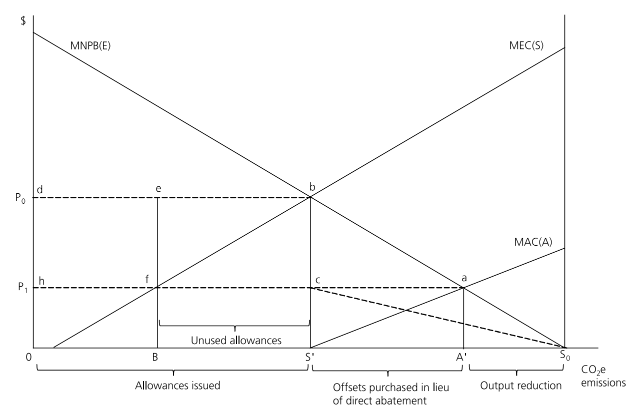
What if the number of allowances is fixed?

The analysis in Figure 10.2 assumes regulated economies take advantage of the option of carbon offsets by reducing the social optimal level of allowances. But this may not occur in reality so Figure 10.3 shows what happens when the number of allowances remains at their original level S′. The depiction of abatement is identical to that of Figure 10.2 except now abatement is shown in positive space. Again we arbitrarily put the intercept of MAC at S′; if co-benefits exist, the intercept is to the right of S′ and carbon offsets benefit developing countries and regulated economies even more.

Figure 10.3

Optimal abatement versus output reduction with fixed allowances and unlimited carbon offsets



By not adjusting allowances with the option of offsets, permit prices drop more than before (to P_1 in Figure 10.3 from point *h* in Figure 10.2). Before, the social cost was area bS_0S' but is now area cS_0S' in Figure 10.3. The net gain is area bS_0c. If allowances were reduced to point *g* in Figure 10.2 as before, then the value of offsets increase (or the financial flows to developing countries increase) by increasing both the price of permits (and hence the price of offsets) and the quantity of offsets (compared to the situation depicted in Figure 10.3). Without reducing allowances when taking advantage of carbon offsets results in a welfare loss for regulated economies as well as for developing countries.

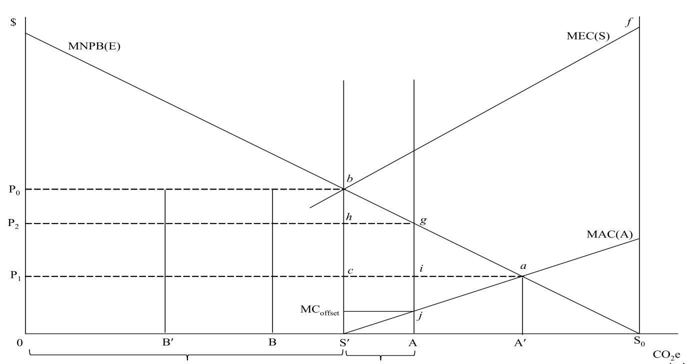
Figure 10.3 also allows us to calculate the welfare gains from having carbon offsets. The country with a cap and trade regime gains area *baA′S* but is required to pay area *caA'S'* for the carbon offsets, resulting in a net welfare gain of area *bac*. The level of unused permits in lieu of purchasing offsets is distance BS'. Developing countries selling the offsets gain area *caS'*. Because of the decline in the permit price from P_0 to P_1 in Figure 10.3, firms under the cap and trade regime save area *dbch* (area *fcS'B* are not savings because it equals the costs of offsets given by area *caA'S'*). Area *dbch* represents a cost to taxpayers (if permits are auctioned) or a decrease in asset values of permits owners (if permits handed out). There is no net gain to society due to lower permit prices other than that generated indirectly, depicted by area *bac*.

What if the number of offsets is limited?

Countries with cap and trade schemes normally restrict the number of carbon offsets available for developing countries. The effect of this is shown in Figure 10.4 where offsets are limited to the distance S'A (equal to the distance BS'). The price of offsets remains equal to the permit price which increases to P_2. The marginal cost of abatement is given by "MC_{offset}" in Figure 10.4. The regulated economy loses area *gai* due to the limit in offsets. However, developing countries selling the carbon offsets may gain or lose, depending on whether area *hgic* is greater or less than area *iaj*. The initial value of allowances (permits) is P_0S'. Afterwards, it is P_2A. The price of permits and carbon offsets are still equal.

