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The welfare consequence of emission trading with pre-existing taxes

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It is generally accepted that permit trading minimises the economic burden of emission restriction, nationally and internationally. However, this conclusion is based on an analysis that does not take into account the existence of other taxes on commodities that emit greenhouse gases, such as petrol and other fuel taxes. In this paper, we use a stylised model to show that with pre-existing taxes (subsidies) on greenhouse gas emitting commodities countries that trade in emissions permits may loose from the trading relative to independent abatement; and permit trading does not necessarily minimize the economic burden for a given level of emission reduction. These results call for harmonization of taxes on GHG emitting commodities. In the absence of such reforms, a tax/subsidy scheme can be introduced to remedy these problems.

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Introduction

It is generally accepted that permit trading minimises the economic burden of emission restriction nationally and internationally (Hinchy, Fisher and Graham 1998, Hinchy et al. 1998; Montgomery 1972; Rubin 1996). However, this conclusion is based on an analysis that does not take into account the existence of other taxes, such as petrol and other fuel taxes, on commodities that emit greenhouse gases (see for example, Montgomery 1972).

The presence of taxes on commodities that emit greenhouse gases implies a pre-existing tax on emissions. At the same time any carbon penalty introduced as a result of emissions trading or otherwise can also be viewed as an increase in pre-existing taxes on these commodities. In the absence of transaction costs and other market imperfections, cost effectiveness requires that the sum of all types of producer and consumer taxes per unit of emission be equal across all sources (Golombek et al. 1995; Stavins 1995).

As fuel taxes are typically levied on commodities not on emissions, in equilibrium the permit price will reflect buyers' and sellers' private marginal values net of the pre-existing taxes. The international permit price therefore will not necessarily equalise the marginal social cost (lost value) of emission permits across nations and sources. This raises a question regarding the cost-effectiveness of permit trading vis a vis independent abatement.¹

As is well known from the dead-weight loss literature on tax reform, the welfare effect of a given increase in a tax rate is highly sensitive to its pre-existing rate. The approximate (first order) measure of the welfare effect of a tax change is given by the product of the pre-existing tax rate and the change in the quantity used of the taxed good caused by the adjustment in the tax rate (see for example, Auerbach 1985; Green and Sheshinski 1979). Given this result it is entirely possible for a permit selling country to have a welfare loss simply because the reduced use of the already taxed good may dominate the welfare gain from permit sales. It is therefore pertinent to ask whether all parties involved benefit from international permit trading, particularly when the countries selling permits are already taxing the emitting commodities at sufficiently high rates (or alternatively, the buying countries are subsidizing at higher rates).

This is not the first paper in which questions have been raised about the role that pre-existing taxes have in determining the welfare implications of climate change policies. Goulder (1995), for example, has shown that pre-existing taxes raise the welfare cost of carbon taxes substantially. Babiker et al. (2000) have shown that the replacement of pre-

¹ For many reasons other than the pre-existing taxes that raise questions on cost-effectiveness of permit trading see Stavins (1995) and references therein. Stavins, however, focuses on the role of transaction cost.

existing energy taxes by a carbon tax helps to mitigate the adverse impact of emission restriction in Annex B countries on the welfare of energy exporting non-annex B countries. We extend this line of inquiry further into the efficiency of an international market for emission permits and explore the welfare effects of permit trading on Annex B countries themselves when there are pre-existing taxes on energy commodities and activities emitting greenhouse gases.

In this paper, we use a stylised model to show that with pre-existing taxes (subsidies) on greenhouse gas (GHG) emitting commodities a country that sells (buys) emission permits under an international permits trading scheme may loose from the trading relative to independent abatement. In addition to this result, we also show that with pre-existing taxes (or subsidies) on GHG emitting commodities permit trading does not necessarily minimise the economic burden for a given level of emission reduction, be it at the national or international level. These results call for the national and global harmonization of taxes on GHG emitting commodities on the basis of their emission contents. In the absence of such reforms, we argue that trade tax on the sale and trade subsidy on the purchase of emission permits in the case of pre-existing tax and reverse in the case of pre-existing subsidy remedy these problems. Under these conditions, the permits market remains efficient and both buyers and sellers of permits gain from the trading relative to independent abatement.

This paper is divided into four sections. In section 2 we use a highly simplified analytical framework to show the two results mentioned above. In section 3 we draw some implications of the results obtained in this paper and argue for a second best policy that reinstates the efficiency of permit markets. Conclusions are set out in section 4.

Welfare analysis of permit trading

2.1 Welfare measure

Let the function $e(p, u)$ denote the minimum expenditure required to attain the utility level u at prices p . The equivalent variation measure of welfare change between any two situations 0 and 1 (such as independent abatement and permit trading equilibrium) can be defined as:

$$(1) \quad EV^{01} = e(p^0, u^1) - e(p^0, u^0)$$

Expanding $e(p^0, u^1)$ around $e(p^0, u^0)$ using Taylor series gives

$$(2) \quad e(p^0, u^1) = e(p^0, u^0) + (u^1 - u^0) \partial e / \partial u \Big|_{(p^0, u^0)} + o(h)$$

Note that $\partial e / \partial u$ is the reciprocal of the marginal utility of income (or the shadow value of a marginal unit of income to the society, say λ) and gives the monetary value of a unit of utility at the margin. Using (2) and ignoring higher order terms (1) can be rewritten as:

$$(3) \quad \begin{aligned} EV^{01} &= e(p^0, u^1) - e(p^0, u^0) \\ &= (u^1 - u^0) / \lambda^0 \end{aligned}$$

Noting that (3) is a linear approximation of (1), it can be seen from (3) that the money metric measure of welfare change given by EV is just the difference in the levels of utility expressed in monetary (numeraire) units with the help of the marginal utility of income evaluated at the point of expansion (p^0, u^0) .

