The Economics of Carbon Pricing (A – Economic analysis)

According to the Stern Review, "climate change is the greatest market failure the world has ever seen"[1]. Using the results from formal economic models, the Review estimates that if we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5 percent of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20 percent of GDP or more.[2]

These conclusions are the starting point for this case study. We do not explore the science of climate change, and accept that, on a business as usual basis, it would impose economic costs of the order of magnitude reported in Stern.

The approach here is to use the diagrammatic tools of marginal cost and marginal benefit, and supply and demand, to address some of the contested issues in the debate about climate change mitigation.

The case study will illustrate the following core concepts in public economics with application to carbon abatement:

This case was written by Professor Ross Guest, Griffith Business School, for the Australia and New Zealand School of Government. The case study consists of two parts: A, an economic analysis, using a diagrammatic approach, of the contested issues in the debate about carbon pricing which act as focus questions and B, a teaching note including questions, activities, and interviews with prominent players in the debate about climate change mitigation.

[1] Stern, N. (2007) *The Economics of Climate Change: The Stern Review.* Cambridge: Cambridge University Press, p xviii.

[2] Ibid., p.xv.

1. The effect of externalities on economic welfare
2. Taxes versus tradable permits as alternative instruments for dealing with negative externalities
3. Marginal cost-marginal benefit analysis
4. Effects of taxes and quotas on a good or service.

Some contested issues in carbon pricing

The following are some of the important contest issues in the debate about carbon pricing. They are framed here as focus questions:

(i) What are the relative merits of alternative instruments for dealing with climate change – in particular a carbon tax versus carbon permits?

(ii) Is there a case for subsidising renewable energy sources in conjunction with a carbon trading scheme?

(iii) Should tax concessions be applied to petrol, for example, in order to compensate consumers?

(iv) Should certain industries be exempt from an emissions trading scheme?

Economic analysis

1. The analytical set up: a diagrammatic approach

Consider the market for carbon represented by **Figure 1a.** Firms, such as those producing coal-fired electricity, produce carbon because it is profitable to do so. It is profitable because this is the most cost-efficient way of producing a product (such as electricity), and the relative benefits of using inputs that produce carbon compared with alternative inputs.

The demand for any product relates to the quantity that buyers are willing and able to purchase at various prices. Buyers will purchase up to the point where price is equal to marginal benefit. Hence the demand schedule in **Figure 1** is labelled the MB (marginal benefit) schedule.[3] The PMC (private marginal cost) schedule is the marginal cost of the input to the firm, which is assumed to be flat, implying that marginal costs do not change as output changes.[4] SMC denotes social marginal cost which is the PMC plus spill-over costs to society from environmental damage from production of carbon. The vertical gap between SMC and PMC is the externality cost[5] of the marginal damage to the environment for each unit of carbon produced. This gap is increasing with greater carbon output reflecting the rising damage per unit of carbon as more carbon accumulates in the atmosphere (the rate of decay of atmospheric carbon is very low).

[3] In more technical economic language, the MB refers to the marginal revenue product of carbon as an input and is a product of the marginal revenue of an additional unit of the final product (e.g. electricity) and the marginal product of the carbon-intensive input. Both marginal revenue and marginal product slope down and hence so does the MB schedule.