FIGURE 10.4

Abatement versus output reduction with limited carbon offsets



Summary

Opportunities for GHG emission mitigation in developing country agriculture revolve around abatement activities, namely changes in production practices and technologies (e.g., REDD, soil carbon sequestration practices, midseason drying of irrigated rice, nutrient management to reduce nitrous oxide emissions and livestock management). Hence, it is important to distinguish marginal abatement costs from output reduction options where reductions in fossil fuel consumption are the primary driver of emission reductions. The case for public subsidies for abatement activities is further strengthened by the resulting correction of multiple market failures, potentially generating significant co-benefits to agricultural producers and society at large. In addition to the public good of reduced GHG emissions, there are multiple market failures in the form of technical externalities, reflecting the multifunctional nature of agricultural production. Multiple non-commodity outputs are produced (both positive and negative technical externalities), thereby providing an additional rationale for public abatement subsidies. Finally, because of knowledge externalities in technological innovation and both learning-by-doing and learning-by-using externalities in the adoption of new technologies, there will be underinvestment by the private sector in technological innovation and diffusion (Jaffe, Newell and Stavins 2005). This provides a further rationale for public expenditure programs in R&D of new agricultural production practices and technologies, and in the diffusion of this new knowledge (e.g., extension services).

The analysis shows how carbon offsets benefit both the cap and trade economy and developing countries. Offsets also provide an incentive for regulated economies to further increase their emission reduction targets. Limits on carbon offsets (as is currently the case and is proposed), however, hurt cap and trade economies while having an ambiguous impact on developing countries.

10.3 The economics of leakage with allowances and offsets

Carbon offset projects under the CDM must have at least the following characteristics:

Additionality: emissions are below that with no carbon offset revenues
Permanence: emission reductions are not simply shifted to another time period
No leakage: emissions are not simply shifted to another location or sector

The concepts of additionality, permanence and leakage have been the cornerstone concerns over project-based GHG mitigation policy with carbon offsets under the CDM. Much has been written on each of these three problems but this section of the paper focuses on leakage. The CDM has explicit language that requires leakages to be taken into account when assessing the viability of a CDM project for emission reduction. The Marrakech Accords' definition is "the net change of anthropogenic emissions by sources of greenhouse gases which occur outside the project boundary, and which is measurable and attributable to the CDM project activity."

Leakage is also a major concern for industries under a cap and trade regime. The response by parties to the Kyoto Protocol has been calls for legislation to implement 'carbon' tariffs against imports from countries with less stringent environmental legislation to guard against leakage due to cap and trade. This tariff may be in the form of the requirement that exporters purchase GHG permits in regulated countries before their product can be shipped. This is equivalent to an import tariff that accounts for the increased carbon costs due to cap and trade[21]. Hence, the issue of leakage is important because it affects developing countries in both directions: the ability to sell offsets and the restrictions imposed on exports to countries with cap and trade regimes.

Definition of leakage

"Leakage" is defined as the physical re-location of economic activity from the regulated country to another country with fewer or no environmental restrictions (or between jurisdictions within a country). "Market" leakage involves a change in market prices and hence affects economic decisions in other countries. Leakage arises from the increased cost imposed on the industry in the complying country due to environmental policies. The amount of direct carbon reductions in complying countries are undermined by carbon releases elsewhere. Therefore, leakage is also an issue for countries with cap and trade regimes; hence the call for carbon tariffs on imports from non-complying developing countries or for producer rebates to compensate the domestic industry for the higher input costs due to the cap and trade scheme.

Leakage is not to be confused with "shuffling" where the environmental policy can be circumvented and so has no impact on sales or prices (Bushnell, Peterman and Wolfram 2008)[22].This has also called primary ('activity shifting) leakage or 'displacement of emissions' in the literature (e.g., Wunder 2009). Furthermore, we assume for now that the emissions per unit output in the regulated country are equal to that of the unregulated economy; i.e., there is no "technical" leakage. Otherwise, leakage can be either compounded or reduced, perhaps even go negative (called reverse leakage)[23]. We allow for these possibilities later.

[21]Other proposals include producer rebates to compensate domestic producers for loss in international competiveness.
[22]As will be shown later, it is possible to have leakage through the market with no or little change in market prices when a country is "small" on world markets. Because the composition and location of production has changed (unlike with shuffling), it is still deemed leakage.
[23]For example, although domestic emissions decline, it is possible that increased production in unregulated economies are such that although production goes up - the per unit emission intensity is so low total emissions decline. See footnote 4 for a counter-example.

The literature to date defines leakage as the phenomena of offsetting increases in GHG emissions in non-complying countries and hence results in the undermining of carbon mitigation initiatives in complying countries. The key concept is "coverage": not all countries are subject to the environmental policy that is mitigating GHG emissions. For example, Stavins (1997):

"…leakage arises when abatement by cooperating countries alters world relative prices in ways that lead non-cooperating countries to increase their emissions[24]."