2.2 Participation in permits trading by a small open economy

Let the economy produce two goods, good 1 (greenhouse gas intensive) and good 2 (non-greenhouse gas intensive) using a given endowment and CRS production technologies. Let z_1 and z_2 denote their output levels. Assume that the commodities release greenhouse gases (GHGs) at a rate $e = (e_1, 0)$ per unit when consumed. Let the economy be small and open and treat domestic and foreign goods as perfect substitutes and a household represent the consumption side of the whole economy and receive all factor incomes and tax revenues. Let all factor and good markets clear continuously and all agents behave competitively. Let $t = (t_1, t_2)$ be the vector of specific excise tax rates on the consumption of commodities with the tax revenue returned to the consumer as a lump sum. Given that the utility function of the household and all production functions are well behaved, the system admits equilibrium. Let (q, p, x, z) describe the equilibrium of the economy with the tax where q is the world price vector faced by producers,

$$(4) \quad p = q + t$$

is the domestic price faced by the consumer, x is the optimal consumption bundle and z is the vector of optimal outputs.

Suppose that this country has ratified the Kyoto Protocol and that the Protocol has entered into force. Suppose further that the country has negotiated a binding emission constraint E such that $e \cdot x = e_1 \cdot x_1 \leq E$. Each party may meet its emission commitment either independently of other parties or jointly via emissions (or permit) trading. A country that chooses to meet its emission commitment independently may do so by imposing either an emissions tax on the consumption of good 1 or introduce a domestic emissions trading scheme with no linkage to any international emissions trading scheme. Let the country under study impose an emissions tax to regulate the level of national emissions and let c^i be the equilibrium tax per unit of emissions. This implies

that $e.c^i$ is the effective carbon tax on a unit of good under independent abatement, which in turn implies a zero tax on good 2 as it is a zero emission good. Let the collection of vectors (q^i, p^i, x^i, z^i) describe the independent abatement equilibrium of the country, where

$$p^i = q^i + t + e.c^i$$

is the vector of prices faced by the consumer and the household income is given by

$$(5) \quad y^i = q^i.z^i + t.x^i + (e.x^i)c^i.$$

Here it is implicitly assumed that other parties to the protocol with emission targets also follow the independent abatement path and the prices and the production equilibrium included in (4) and (5) are consistent with the global equilibrium. Let $v(p^i, y^i)$ be the (indirect) utility level attained by the consumer under the independent abatement equilibrium such that

$$(6) \quad e.x^i = E.$$

If the parties to the protocol trade emission permits and meet the emissions targets jointly, then a single member country may consume more or less of the greenhouse gas intensive good than it would under independent abatement. We now make two simplifying assumptions - that for this small open economy, all sectors have a Leontief production function; and that world price vector is not affected by permit trading. The first assumption implies that emission trading does not alter its production equilibrium the second one avoids the terms of trade effects.¹ Given that E is the allocation of emission quota for the country under study (understanding that similar numbers exist for other member countries), and if c^t is the equilibrium global carbon tax rate (or the global price of an emissions permit) we can characterise the equilibrium of the country under international emission trading by (q^i, p^t, x^t, z^i) , where

$$(7) \quad p^t = q^i + t + e.c^t$$

and the income of the regional household is given by

$$(8) \quad y^t = q^i.z^i + t.x^t + (e.x^i)c^t.$$

¹ Although not reported in this paper, the main results of this paper remain valid in stylised simulations of a fully flexible general equilibrium model (Global Trade and Environment Model) with these assumptions relaxed.

The utility level of the household under the trading equilibrium is given by the value of the indirect utility function at (p^t, y^t) which can be approximated by the following second order Taylor series expansion around the independent abatement equilibrium:

$$(9) \quad v(p^t, y^t) = v(p^i, y^i) + (p^t - p^i) \partial v / \partial p + (y^t - y^i) \partial v / \partial y \\ + 1/2[(p^t - p^i)'(\partial^2 v / \partial p \partial p')(p^t - p^i) \\ + (p^t - p^i)'(\partial^2 v / \partial p \partial y)(y^t - y^i) \\ + (y^t - y^i)^2(\partial^2 v / \partial y^2)] + o(h)$$

where all partial derivatives are evaluated at the point (p^i, y^i) . In a two-good world with the above characteristics (that good 1 is greenhouse gas intensive and good 2 is a zero emissions good and that equations (4) - (8) are satisfied) equation (9) can be simplified and rewritten as

$$(10) \quad v(p^t, y^t) = v(p^i, y^i) + (p_1^t - p_1^i) \partial v / \partial p_1 + (y^t - y^i) \partial v / \partial y \\ + (1/2)[(p_1^t - p_1^i)^2(\partial^2 v / \partial p_1^2) \\ + 2(p_1^t - p_1^i)(\partial^2 v / \partial p_1 \partial y)(y^t - y^i) \\ + (y^t - y^i)^2(\partial^2 v / \partial y^2)] + o(h)$$

Using Roy's identity one can deduce that

$$(11) \quad \partial^2 v / \partial p_1 \partial y = \frac{\partial}{\partial y} \left(-x_1 \frac{\partial v}{\partial y} \right) \\ = -x_1^i \frac{\partial^2 v}{\partial y^2} - \frac{\partial x_1}{\partial y} \frac{\partial v}{\partial y}$$

and

$$(12) \quad \partial^2 v / \partial p_1^2 = \frac{\partial}{\partial p_1} \left(-x_1 \frac{\partial v}{\partial y} \right) \\ = -x_1 \frac{\partial^2 v}{\partial y \partial p_1} - \frac{\partial x_1}{\partial p_1} \frac{\partial v}{\partial y} \\ = (x_1^i)^2 \frac{\partial^2 v}{\partial y^2} + x_1^i \frac{\partial x_1}{\partial y} \frac{\partial v}{\partial y} - \frac{\partial x_1}{\partial p_1} \frac{\partial v}{\partial y}.$$