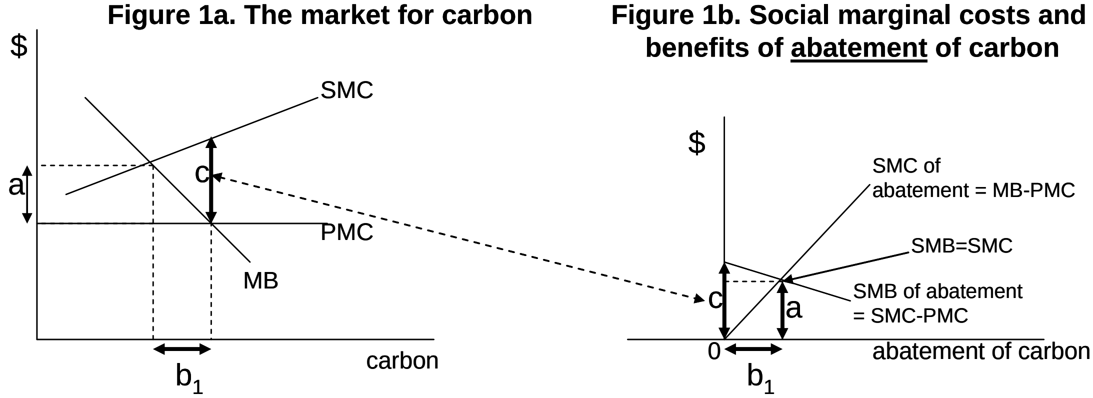
[4] It would slope upwards if the per unit costs of extracting the carbon intensive resource increased as the remaining stock of the resource dwindles; and/or if the firm had buying power in the market for its inputs.

[5] The externality is the present value of all future environmental costs from the marginal unit of carbon.

The divergence between social and private marginal costs of carbon is the source of the **market failure** in the production of carbon.

Figure 1. The market for carbon and carbon abatement

Figure 1a. The market for carbon **Figure 1b. Social marginal costs and benefits of <u>abatement</u> of carbon**



For the industry, the optimal level of carbon output occurs where the MB and PMC schedules intersect. But the optimal carbon output for society occurs where the MB and the SMC schedules intersect. Hence the market failure causes an excessive production of carbon from society's point of view, and it is socially optimal to abate a quantity of carbon equal to *b* in the diagram.

The optimal carbon abatement, *b*, is further illustrated in **Figure 1b**. Here the upward sloping schedule is the social marginal benefit (SMB) of abatement, which equals the vertical difference between SMC and PMC schedules; it is the present value of the marginal damages averted per unit of carbon reduction. The SMC of abatement is the vertical difference between the MB (marginal benefit) and PMC schedules due to the loss of private economic value that derives whenever a unit of carbon produces private benefits over private costs. By cutting back a unit of carbon from the optimal level, there is an excess of MB over PMC which is the loss of economic value from cutting back that unit of carbon. The more carbon that is abated, the greater the difference between MB and PMC for each unit abated and hence the SMC of abatement rises. Note that the SMC of abatement is the loss of private economic value, which is also the social loss of value, and hence we could have used MC (marginal cost) synonymously with SMC.

Note that if cleaner production methods become cheaper due to technological developments, there would be a substitution of clean technology for carbon-intensive technology. This would imply a downward shift in the MB curve for carbon and therefore a reduction in the SMC of abatement. The result would be a higher optimal level of abatement.

While this simple framework is helpful in thinking about the core ideas of private costs, social costs, benefits and optimal abatement, it ignores a number of real world complications. These factors, which are discussed below, include:

- uncertainty about the costs and benefits of abatement
- the irreversibility of investments in carbon abatement but also irreversibility of environmental damage
- the very long time horizon requires judgments about the value that we place on costs and benefits into the future.

2. Taxes and tradable permits

2.1 A carbon tax

The optimal degree of abatement, b_1, can in principle be achieved in two ways. One way is by imposing a tax per unit of carbon equal to a. This will shift the PMC schedule in **Figure 1a** upwards by a so that it cuts the SMC schedule at the optimal output of carbon, implying an abatement of b_1 units of carbon. In terms of **Figure 1b**, a tax of a creates a private MB of abatement (because the tax is avoided for each unit of abatement) which firms equate with the MC of abatement, leading to the optimal level of abatement, b_1.

It is important to remember that the benefits of abatement, in particular, have an inter-temporal dimension. Greenhouse gases (GHG) caused by burning carbon accumulate in the atmosphere and it is the accumulation of GHG in the atmosphere at any given time that causes damage at that time. Hence abatement of GHG has long run benefits. The MB of abatement today is therefore the present value of the gains from the resulting reduction in GHG over all future time periods.