In the context of global climate change, leakage is "international"; it occurs in another jurisdiction with no environmental regulations. Stavins (1997) goes on to identify two primary channels of carbon leakage:

C1: costs of production for carbon-intensive products increase in complying countries, resulting in a market price increase that induces an offsetting increase in production and therefore emissions in non-complying countries ('supply' side leakage)

C2: as a result of the lower demand for fossil fuels, the (world) market price of fossil fuels decline and so the consumption of fuel (and hence emissions) increase in non-complying countries ('demand' side leakage)

This definition of leakage is somewhat restrictive because it focuses on the "international" component only; the changes in market prices in each channel identified above also affects domestic production and consumption. In the case of unregulated sectors like REDD and to some extent agriculture, one has to include a measure of "domestic" leakage as well; otherwise, not all emissions are accounted for. In other cases (e.g., a cap and trade for electricity production only), domestic leakage cannot occur because although the domestic supply curve shifts up due to a cap and trade regime (thereby increasing world market prices), any increase in domestic output in response to this price increase must buy permits so total domestic emissions are fixed[25]. Hence, in this case, the definition of leakage in the literature is appropriate[26].

Why is REDD and agriculture not like a cap and trade regime for electricity production? Forestry and agriculture are unregulated sectors within a cap and trade regime and so the upward shift in the forestry supply curve due to a policy that reduces deforestation (or in the agricultural supply curve due to higher fossil fuel

[24]This is in contrast to "free riding" where non-complying countries benefit from global abatement but do not contribute to it.

[25]However, as we will show later, in this case international leakage is higher than normally recognized.

[26]Because of emissions from land use change due to electricity produced from biomass, even electricity production now has domestic leakage.

prices resulting from the cap and trade policy) reduces emissions in two ways. First, there will be reduced purchases of inputs with carbon content (but potentially very little, especially with forestry). Second, much of the saved emissions in reduced forestry and agricultural output are not from the reduced purchased inputs with embodied carbon covered under the cap but from the production process itself. For example, in the case of fertilizer, not only will emissions decline due to the reduced use and hence production of fertilizer (carbon embodied in the production of fertilizer), but emissions also decline because of the emissions associated with the application of fertilizer. The latter emissions are uncapped. In the case of forestry and agriculture, we will argue that uncapped emissions are far more important than fossil fuel consumption and so domestic leakage becomes an important issue, just like for international leakage that only considers emissions escaping outside the country covered by a cap and trade scheme.

The key characteristic determining whether or not domestic leakage is important is how much of the emissions are due to fossil fuel consumption (embodied in the production of purchased inputs covered under the cap and trade regime) and how much are due to production practices and land use changes. Because deforestation is the largest source of emissions (that occurs mostly in developing countries) and is primarily caused by land conversion to agriculture, activities in land use, land use change and forestry (LULUCF) both remove (e.g., via sequestration) and release (e.g., land use change) GHGs. The main ways forestry can mitigate GHGs is through afforestation and reforestation (A/R), forest management (FM) and avoided deforestation and degradation (REDD).

Reducing forest land into agricultural production will cause food shortages unless complementary policies are introduced for new technologies that generate intensification in agricultural production. Induced land shortages are more pronounced with REDD than A/R which is often carried out on degraded land with low economic value (Wunder 2009). In fact, REDD induces an increase in the price of wood products, thereby creating an incentive for A/R, i.e., a good leakage (Murray, Lubowski and Sohngen 2009). Because it takes decades to grow a new forest and growth in the forest stock as well as sequestration potential, the outcome depends on the type of forest, its vintage and what you do with it (slash and burn or make wood products where CO_2 slowly emits over time) (Mendelsohn and Dinar 2009).

REDD are difficult to measure, monitor and verify the real reductions. To date, the CDM has had very limited success in the LULUCF sector, with a total of seven afforestation and reforestation projects (one in 2006 and six in 2009, with three large scale and four small scale projects) with 286,995 tonnes per year CO_2e

reductions. There are four registered projects that are indirectly related to A/R: biomass residues from forestry, with 415,181 tonnes per year of CO_2e reductions[27].

Apart from REDD, A/F and FM, sources of agriculture's reduction opportunities include emission reductions (manure management, enteric fermentation and fertilizer practices), biological sequestration fluxes (tillage, crop rotations, cover crops and grazing practices) and avoided fossil fuel emissions from efficiency improvement and from substitution for fossil fuels (with liquid transportation biofuels, thermal biopower/bioheat or renewable electrical power).

Experts generally agree that the five key areas of GHG mitigation potential in agriculture is in terms of production processes and not necessarily in reduced use of purchased inputs. These production processes that can reduce emissions substantially are REDD, soil carbon sequestration practices, midseason drying of irrigated rice, nutrient management to reduce nitrous oxide emissions and livestock systems.