Assuming that the underlying utility function is homothetic, which implies that the second order derivative of the indirect utility function with respect to income vanishes, and ignoring the higher order terms, equation (10) can be rewritten using (11) and (12) as:

$$\begin{aligned}
 (13) \quad \nu(p^t, y^t) &= \nu(p^i, y^i) + (p_1^t - p_1^i) \partial \nu / \partial p_1 + (y^t - y^i) \partial \nu / \partial y \\
 &\quad + (1/2) [(p_1^t - p_1^i)^2 \{x_1^i (\partial x_1 / \partial y) (\partial \nu / \partial y) - (\partial x_1 / \partial p_1) (\partial \nu / \partial y)\} \\
 &\quad - 2(p_1^t - p_1^i)(y^t - y^i)(\partial x_1 / \partial y)(\partial \nu / \partial y)]
 \end{aligned}$$

Using Roy's identity once again and simplifying equation (13) gives:

$$\begin{aligned}
 (14) \quad &[\nu(p^t, y^t) - \nu(p^i, y^i)] / (\partial \nu / \partial y) \\
 &= -(p_1^t - p_1^i)x_1^i + (y^t - y^i) \\
 &\quad + (1/2) [(p_1^t - p_1^i)^2 \{x_1^i (\partial x_1 / \partial y) - (\partial x_1 / \partial p_1)\} \\
 &\quad - 2(p_1^t - p_1^i)(y^t - y^i)(\partial x_1 / \partial y)]
 \end{aligned}$$

Note that

$$(15) \quad x_1^t - x_1^i = (p_1^t - p_1^i) \{(\partial x_1 / \partial p_1) - x_1^i (\partial x_1 / \partial y)\} + (y^t - y^i) (\partial x_1 / \partial y)$$

where the terms in the braces represent the Slutsky decomposition of the price effect at given money income and the last term represents the effect of income change on the demand for the greenhouse gas intensive good at constant prices.

Noting that the left-hand side of the equation (14) is the EV^{it} by (3) we can further simplify (14) by using (15), giving:

$$\begin{aligned}
 (16) \quad EV^{it} &= -(p_1^t - p_1^i)x_1^i + (y^t - y^i) \\
 &\quad - (1/2)(p_1^t - p_1^i)[(x_1^t - x_1^i) + (y^t - y^i)(\partial x_1 / \partial y)]
 \end{aligned}$$

Using definition (4) and (7) of prices and definition (5) and (8) of incomes in the two equilibria equation (16) can be rewritten as:

$$\begin{aligned}
 (17) \quad EV^{it} &= -t_1(x_1^i - x_1^t) + 1/2e_1(c^t - c^i)(x_1^i - x_1^t) \\
 &\quad + (1/2)e_1(c^t - c^i)(x_1^i - x_1^t)t_1(\partial x_1 / \partial y) \\
 &\quad - (1/2)e_1^2(c^t - c^i)^2 x_1^i (\partial x_1 / \partial y).
 \end{aligned}$$

Now we have a very specific representation of the welfare change induced by permit trade relative to independent abatement. This change can be decomposed into its sources under strong assumptions to help focus on the main underlying factors. It is now possible to see what the terms on the right-hand side of equation (17) actually represent and what inferences regarding the welfare effects of permit trading can be drawn from their properties.

The first term captures the change in excise tax revenue resulting from changes in the quantity of the greenhouse gas intensive good being consumed. This term measures the

first order welfare effect of the change in the tax rate as discussed in Auerbach (1985) and Green and Sheshinski (1979). This term is positive for a permit buyer and negative for a permit seller¹.

The remaining terms are introduced into the calculus due to the quadratic approximation of the indirect utility function and are related to the area of the welfare triangles and the welfare effects of a shift on the demand curve caused by income changes. The second term measures the welfare gain or dead-weight loss associated with a fall or a rise in the tax rate, holding the income unchanged. Permit trading raises permit price in a selling country and lowers the permit price in a buying country. This, in other words, means that the effective tax on greenhouse gas intensive good will fall in the permit buying country and rise in the selling country. Hence the second term measures the approximate area of the welfare triangles associated with this change. It is easy to see that the sign of the second term is positive irrespective of whether a country is a buyer or a seller of permits.

The third and fourth terms are derived from the last term of equation (16). These terms simply estimate the additional welfare effect of the consequent shift of the permits demand curve (or demand for the greenhouse gas intensive good) that results from the change in income of the country which, in turn, is induced by the permits trade. These terms will vanish if the demand for the greenhouse gas intensive good does not respond to changes in income (i.e. if $\partial x_1 / \partial y = 0$). In particular, the third term introduces a correction to the first term and the fourth term introduces a correction to the second term. The third term is positive and the fourth term is negative for both buyers and sellers, provided that the income effect is positive.

As the sum of these four terms determine the net welfare effect of international permit trading, we summarise the results in the following propositions:

Proposition 1: Given that permit trading is fully decentralised; and there is a pre-existing tax (subsidy) on the greenhouse gas intensive good, the direction of the welfare change for a seller (buyer) under permit trading relative to independent abatement is ambiguous whereas the buyer (seller) will gain unambiguously. If the first order effects dominate the second and higher order effects, then the selling (buying) country will lose unambiguously.

Proof: Let

¹ It is important to note here that the first term on the right hand side of (17) would be negative for a permit buyer and positive for permit seller if $t_1 < 0$, which means the GHG emitting commodity has been subsidised rather than taxed.

