in making X than are X and z in making x (as we will assume from here on) so that the effect of a_{LX} falling dominates that of a_{Xx} rising. In this case, a rise in τ reduces x and raises Y as depicted in Figure 2. Hence, the demand function for emissions is downward sloping.

Next we turn to the effect of an increase in p, keeping τ fixed, on the demand for emissions. The effect of an increase in p on the demand for emissions is straightforward. The increase in p shifts equation (1) outwards which raises r while reducing w and forces the price of X to rise to remain equal to its cost. Thus, for a given τ, $\frac{c^X(w,r)}{\tau}$ rises and due to the technique effect $a_{zx}(\frac{c^X(w,r)}{\tau})$ rises as well for a given τ. This works to *shift* the demand for emissions outward.

Figure 2: Effect of an increase in τ on final goods output



Moreover, at a given τ, as $a_{Xx}(\frac{c^X(w,r)}{\tau})$ falls while $a_{LX}(\frac{w}{r})$ and $a_{LY}(\frac{w}{r})$ rise, for limited substitutability in X and z in making x, the L curve will shift inwards while the K curve will shift outwards raising x and reducing Y. This is the normal positive supply response.

$$\overbrace{a_{LX}(\frac{w}{r})}^{\uparrow}\overbrace{a_{Xx}(\frac{c^X(w,r)}{\tau})}^{\downarrow}x+\overbrace{a_{LY}(\frac{w}{r})}^{\uparrow}Y = L \tag{13}$$

$$\overbrace{a_{KX}(\frac{w}{r})}^{\downarrow}\overbrace{a_{Xx}(\frac{c^X(w,r)}{\tau})}^{\downarrow}x+\overbrace{a_{KY}(\frac{w}{r})}^{\downarrow}Y = K. \tag{14}$$

As a result, an increase in p shifts the demand for emissions outwards and raise the equilibrium level of τ.

$$z = \overbrace{a_{zx}(\frac{c^X(w,r)}{\tau})}^{\uparrow}\overbrace{x}^{\uparrow}$$

Result 2 An increase in p shifts out the demand for emissions at a given τ. This will raise the equilibrium level of τ assuming $\bar{Z}$ is exogenously set, and the equilibrium level of $\bar{Z}$ if τ is exogenously set.

We are finally able to consider the effects of an exogenous reduction in Z. From Result 1 we know that this increase in τ will reduce x for a given p (i.e. shift the supply of x at a given p inwards) and thereby raise the equilibrium level of p. This increase in p will trigger a supply response at home and abroad. Thus, we know the following:

Result 3 A decrease in the exogenously set level of $\bar{Z}$ will raise τ.

It is worth noting that while the supply response at home will be tempered by further increases in the price of emissions at home in response to this increase in p so that there will be no effect on total emissions at home, the same is not true abroad. Unless the rest of the world has limits on their emissions, the increase in the world price of x will result in an increase in the rest of the world's supply and consequently in their emissions. This "leakage" is the cause of much of the concern in the literature. Babiker (2005) argues that when relocation is explicitly allowed for in a computable model with oligopolistic markets, that leakage could be quite large.[9] In contrast, while examining the EU's emissions trading program, Grubb and Neuhoff (2006) argue that the net value at stake is low for most sectors as the cost increases by emissions trading in the 10 to 30 Euro range are small for all but a few industries. However, if firms are very responsive to such differences, even small changes could have large effects.

Hence, not just the level, but the *existence* of emissions controls in the rest of the world matters. Getting the rest of the world to commit to controls on emissions, even if the level of emissions is high, is a step in the right direction as this affect the nature of international transmission. If the ROW has no controls on emissions, then $\tau^*$is fixed (at a low number or zero) no matter what policy home enacts. If the rest of the world has any limit on emissions, then tightening emissions at home will raise demand for emissions abroad and raise τ^*, reducing leakage abroad and making the home country more willing to reduce its own emissions.

[9]Cherkashin et al (2010) argue that entry/exit effects to the lions's share of the work when responses to trade policies are considered and can be very large in heterogeneous firm oligopolistic models, suggesting that such settings might give large leakage effects in the emissions control context as well.

2 Conclusions

If we learnt one thing from the MFA of relevance for controlling emissions, it is that implementation details matter.[10] It is worth noting that the experience of the various countries differed quite dramatically, with Hong Kong faring quite well, but India and Bangladesh bleeding from self inflicted wounds associated with poor, though well meant, policies.

In the context of emissions permits, there are a number of lessons that can be learnt from developing countries experiences with the MFA. While the five below are not the only lessons, they are in many ways the most important ones.

Lesson 1: Beware of creating rents:

Once rents are created, they stand in the way of future reforms. The MFA created quota rents for all exporters, but while some would have been competitive in the absence of quotas, others would not. As might be expected, the least competitive developing countries (like the Caribbean countries) had the most to lose from the removal of the MFA and opposed its removal. So think ahead.

Lesson 2: Regulation begets more regulation

Take the allocation of permits as an example. In order to make restrictions palatable to producers, governments tend to allocate permits to existing producers, rather than selling them.[11] While this certainly helped getting producers on board, it created a number of problems down the road. Such an allocation procedure gives existing producers an advantage over newcomers. To overcome this unfairness, governments historically opt to give entrants the same privileges as existing ones once they are established. But doing so makes the quota allocation dependent on output and acts like a production subsidy resulting in excessive output and entry relative to the (possibly constrained) welfare maximum.[12].

Lesson 3: Developing country exports and BTAs

It is worth noting that BTAs may have large effects on non complying developing countries which is a major concern of theirs. While competitive

[10] See Krishna and Tan (1998) for a detailed analysis.

[11] If the allocation of permits is a once and for all matter, then it has no effect on outcomes, only on the allocation of rents, a la Coase, so this was seen as having no real consequences. See Hahn and Stavins (2010) for a recent discussion of this issue.

[12] See Krishna and Tan, (1998) and (2010) for more on the effect of allocation rules in the context of quotas.

models would suggest that lower exports to the US could be made up by larger exports elsewhere, in monopolistically competitive settings, the opposite prediction exists. Lower exports to the US due to BTAs would be accompanied by *lower* exports to *all* other markets. This occurs because the fall in expected profits from the US reduces entry and as entry falls, sales to all markets fall. As a result, the short run effects, with entry held constant, are likely to be very different from the long run ones.[13] It would be unfortunate if the adverse effects on developing country exports of BTAs were under estimated.

Lesson 4: Act short term, think long term.

Long term sustainability of emissions controls is an under-appreciated issue. Consider the incentives of countries to join the emissions controlling club. BTAs provide incentives for countries to impose emissions controls themselves as then they get to keep the revenues from emissions permit sales rather than giving them to foreigners in the form of BTAs. In fact, if they are allocated sufficient permits and permits are internationally tradeable, they may even make money selling their permits to DCs! But as more countries join the emissions controlling club, and as the controls imposed by members become more stringent, the advantage of not joining is likely to be higher if BTAs are based on emissions of club members. To encourage entry into the club, BTAs may need to increase as the membership of the club increases or as emissions controls become more stringent. See Karp (2010) for more on this issue.

Lesson 5: Prices versus quantities

Not just the level, but the *existence* and *form* of emissions controls in the rest of the world matters as it affects the nature of international transmission. If the rest of the world has a cap on total emissions in place, tighter standards at home must reduce global pollution. If not, even if the rest of the world has taxes on emission in place, leakage occurs and total emissions may even rise.

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