Taking livestock as an example (which emits more GHGs worldwide that the entire transportation sector), 94 percent of GHG emissions are due to production practices (e.g., enteric fermentation, land use and land use changes, and manure and slurry management)[28]. The remaining 6 percent is due to fossil fuel use which would be capped under a cap and trade scheme. Overall, in the case of agriculture, the composition of production (crop type or number of livestock) and the type of production practices will be the key factors in reducing GHG emissions (including LULUCF).

Isolating international leakage only (as the literature does by defining leakage as that which occurs outside the countries "covered") implies that if all countries are part of the climate agreement, then no leakage occurs with changes in market prices. We will show that this will not be the case and so the current definition of leakage is very restrictive because domestic leakage occurs in the case of REDD and agriculture, even if all countries were party to a climate agreement.

We will show that domestic leakage can easily be greater than international leakage. This has implications for the proposed carbon import (export) tariffs (subsidies) on developing country trade and compensatory producer rebates or production subsidies in complying countries. Furthermore, the two channels identified in the literature are interdependent: the decline in oil prices in C2

[27] According to Zomer et al. (2009), agro-forestry is widespread, found on 46 percent of all agricultural land area globally, and affecting 30 percent of the rural population. Large scale tree cover patterns cannot be fully explained by aridity, population density or region, indicating the importance of other factors like tenure, markets, or other policies and institutions that affect incentives for tree planting and management, as well as initial conditions due to historical circumstances.

[28] On-farm fossil fuel use is included in this 94 percent figure, however, as we are unable to separate it out.

shifts the supply curves in both complying and non-complying countries, thereby augmenting both the domestic and international leakages in channel C1.

The issue of leakage is therefore very important and must be clearly understood. As it stands now, there is an asymmetry in the treatment of leakages: countries party to the Kyoto Protocol (or the successor agreement) are able to deny offsets from developing countries due to leakage (e.g., offsets under REDD) while at the same time imposing import restrictions on developing country exports because of international leakage originating in their own economies with cap and trade regimes (while conveniently ignoring domestic leakage).

We now develop a general theory of leakage to incorporate all of these considerations.

A general theory of leakage

Consider a country that is party to the Kyoto Protocol or successor agreement is an importer while the exporter is a developing country that is not a participant in the climate agreement[29]. But before we consider international trade, let us first define leakage under autarky (a hypothetical situation when there is no trade)[30]. The environmental policy shifts the home supply curve S up in the 1st panel of Figure 10.5 to S'. This shift can either be due to a cap and trade scheme increasing input prices or a policy that reduces deforestation by withdrawing forests from the market (Murray 2008). Assume the sector in the home country is unregulated; i.e., is affected by the increased costs of inputs using fossil fuels but is not part of the cap and trade scheme. The initial level of output reduction (and emission reduction as we assume a one-to-one relationship between emissions and output) is given by the distance *ab*.

But even without trade, there is leakage as defined by Stavins (1997) and the literature in general where supply increases as a result of the market price increase. This also occurs in a market without international trade. The amount of leakage is given by the distance ac. We define this as "autarky" leakage. The more inelastic the home demand curve and the more elastic the home supply curve, the larger the leakage (Murray, McCarl and Lee 2004). "Autarky" leakage is 100 percent if the home demand curve is vertical or the home supply curve is flat.

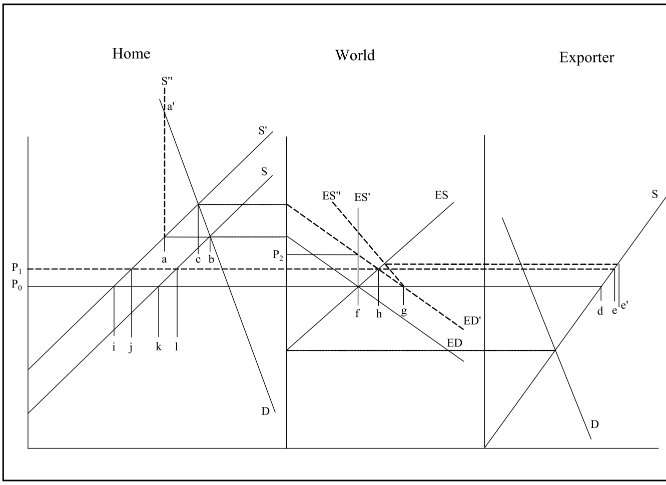
It is important to note that we are assuming that the emissions in the unregulated sector in the 1st panel of Figure 10.5 are mostly from production practices (e.g.,

[29]The results that follow hold for either case of the complying country being an importer or exporter.

[30]Autarky is not so hypothetical, given the excessive levels of subsidies and protection for agriculture in OECD countries. The implications of the analysis to follow are that there is more domestic leakage because of these agricultural policies, thereby emphasizing the need for agricultural policy reform in developed countries to aid in the mitigation of GHGs.