(19a) $EV_1^{it} = -t_1(x_1^i - x_1^t)$ and

(19b) $EV_2^{it} = -1/2e_1(c^t - c^i)[(x_1^t - x_1^i) + \{t_1(x_1^t - x_1^i) + e_1(c^t - c^i)x_1^i\}(\partial x_1 / \partial y)]$

then EV_1^{it} measures the contribution of the first order effects and EV_2^{it} measures the contributions of the second order terms to the total welfare change that arises from a move to permit trading equilibrium from independent abatement. We thus have $EV^{it} = EV_1^{it} + EV_2^{it}$. Since, $x_1^t < x_1^i$ for a permit seller and $x_1^t > x_1^i$ for a permit buyer, it follows that $EV_1^{it} < 0$ for a seller and $EV_1^{it} > 0$ for a buyer for $t_1 > 0$ and the signs are reversed for $t_1 < 0$. Moreover, as it is shown in the appendix that EV_2^{it} is positive whether the country is a permit buyer or a seller irrespective of whether the commodity is taxed or subsidised, we conclude that EV^{it} is positive for a buyer but cannot be signed a priori for a seller in case of tax, and EV^{it} is positive for a seller but cannot be signed a priori for a buyer in case of subsidy.

If, however, the first order effect dominates the second (and higher) order effects in magnitude, then the second part of the proposition follows directly from (17). The hypothesis implies that $sign(EV^{it}) = sign(EV_1^{it})$. But $sign(EV_1^{it})$ is positive for a buyer and negative for a seller, and hence the proposition. $\square\square\square$

Proposition 2: If the economy did not have any pre-existing taxes on commodities, that is, $t = 0$, then international permit trading is unambiguously welfare improving relative to independent abatement whether the country is buying or selling emission permits.

Proof: Setting $t=0$ (17) one obtains

(18) $EV^{it} = (1/2)e_1(c^t - c^i)[(x_1^i - x_1^t) - e_1(c^t - c^i)x_1^i\partial x_1 / \partial y].$

But, we can infer that the expression $(x_1^i - [x_1^t + e_1(c^t - c^i)x_1^i\partial x_1 / \partial y])$ is positive for a seller and negative for a buyer. This is so because the income effect adjusted demand for the greenhouse gas intensive good under trading cannot exceed its level under independent abatement for the seller and similarly it cannot fall below its independent abatement level for the buyer otherwise they can not remain as a seller and as a buyer respectively. Hence the expression within the square brackets in (18) is positive for a seller and negative for a buyer of permits. As $(c^t - c^i)$ is positive for a seller and negative for a buyer, we conclude that EV^{it} in (18) is positive irrespective of the trade orientation of the country in the permits market and hence the proposition.

Proposition 2 confirms the results of Hinchy, Fisher and Graham (1998), Hinchy et al. (1998), Montgomery (1972) and Rubin (1996).

2.3 Interpretation of the results: a graphic exposition

We now provide a graphic exposition of the welfare change results derived above with the help of figure 1 for a permit selling country and with the help of figure 2 for a permit buying country under assumption that income effects are negligible and that $t_1 > 0$.¹

In both figures, it is assumed that the consumption of a unit of good 1 emits a unit of GHG. It is thus easy to track the level of emissions from the level of consumption of the greenhouse gas intensive good and the analysis of the market for good 1 is thus illuminating. In both figures, the vertical axis measures the price and the horizontal axis measures the units of the greenhouse gas intensive good.

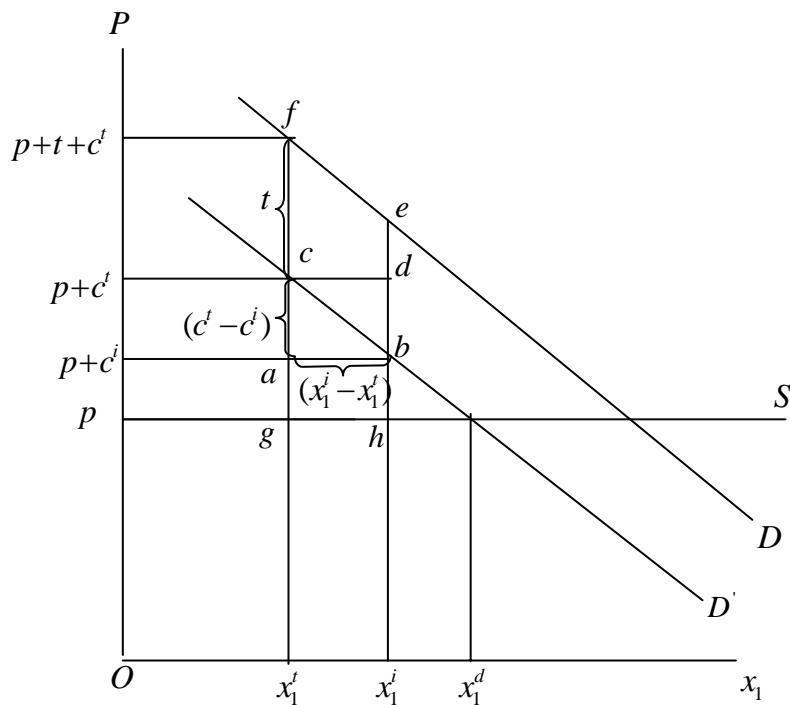


Figure 1: welfare effects in a permit selling country

The horizontal supply curve labeled S reflects the supply conditions in this small and open economy.² Any quantity of good 1 can be supplied at the fixed world price p . The

¹ We will maintain this assumption of $t_1 > 0$ for the rest of the paper.

² The same results can be obtained for an upward sloping supply curve.

curve D reflects the aggregate demand curve for good 1. The curve D' reflects the demand curve D net of the specific tax on good 1 at the rate t . Hence with the pre-existing commodity tax t and without any environmental regulations the economy consumes x_1^d units of good 1 emitting x_1^d units of GHGs. Suppose that an emission restriction is imposed at a level such that the economy ends up consuming x_1^i units of good 1 while meeting the target independently. The carbon tax rate required to attain this consumption equilibrium consistent with the emission target is given by c^i .