This inter-temporal aspect raises two issues. One is the need for discounting which we discuss later on. The other issue is the scope for the development of new cleaner technologies over time and the related issue of the adjustment over time by consumers and firms to higher costs of carbon. Over time consumers will be better able to adjust to higher costs of carbon and firms will develop cleaner technologies. Both of these effects will reduce the marginal cost of abatement. Also the marginal benefit of abatement over time can be expected to rise because the higher accumulated stock of GHG means that a given increase in GHG is more costly and therefore a given reduction is more beneficial.

Hence over time costs of abatement fall (the SMC schedule in **Figure 1b** shifts to the right) and the SMB of abatement rises (the SMB schedule shifts to the right). Both of these shifts imply a rising optimal level of abatement over time. This implies that it is optimal to increase the carbon tax over time thereby ensuring that abatement rises over time.

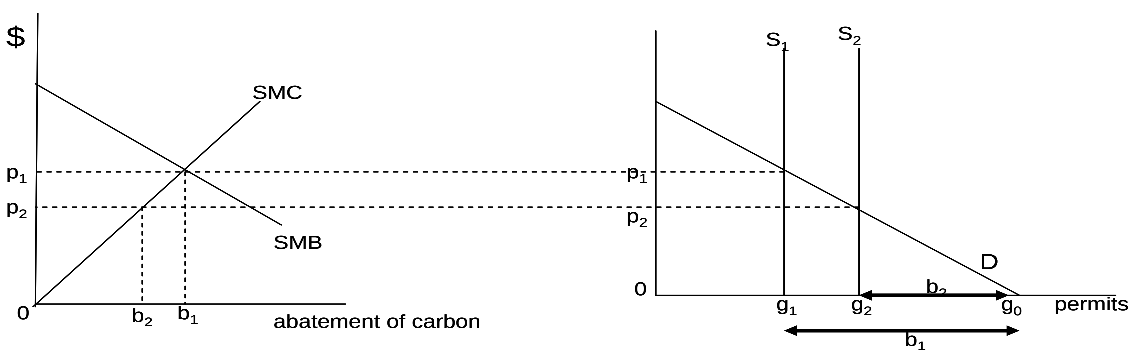
2.2 Tradable permits

Another way of achieving the optimal level of carbon output is to issue permits to produce carbon that in total equal the optimal carbon output. Permits can be either granted to existing producers of GHG or they can be auctioned. Either way, once they are allocated they can be traded.

To see how the permit system works, consider **Figures 2a** and **2b**. **Figure 2a** is a version of **Figure 1b**. It shows the SMC and SMB of carbon abatement, implying an optimal level of abatement of b_1. Firms will abate carbon as long as the cost of abating is less than the cost of not abating, in other words of emitting, which is the price of a permit required to emit. At p_2 for example firms will abate up to b_2.

Figure 2. The market for tradable permits

Figure 2a. **Figure 2b.**



In the absence of a price on permits there would be zero abatement. This position is represented in **Figure 2b** by point g_0 which is by implication the demand for permits when the price of a permit is zero. The demand schedule in **Figure 2** shows the number of permits that firms are willing and able to buy at various permit prices. For example, if the permit price is p_1, firms will want to abate a quantity of b_2 which implies a demand for permits equal to $g_2(=g_0-b_2)$. See also Weber (2002)[6] for a similarly derived demand for permits schedule.

The vertical S schedule in **Figure 2b** is the fixed supply of permits issued. Suppose that the initial level of permits issued is S_2. This will imply a permit price of p_2, a quantity of permits demanded equal to g_2, and abatement of b_2. Note however that this is not the socially optimal level of abatement which is b_1. In order to get the socially optimal level of abatement the supply of permits has to be reduced to S_1 which raises the price to p_1. This price is the optimal price in

[6] Weber, D. (2002) "Pollution Permits: A Discussion of Fundamentals" *Journal of Economic Education*" 33, 3, 277-290.

the sense that it implies the optimal level of abatement. Note also that this price is equal to the optimal carbon tax because both the optimal permit price and the optimal carbon tax occur at the intersection of the SMC and SMB of abatement schedules.