FIGURE 10.5

Defining domestic versus international leakage



LULUCF) and we ignore the reduction in the carbon emissions due to fossil fuel consumption embodied in the purchased inputs whose purchases have now declined due to the environmental policy. This assumption is fairly realistic for forestry and is an empirical question as to how important it is for agriculture. If the cap and trade scheme was for electricity production only, then no autarky leakage is possible as the sector would be unable to expand production as no permits can be purchased from another sector. The supply curve in this case would be vertical, given by S″ in Figure 10.5 (assuming fixed coefficients of production between fossil fuel and other inputs) and so the equilibrium price would be given at point *a′* in Figure 10.1[31].

Now that "autarky" leakage has been defined (which is by definition 100 percent "domestic" leakage), let us determine the outcome with international trade[32].

[31]If emissions for the unregulated sector are due to carbon embodied in the purchased inputs, then output could still increase as shown in the first panel of Figure 5 but no autarky leakage can occur because allowances or permits need to be purchased from other sectors. Therefore, net fossil fuel use and hence emissions are fixed. However, for agriculture and forestry, emissions are from the production practices and aspects related to LULUCF, and so a movement up the new supply curve S′ increases emissions (e.g., more land is used relative to non-land inputs). This is exactly the same general model of leakages described in the literature (e.g., Murray 2008).

[32]Autarky leakage may be the only type of leakage if the domestic economy is not linked with world markets, as is the case in many developing country situations where local or subsistence agricultural production is not linked to world market prices.

Does domestic leakage disappear? If not, why is the focus in the literature on international leakage only? As we will show, not only does domestic leakage not disappear, it can be greater than international leakage. This has major implications for proposals that recommend carbon tariffs and production rebates to compensate for the so-called "international" leakage (while ignoring the possibility for and the implications of domestic leakage). It also has implications for denying carbon offsets to developing country agriculture because of leakage.

With international trade, the initial pre-policy equilibrium in Figure 10.5 is given where the home country excess demand curve ED intersects the excess supply curve ES of the foreign country exporter, generating an equilibrium market price P_0. Again, the environmental policy (e.g., removing forest from the market or a cap and trade scheme) shifts the home supply curve S up in the 1st panel of Figure 10.5 to S'. The initial level of output reduction (and hence reduction in emissions) is given by the distance *ik* (equal to the distance *ab* analyzed in the autarky situation above). However, the upward shift in the home supply curve S causes the excess demand curve ED to shift up to ED' (note that this vertical difference in ED' and ED is less than the upward shift in the home supply curve, the extent to which depends on the elasticity of home country domestic demand). The new world market price is given by P_1.

We are now in a position to identify domestic *versus* international leakage. Domestic leakage is given by the distance *ij* while international leakage is given by the distance *de*[33]. If the excess supply curve facing the home country importer is flat, then the level of international leakage is at its maximum and equals the maximum possible total leakage given by the distance *ik*[34]. Domestic leakage is zero in this case.

On the other hand, if the excess supply curve facing the home country is vertical (given by ES' in the middle panel of Figure 10.5), international leakage is zero and domestic leakage is at its maximum denoted by the distance *ac* (equal to autarky leakage because P_2 minus P_0 is equal to the vertical difference between ED' and ED). Hence, the two extreme outcomes can be determined: total leakage is at its maximum of the initial level of output/emissions reduction when the excess supply curve is flat, or equals autarky leakage when the excess supply curve is vertical. For all values of the excess supply elasticity between 0 and ∞, total leakage lies between the distance *ik* and *ac*. This difference could be quite small so emphasis on international leakages may be misplaced.

[33]Note that we assume the per unit emissions from foreign production equals that of home production.

[34]To prove that the horizontal shift in ED is identical to that of the horizontal shift in S, consider the horizontal difference between D and S' at the intercept of ED. This horizontal difference must equal the horizontal difference in the ED and ED' curves. Hence, distance fg equals distance ab

Note also that the level of domestic leakage *ij* can be greater than or less than international leakage *de*. The outcome depends on the relative elasticity of excess demand ED and excess supply ES. The factors determining the values of these trade curves are now discussed.