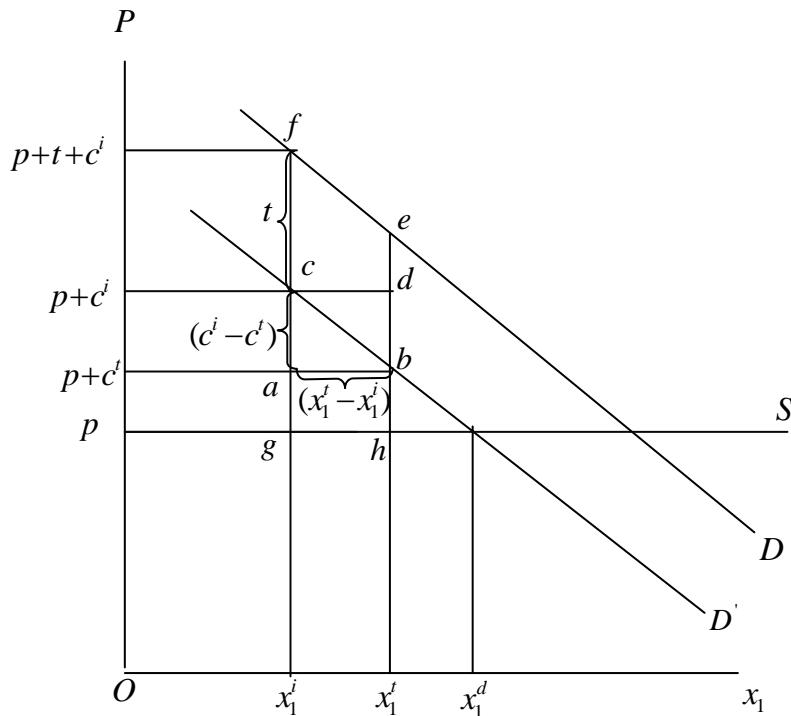


Figure 2: welfare effect of permit trading in a buying country

Let us assume that this country trades with other countries in emission permits meeting the emission targets jointly and c^i is the resulting permit price (or the global carbon tax rate) and x_1^t be the quantity of good 1 consumed at the trading equilibrium. If $c^t > c^i$ the country will sell permits (see figure 1) which implies $x_1^t < x_1^i$ and buy permits if $c^t < c^i$ (see figure 2) in which case we will have $x_1^t > x_1^i$.

Using figure 1, the welfare change in a permit selling country can be obtained as follows:

$$\begin{aligned}
 \text{Welfare change} &= \text{area } ghdc - \text{area } ghef \\
 &= \text{area } ghdc - \text{area } ghba - \text{area } abc - \text{area } befc \\
 &= c^t(x_1^i - x_1^t) - c^i(x_1^i - x_1^t) - 1/2(c^t - c^i)(x_1^i - x_1^t) - t(x_1^i - x_1^t) \\
 &= -t(x_1^i - x_1^t) + 1/2(c^t - c^i)(x_1^i - x_1^t).
 \end{aligned}$$

Similarly figure 2 can be used to obtain the welfare change in a permit buying country as follows:

$$\begin{aligned}
 \text{Welfare change} &= \text{area ghef} - \text{area ghba} \\
 &= \text{area ghba} + \text{area abc} + \text{area befc} - \text{area ghba} \\
 &= -t(x_1^i - x_1^t) + 1/2(c^t - c^i)(x_1^i - x_1^t).
 \end{aligned}$$

Under the assumption that income effects are zero, these graphic explanations illustrate the measure and decomposition of welfare change derived in equation (17).

Proposition 3: Given that pre-existing tax rates on greenhouse gas intensive goods are different in different countries, permit trading does not guarantee that marginal costs of abatement are equalised across countries and thus the global cost of abatement is not necessarily minimised.

Proof: For simplicity let us assume that one unit of greenhouse gas intensive good emits a unit of emission (GHG). Let t_1^r be the per unit pre-existing tax levied on the greenhouse gas intensive good in country r. This means that there is a pre-existing tax on a unit of emission at the rate of t_1^r , which is levied on the good, not on emissions directly.¹ With permit trading the social marginal cost of abatement (i.e. the marginal social value that can be generated using a unit of emission permit) in region r would be $t_1^r + c^t$, where c^t is the global permit price (or carbon tax). For any two regions, r and s, we have $t_1^r \neq t_1^s$ by hypothesis; and hence the social marginal cost of abatement will be higher in the country with the higher pre-existing tax rate. A re-allocation of abatement activity from a high tax to a low tax country will reduce the global cost of abatement. Therefore, in the presence of pre-existing taxes on greenhouse gas intensive commodities permit trading does not guarantee the minimisation of the global cost of abatement.

Corollary 1: Given that pre-existing tax rates on greenhouse gas intensive commodities are different for different sources of emission, permit trading does not guarantee that marginal costs of abatement are equalised across various sources within a country and thus the national cost of a given level of abatement is not necessarily minimised by permit trading.

Proof: Take r and s as two sources of emission in a given country. As we have $t_1^r \neq t_1^s$ by hypothesis; the social marginal cost of abatement with permit trading will be higher at the source with the higher pre-existing tax rate. A re-allocation of abatement activity from a high tax to a low tax source will reduce the national cost of abatement. An optimal allocation will be obtained by imposing carbon taxes at differential rates so that

¹ We continue to assumption that the per unit emission is unity.

the sum of pre-existing tax rate and the emission tax rate are equalised between the sources.