The question now becomes what determines the size of the excess supply elasticity facing the home country importer (or of the excess demand elasticity facing the home country if the latter is an exporter)? Consider two importing countries: country 1 is the home country with imports of M_1 and country 2 is the competing importer with imports of M_2. There is one exporting country with exports given by X. The excess supply (trade) elasticity facing the home country importer (country 1) is given by the following formula:

1. $$\eta_X\left(\frac{X}{M_1}\right)-\eta_{M_2}\left(\frac{M_2}{M_1}\right)$$

where η_X is the elasticity of excess supply of the exporting country defined as

2. $$\eta_X=\eta_X^S\left(\frac{Q_X}{X}\right)-\eta_X^D\left(\frac{C_X}{X}\right)$$

where η_X^S and η_X^D are the domestic supply and demand elasticities in the exporting country with levels of production Q_X and consumption C_X,

and continuing from equation (1), η_{M_2} is the elasticity of excess demand for the competing importing country defined as

3. $$\eta_{M_2}=\eta_{M_2}^D\left(\frac{C_{M_2}}{X}\right)-\eta_{M_2}^S\left(\frac{Q_{M_2}}{X}\right)$$

where $\eta_{M_2}^D$ and $\eta_{M_2}^S$ are the domestic supply and demand elasticities in the competing importing country with levels of consumption C_{M_2} and production Q_{M_2}.

From equation (1), two key properties of the excess supply curve facing the home country importer are:

- As the world market share of the home country's imports approaches zero, the elasticity of excess supply facing that country tends to ∞
- As the share of the competing country imports of world market approaches zero, the elasticity of excess supply facing the home country importer

approaches its minimum value, the elasticity of excess supply of the exporter η_X^S

Therefore, in general, the trade elasticity (export/import) facing a country (importer/exporter) becomes more inelastic as that country's share of world markets increase.

From equation (2), the elasticity of the excess supply curve facing the home country also becomes more inelastic with a more inelastic export supply of the exporting country which falls with:

- A lower domestic supply and demand elasticity in the exporting country
- A lower share of domestic production (consumption) to exports.

Likewise, from equation (3), the elasticity of the excess supply curve facing the home country also becomes more inelastic with a more inelastic import demand of the competing importing country which falls with:

- A lower domestic supply and demand elasticity in the competing importing country, and
- A lower share of domestic production (consumption) to imports.

What happens if there are domestic or border policies that put a wedge between the domestic and world prices (or sever the link with between the domestic and world prices) in any of the three countries? The effect of policies is to reduce the domestic-world price transmission and so make the trade elasticity even more inelastic.

To summarize, the "contributions" to the value of the price elasticity of excess demand (excess supply) <u>facing</u> an exporter (importer) are:

- Exporter (importer) market share of world exports (imports) - *higher the share, more inelastic* the excess supply (demand) curve
- Proportion of the rest of the world's consumption (production) that is imported (exported) – *larger the proportion, more inelastic* the excess supply (demand) curve
- Proportion of the competing exporter's (importer's) production (consumption) that is exported (imported) – *larger the proportion, more inelastic* the excess supply (demand) curve
- Domestic supply and demand elasticities in the competing exporting (importing) countries and importing (exporting) countries – *lower the elasticities, more inelastic* the excess supply (demand) curve
- Government policies in importing (exporting) and competing exporting

(importing) countries – *more policies, more inelastic* the excess supply (demand) curve

Combining the discussion of Figure 10.5 with that of equations (1)-(3) above, we can determine the factors that impact the effect of an environmental policy in the home country importer (exporter): a country has a bigger impact on world prices when the trade curve *of* the country is more *elastic* and the trade curve *facing* the country is more *inelastic*. The trade curve of the country is more elastic when the home importer – a large 'producer' (home exporter – a large consumer) has a small fraction of consumption (production) imported (exported). The trade curve *facing* the home country is more inelastic when it is a large importer (exporter) on world markets. Hence, we can distinguish 'large country' *versus* 'large trader' effects. For example, a country such as Canada may be a large trader on world markets for wheat (like the United States) but relatively a "smaller" country because a large share of home production is exported (unlike the United States).

As we showed in Figure 10.5, the magnitude of the total leakage and the share between domestic and international leakage is heavily dependent on the elasticity of the trade curve *of* the home country and the elasticity of the trade curve *facing* it. These elasticity values are also important in analyzing the effect of tariffs and production subsidies in response to international leakages (analyzed later).

Although the discussion of Figure 10.5 is in terms of leakage associated with a cap and trade regime, the analysis is equally applicable for carbon offsets. For example, a REDD program in a developing country suffers from leakage to countries with a cap and trade regime because REDD is limited in coverage as agriculture and forestry are unregulated sectors in countries with cap and trade (it also suffers from leakage between developing countries and because offsets are voluntary, there can be leakage within a country although the latter should not be confused with shuffling where reallocation of land occurs with no impact on costs or market prices).

An example of 'technical leakage" is U.S. ethanol tariffs that encourage corn-based ethanol production over sugarcane-based ethanol from Brazil. Although U.S. biofuel mandates and tax credits do not discriminate against trade, ethanol import tariffs and production subsidies do. By not allowing Brazil to export ethanol to the United States, CO_2e emissions substantially higher than otherwise (for same level of ethanol production) because (1) corn-ethanol obtains half the yield per hectare (so require twice the land area); (2) crops displaced now have to be produced elsewhere (e.g., corn yields in Brazil are 1/3 that of the U.S.); and (3) annual net sequestration per hectare is much higher in Brazil.