3. A second best solution

The main reason for the above result is the divergence of the marginal social and private benefits from permits trading in a permits selling country. The private marginal benefit of an emission permit (to its holder) is its market price (or the carbon tax rate on a unit of emission). The marginal social benefit of an emission permit is, however, given by the sum of the market price of permits (global ‘carbon tax rate’ per unit of emission in the case of international trading) and the implied tax on a unit of emission from the pre-existing tax on greenhouse gas intensive commodities. Hence these two quantities differ by the implied emission tax equivalent of the pre-existing energy tax rates. In other words, the marginal social value will always exceed the marginal private value of emission permits if energy tax rates are positive. Hence, as shown above, if a selling country has a sufficiently high tax rate on energy commodities, it may loose from permit trade simply because it could be selling a high value good at a lower price. Moreover, national and international permits market will not necessarily remain efficient if the pre-existing tax rates are different across sources and trading countries.

As both problems are caused by the divergence of the private and social marginal values of emission permits which, in turn, is caused by the presence of a tax on greenhouse gas intensive commodities, the first best solution is the removal or harmonization of taxes on greenhouse gas intensive commodities and the auctioning of tradable permits (or some form of cap and trade provision). The likelihood of such a tax reform, however, is small. A second best solution to this problem is to impose a tax and subsidy on international permit trade.¹ If each country imposes a tax on the sale (exports) of permits equal to the pre-existing tax rate on a unit of emission and a subsidy at the same rate on the purchase (imports) of an emission permit, then as is shown below, international permit trade will be efficient.² Under these circumstances, the marginal social value of emission permits will be equalised in all participating countries and sources and it will be equal to the market (global or local) price of an emission permit.

¹ In the case of national permit trade the overall gain may be quite small if distributional consequences are ignored. Although it is possible to see a welfare loss arising out of permit trading compared to no trading.

² If there are pre-existing subsidies, not taxes, then exports need to be subsidised and imports need to be taxed. If, however, there are a mixture of both taxes and subsidies, when there are many GHG emitting commodities, some form of tax reform may be necessary or some form of association between the GHG emitting commodity of emission permit may need to be introduced.

In figure 3a, and 3b, we consider two countries, 1 and 2, having the same emission permits limited at ob (as shown by supply curve bQ). D_1 and D_2 are their demand curves for emission permits. Under independent abatement (figure 3a) these countries will have permit prices determined at T_1 and T_2 respectively. Country 1 having the lowest cost of abatement will have excess supply (given by the curve S_1 , which is the relevant segment of the mirror image of line D_1 along the emission quota line bQ) and country 2 will have excess demand (given by D_2) for permits if the two countries trade. We can see in figure 3a that in the absence of taxes on greenhouse gas intensive commodities (no distortions), the global permit price will be determined at T^g and country 1 will sell ab units of permits to country 2. From this trade country 1 is better off by the area 'efg' and the country 2 gains the area 'ghk'.

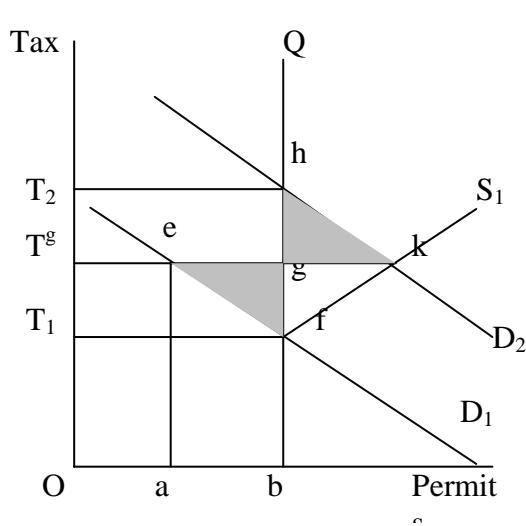


Figure 3a: Permit trade without distortion

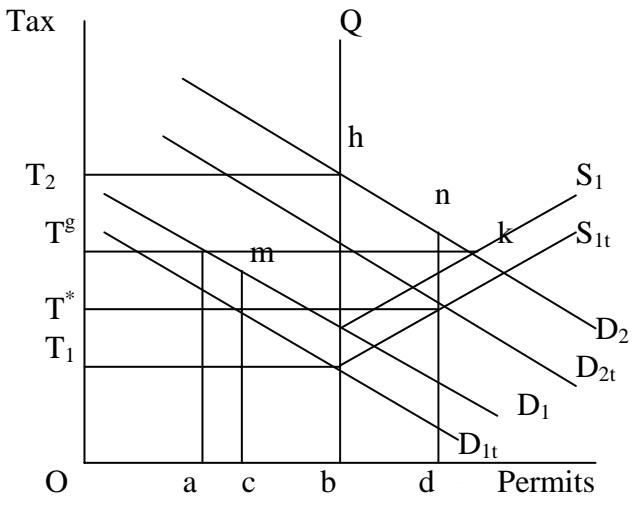


Figure 3b: Permit trade with distortion

Now in figure 3b we consider the effect of pre-existing taxes on the efficiency of permit trade and on the welfare changes. With taxes on greenhouse gas intensive commodities, the demand curves for emission permits shift downward to the left to D_{1t} and D_{2t} in countries 1 and 2 respectively. The excess permit-supply curve for country 1 is now given by the curve S_{1t} and the excess permit-demand curve of country 2, is given by D_{2t} . Equilibrium in the permits market requires a global price of permits at T^* . At this price country 1 sells cb units of permits to country 2. The marginal social value of an emission permits in country 1 is cm and that in country 2 is dn . As $dn > cm$, it is possible to reduce the global cost of abatement by selling more permits from country 1 to country 2 than is being sold at equilibrium. Hence, this outcome is not efficient. If, however, country 1 imposes a tax on the sale of permits at the rate equivalent to its tax on the greenhouse gas intensive good this will shift the excess supply curve up to S_1 . Similarly, if country 2 provides a subsidy on the purchase of permits at a rate equivalent to the tax it will collect from the increased use of the greenhouse gas intensive good then its excess demand schedule will also shift to D_2 to the right of the line bQ . As can be seen from the diagram, the excess demand and supply schedules return to the position where they would have been were there no taxes on greenhouse gas intensive

commodities. As a result the equilibrium market price of permits is equal to T^g , which is the permit price determined at the trading equilibrium without pre-existing taxes on greenhouse gas intensive commodities. As excess demand and supplies of emission permits will be exactly the same as the excess demand and supply functions had there been no pre-existing taxes on greenhouse gas intensive commodities, both parties will gain from permit trade by proposition 2.

Now we can draw a corollary to the above discussion for domestic emission trading. In a country where there are a range of energy taxes and subsidies imposed at different rates on greenhouse intensive goods, if the government auctions its emission permits under competitive conditions, then the price that emerges at the equilibrium will not minimise the domestic cost of abatement. However, if a subsidy/tax equivalent to the tax rate on greenhouse gas intensive commodities is announced then all buyers and sellers will adjust their respective demand and supply curves accordingly and the price that emerges at equilibrium will minimise the social cost of abatement. The proof follows immediately from figure 3b. In general, if permits are allocated by some rule, say grandfathering, and various agents face different tax rates on greenhouse gas intensive commodities, then the efficiency of permit trading can only be maintained if all sellers are taxed and buyers are subsidised appropriately (reverse in case of pre-existing subsidies).

4 Conclusion and Implications

Several studies have argued for permit trading as a means of reducing the cost of emission restriction such as the one proposed under the Kyoto Protocol. Their argument is based on models in which emissions were considered tax free prior to the imposition of the emission restriction. Under this assumption, shifting the emission reduction activity from a high cost region to a low cost region through permit trading would naturally benefit everyone and the global or national, as the case may be, cost of emission reduction would be minimised. Our analysis shows that in the presence of pre-existing taxes on greenhouse gas intensive commodities, permits markets would not necessarily be efficient.

Moreover, in the context of international permit trading, we have also argued that if there are pre-existing taxes on greenhouse gas intensive commodities then permit trading will not necessarily be welfare improving to a permit-selling country while it may benefit a buying country. The possibility of a selling country (with sufficiently high rate of pre-existing taxes on energy commodities) losing from permit trade relative to independent abatement has been clearly demonstrated in this paper. This conclusion does not rest on the optimality of pre-existing taxes. It is based on the standard Harberger(1971) type assumption that the aggregate demand curve reflects the marginal social value and the supply curve reflects the social costs at the margin.

We have also shown, more importantly, that taxing the sellers and subsidising the buyers of emission permits as a general rule assures the efficiency of the permits market under given conditions and in the case of international trade, both buying and selling

countries will gain from such a trade. The tax rate on permit sales to ensure efficiency should be the emission tax equivalent of the pre-existing tax on greenhouse gas intensive commodities whose use is discouraged by the permits sale. Similarly, the subsidy rate on the purchase of the permits should be emission tax rate equivalent of the pre-existing tax rate on greenhouse gas intensive commodities whose use will be increased by the use of additional emission permits.

Further research is required, however, to determine the appropriate tax/subsidy rates when the sale of a permit discourages and a purchase encourages the use of more than one greenhouse gas intensive good that are taxed and or subsidised at different rates.

Appendix –1

Proposition 5: The welfare effect of the second order terms is positive whether a country is a buyer or a seller of the permits at the permit trading equilibrium.

Proof: We know that $x_1^t + (y^t - y^i) \partial x_1 / \partial y < x_1^i$ for a permits selling country and $x_1^t + (y^t - y^i) \partial x_1 / \partial y > x_1^i$ for a permit buying country. Noting that $y^t - y^i = t(x_1^t - x_1^i) + (c^t - c^i)x_1^i$ we have

$$(A1) \quad (x_1^t - x_1^i) + [t_1(x_1^t - x_1^i) + e_1(c^t - c^i)x_1^i] \partial x_1 / \partial y < 0$$

for a permit seller and

$$(A2) \quad (x_1^t - x_1^i) + [t_1(x_1^t - x_1^i) + e_1(c^t - c^i)x_1^i] \partial x_1 / \partial y > 0$$

for a permits buyer.

Since $c^t > c^i$ for a permit seller and $c^t < c^i$ for a permit buyer, it follows from (A1), (A2) and (19b) that

$$(A3) \quad EV_2^{it} = -1/2e_1(c^t - c^i)[(x_1^t - x_1^i) + \{t_1(x_1^t - x_1^i) + e_1(c^t - c^i)x_1^i\}(\partial x_1 / \partial y)] > 0,$$

for both buyers and sellers and hence the proposition.

Appendix - 2

In this appendix, we will demonstrate, with the help of an example, that imposition of a tax on sale and subsidy on purchase of emission permits re-establishes the efficiency of permits market. With this tax/subsidy scheme, the marginal cost of abatement is equalised across sources and countries and both buyer country and selling country gain from permits trade despite the presence of the pre-existing tax on greenhouse gas intensive commodities.

To focus on the main issue, let us assume that the demand for emission permits in the two countries is given by

$$(A4) \quad D_1 = a - bT_1 \text{ and } D_2 = k - bT_2 \text{ with } k > a.$$

The demand functions specified in (A4) maintain that the slope of emission demand curve is identical in both countries, they differ only on the intercept. Hence the two curves are parallel and imply that the marginal value of emission permits in country 2 is greater than that in country 1. Let us further assume that both countries are entitled to the same amount of emission quota, Q.