An example of "shuffling" is U.S. sustainability standards for ethanol where incentives are given for ethanol producers to use relatively "clean" inputs (e.g., natural gas) while the "dirtier" inputs (e.g., coal) that might otherwise have been used will simply be used by producers of other corn products not covered by the sustainability standard (e.g., bourbon). Sustainability standards reshuffle who is using what inputs with no net reduction in national emissions.

An important implication of the analysis of Figure 10.5 above is that international trade does not necessarily cause leakage nor does non-compliance by another country. Non-compliance is an issue but should not be synonymous with the term "leakage". Non-compliance also reflects free riding and less effectiveness of solving the global climate change problem. Even with 100 percent compliance, domestic leakage occurs at home and abroad. But even with international leakage because of less than 100 percent coverage, domestic leakage can still be greater than international leakage.

What if there is no autarky leakage?

Let us suppose the cap and trade regime is for electricity production only. There is no domestic sector that is unregulated and all emissions are accounted for. This means the supply curve is vertical (denoted by S") and the excess demand curve is now given by ED". This generates a higher world price and an increase in international leakage, now given by distance *de'*.

The effects of a carbon tariff

The standard response in the literature to deal with international leakage (domestic leakage is not recognized) in non-complying countries like developing countries is given in Stavins (1997):

"What can be done to reduce emissions leakage? If the coalition is a net importer (exporter) of carbon-intensive products in the absence of a carbon tax, then a tariff (subsidy) imposed on these net imports (exports) can reduce emissions leakage through the terms of trade."

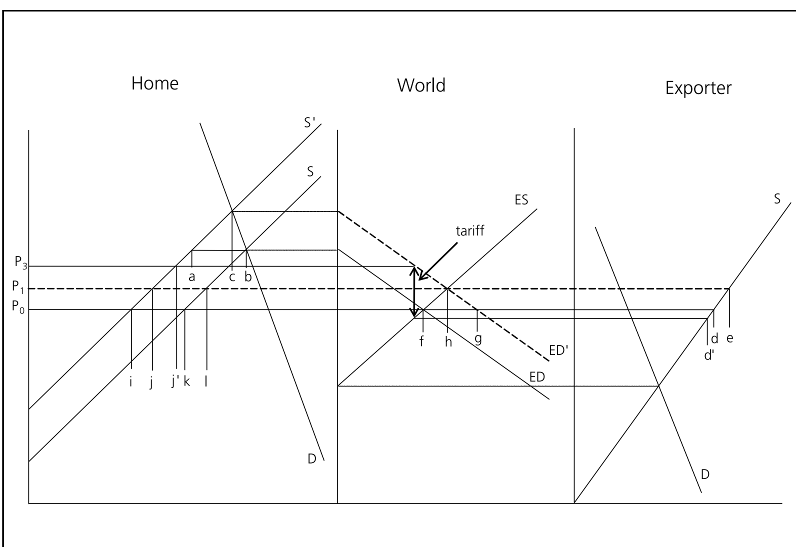
One way of implementing the tariff is to require the exporter to purchase permits according to the carbon content of the product[35]. One problem with this approach is that if there is domestic leakage along with international leakage, an import tariff (or export subsidy) can easily worsen total leakage, and in specific cases the increase in total leakage is beyond the initial reduction in emissions due to the environmental policy. Clearly this is counterproductive and contrary to the goals of any carbon import tariff (export subsidy). Although international leakage will go down and even become negative with a carbon tariff, total leakage can easily increase and

[35]There may also be a problem of international shuffling as exporters will use 'clean' inputs in the product exported (e.g., natural gas) and use 'dirty' inputs (e.g., coal) for production consumed domestically.

in some cases will automatically increase even with international leakage going negative.

This is shown in Figure 10.6 where a carbon tariff equal to the vertical difference in the S' and S supply curves generates a negative international leakage (production in the exporting country goes below the pre-cap and trade policy level by the distance *d'd*)[36]. But domestic leakage will automatically increase by distance *jj'* which may be greater or less than the decrease in international leakage of distance *d'd* (even if the carbon tariff is limited to the vertical difference in the ED' and ED curves). Therefore, not only will the carbon tariff not solve the problem, it may make the problem worse. It only solves the international leakage problem but makes domestic leakage worse, with the net effect being ambiguous. In fact, domestic leakage can easily surpass autarky leakage and approach the initial emission reduction of distance *ik* with the shift left in the supply curve S to S'. If the distance *cb* is relatively low, then a carbon tariff overcompensates.

FIGURE 10.6
Effects of a carbon tariff



[36] A tariff equal to the vertical difference in the ED' and ED curves will exactly offset the international leakage.

Under what conditions will total leakage increase? The outcome depends on the relative elasticity of excess supply and demand. It can be easily shown that if the elasticity of excess supply (excess demand) facing the home country importer (exporter) is relatively more elastic than the excess demand (supply) of the home country importer (exporter), then total leakage declines with a carbon tariff (and vice-versa if more inelastic). Even if total leakage declines, the carbon tariff always overcompensates and is nowhere near the tariff that generates the minimal level of total leakage. All in all, calling for carbon tariffs may only be relevant in the cases where developing country agriculture is subject to a cap and trade regime (not the other way around). Perhaps carbon tariffs are not to reduce leakage but are a political means to increase protection to rich country industries, including agriculture which is already heavily subsidized and protected[37].

Implications for carbon tariffs

1. By ignoring domestic leakage and recommending carbon tariffs to reduce international leakage, total leakage could increase as a result. Therefore, the optimal carbon tariff may be negative.
2. Even if total leakage declines with a carbon tariff, the optimal carbon tariff is lower than the vertical shift in the supply curve S (as the literature recommends the tariff to be)[38.]
3. In the case of agriculture, it is well documented that OECD countries (that will likely make up the bulk of the countries party to any post-Kyoto Protocol climate agreement) have huge agricultural subsidies and protection relative to their developing country counterparts whose economies will not be subject to a stringent cap and trade regime. Hence, any carbon tariff or producer rebate to compensate for international leakage is likely not required, regardless if one does or does not recognize the importance of domestic leakage. This is because the home supply curve S has shifted down in the first place with subsidies and protection before a cap and trade regime is put in place. At a minimum, not only should domestic leakage be recognized but any relative advantage due to subsidies or trade protection should be incorporated in the analysis before any carbon tariff or producer rebate is considered.
4. As discussed in Section 3 above, carbon offsets should be purchased from developing country agriculture with co-benefits that will increase developing country exports. The co-benefits increase productivity and corrects for other market failures such that there is a reduction in international leakage as well (domestic leakage in complying countries) associated with carbon offsets

[37]Perhaps import tariffs (export subsidies) should be limited to the carbon-intensive products used as inputs to the agricultural production process and not on agricultural products per se (Frankel 2009). But then exporters could circumvent the cap and trade by exporting carbon in the final products.

[38]Stavins (1997) does however recognize that the gains in reducing international leakage might very well be lower than the loss in welfare due to the tariff but that is an entirely different issue.

because production in the rest of the world declines with the reduced world market prices. Therefore, there is a double dividend with carbon offsets: reduced emissions with the offset project and reduced international leakage provided the analysis is for an unregulated sector (i.e., leakage in the 'home' economy in Figures 5 and 6 that have a cap and trade regime but agriculture and forestry are unregulated sectors). Meanwhile, carbon tariffs or producer rebates in complying countries will therefore do the opposite of what is optimal not only for global climate change but also for economic welfare in both complying and non-complying countries.

5. Because OECD countries will implement cap and trade regimes, these countries as a group have a large share of key world commodity markets and hence will be facing relative inelastic supply curves. This coupled with the well known fact that developing country agricultural supply curves are more inelastic than their rich country counterparts; it is very likely that the analysis in Figure 10.5 has domestic leakage relatively more prominent. Analysis in Figure 10.6 indicates that total leakage may easily increase with carbon tariffs or producer rebates.

Implications of leakages in the fossil fuel market

The analysis so far on carbon tariffs in Figure 10.6 only assess leakage through channel C1, namely the international leakage that follows from the increased costs of production in the home country due to the cap and trade regime (so-called "supply-side leakage"). There is also the second channel C2 (so-called "demand-side leakage") where lower fuel prices due to the cap and trade regime will generate *international leakages* in higher fuel consumption in non-complying countries. The literature again ignores *domestic leakage* due to lower fuel prices. With lower fuel prices, the supply curves in both the home and foreign country shift down, generating more production. But the shift will not be equal. The stylized facts indicate that OECD country agriculture is more energy-intensive than their developing country counterparts so the supply curve S in the home country in Figure 10.6 shifts down more than developing country supply curves due to demand-side leakage. This means domestic leakage is even higher than international leakage compared to the analysis so far.

To show this, consider Figure 10.7 where the shift in the supply curve in the foreign country (3rd panel) is normalized to zero so the downward shift in S' in the home country reflects the net shift relative to the exporting country. Domestic leakage goes up by the distance *jj'* while international leakage declines by the distance *dd'*.

The implication of Figure 10.7 is that carbon tariffs, already shown to be too high (and possibly should be negative to minimize total leakage), should be even lower when taking into account demand-side leakage. Implementing even higher import