Under independent abatement we have:

$$(A5) \quad T_1 = (a - Q) / b \text{ and } T_2 = (k - Q) / b.$$

As $k > a$, we have $T_2 > T_1$, that is the permit price in country 2 will be higher than in country 1.

If the two countries trade, country 1 will sell emission permits to country 2. The excess supply curve of country 1 is given by

$$(A6) \quad ES_1 = Q - (a - bT)$$

and excess demand for permits in country 2 is given by

$$(A7) \quad ED_2 = (k - bT) - Q$$

Equilibrium requires the excess demand to be equal to excess supply for which the equalised permit price is required to be:

$$(A8) \quad T^s = (k + a - 2Q) / 2b.$$

And the permits sold by country 1 is given by:

$$(A9) \quad S_1^* = (k - a) / 2.$$

Now assume further that both countries had pre-existing taxes on greenhouse gas intensive commodities and let τ_1 and τ_2 be the equivalent tax rates per emission unit of the pre-existing taxes in countries 1 and 2 respectively.

With pre-existing taxes, the emission demand functions specified in (A4) become

$$(A10) \quad D_1 = a - b(T_1 + \tau_1) \text{ and } D_2 = k - b(T_2 + \tau_2)$$

As a result under independent abatement the permit prices in the two countries become:

$$(A11) \quad T_1^\tau = (a - b\tau_1 - Q) / b \text{ and } T_2^\tau = (k - b\tau_2 - Q) / b$$

respectively.

It follows from (A5) and (A11) that –

Proposition 6: Permit prices under independent abatement will be lower with pre-existing taxes in all countries than without such taxes.

If the two countries trade the equilibrium permit price will become:

$$(A12) \quad T^{\tau_g} = (k + a - 2Q) / 2b - (\tau_1 + \tau_2) / 2$$

It can clearly be seen from (A8) and (A12) that the global price of permits will be lower with pre-existing taxes on greenhouse gas intensive commodities than without.

The amount of permits sold by country 1 is given by:

$$(A13) \quad S_1^{\tau^*} = (k - a) / 2 + b(\tau_1 - \tau_2) / 2$$

A comparison of (A9) with (A13) reveals that -

Proposition 7: Whether the quantity of permits traded will be higher or lower with pre-existing taxes than without depends on whether the pre-existing tax rates are higher in the selling country than in the buying country or not.

Now if we impose taxes on permit sales and a subsidy on the purchase of emission permits as discussed in the text, the excess supply function of country 1 can be written as:

$$(A14) \quad ES_1^{\tau} = Q - (a - b\tau_1) + b(T - \tau_1)$$

and the excess demand function of country 2 becomes:

$$(A15) \quad ED_2^{\tau} = (k - b\tau_2) - b(T - \tau_2) - Q$$

Then it is easy to see that equation (A14) is equation (A6) and equation (A15) is equation (A7). Hence, we conclude:

Proposition 8: If there are pre-existing taxes on greenhouse gas intensive commodities before a emission restriction is imposed and permit trade is allowed, then a tax on the sale and subsidy on the purchase of emission permits at specific rates equivalent to pre-existing taxes on greenhouse gas intensive commodities removes the inefficiency of the permit market and both buyers and the sellers gain from permit trade.

Proof: Excess demand of country 2 and excess supply of country 1 are equalised when the permit price in both countries are equalised and given by (A8). As the equilibrium volume of permit trade is given by (A9) and both price and quantity of permits trade confirm the price and quantity of permit trade in the absence of taxes on greenhouse gas intensive commodities both buyers and sellers must gain by proposition 2.

References

Auerbach, A. J. 1985, 'The theory of excess burden and optimal taxation', in Auerbach, A. J. and Feldstein, M. (eds.), *Handbook of Public Economics*, North-Holland.

Babiker, M., Reilly, J. M. and Jacoby, H. D. 2000, 'The Kyoto Protocol and developing countries', *Energy Economics* **28**, 525-36.

Babiker, M., Maskus, K. E. and Rutherford, T. F., 1997, 'Carbon taxes and global trading system', paper presented at the International Energy Workshop and Energy Modeling Forum Meeting at IIASA, June 23-25. (Available from: <http://robles.colorado.edu/~tomruth/papers.htm>).

Golombok, R., Hagem, C. and Hoel, M. 1995, 'Efficient incomplete international climate agreements', *Resource Energy Economics* **17**, 25-46.

Goulder, L. H. 1995, 'Effects of carbon taxes in an economy with prior tax distortions: an intertemporal general equilibrium analysis', *Journal of Environmental Economics and Management* **29**, 271-97.

Green, J. R. and Sheshinski, E. 1979, 'Approximating the efficiency gain of tax reforms', *Journal of Public Economics* **11**, 179-195.

Harberger, A. C. 1971, 'Three basic postulates for applied welfare economics: an interpretive essay', *Journal of Economic Literature* **9**, 785-797.

Hinchy, M., Fisher, B. and Graham, B. 1998, 'Emission trading in Australia: developing a framework', ABARE Research Report 98.1, Canberra.

Hinchy, M., Hanlson, K., Fisher, B. and Graham, B. 1998, 'International trading in greenhouse gas emissions: some fundamental principles', ABARE Research Report 98.3, Canberra.

Montgomery, W. D. 1972, 'Markets in licenses and efficient pollution control program', *Journal of Economic Theory* **5**, 395-418.

Rubin, J. D. 1996, 'A model of intertemporal emission trading, banking and borrowing', *Journal of Environmental Economics and Management* **31**, 269-286.

Stavins, R. N. 1995, 'Transaction costs and tradeable permits', *Journal of Environmental Economics and Management* **29**, 133-148.

Titenberg, T. H. 1973, 'Specific taxes and the control of pollution: a general equilibrium analysis', *Quarterly Journal of Economics* **64**, 503-522.