3. Should some industries get free permits? For example trade-exposed, emission intensive industries (TEEIs)

Suppose that special assistance is provided to certain industries (or firms within an industry) such as trade exposed, emission intensive industries (TEEIs). A justification might be that these industries would otherwise shift operations to countries that have a lower carbon price implying no change in global emissions while imposing an economic cost to the host country.
These firms could either be exempted from the obligation to hold permits or receive cash credits as compensation for the need to hold permits. The latter is the recommendation in Garnaut (2008)[7] with respect to TEEIs and is assumed to apply here.

Providing assistance to fims implies that their costs of a given level of abatement are higher which leads them to abate less than they otherwise would. The private marginal cost of any given aggregate abatement level is thereofr higher, yet the social marginal cost is unchanged. This creates a divergence between the social marginal costs and private marginal costs of abatement. With marginal costs of abatement being higher the demand for permits is also higher and hence the equilibrium carbon price is higher. The effect is to redistribute the financial burden of a given degree of abatement away from firms receiving assistance to other firms who now pay a higher price for carbon permits.

4. Are tax concessions on particular goods (such as petrol) a good idea?

A similar result occurs if tax concessions (such as a reduction in excise tax or other indirect taxes) apply to certain goods in order to offset the effect of carbon permits on prices to consumers.

Assume that the excise tax on petrol is reduced, which increases the quantity of petrol demanded and therefore raises the derived demand for carbon. This implies that the PMC of abatement of carbon to oil companies is now higher, which reduces the privately optimal level of abatement by oil companies at any carbon price. If oil companies are abating less, then other companies must abate more in order to achieve the target abatement level. This can only be achieved at a higher carbon price.

As in the case of free permits, one group of firms abates too little while another abates too much; and the carbon price is higher than it would otherwise be.

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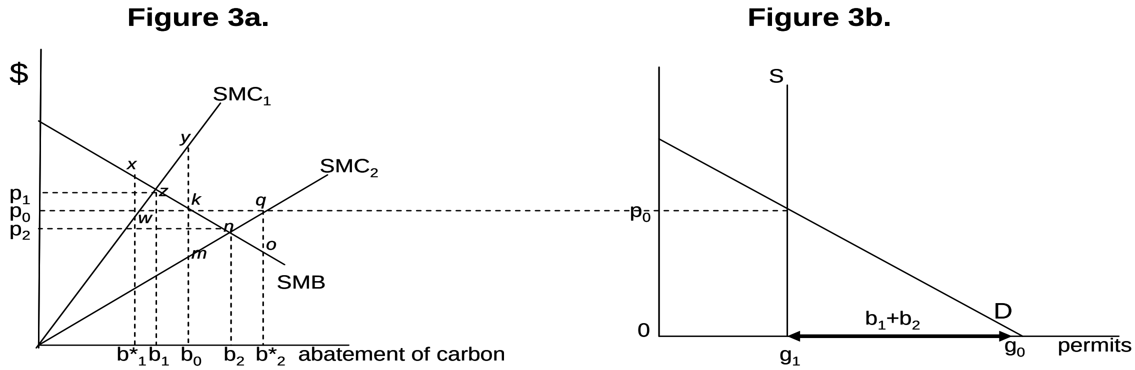
[7] Garnaut, R. (2008) "Garnaut Climate Change Review. Interim Report to the Commonwealth, State and Territory Governments of Australia", available at: http://www.garnautreview.org.au/domino/Web_Notes/Garnaut/garnautweb.nsf.)

5. What if firms face different costs of abatement?

Allowing the trading of permits potentially confers efficiency gains to society compared with a fixed allocation of permits to firms. This is illustrated using **Figure 3** where it is assumed that there are two firms in the industry and each have different SMC of abatement which may be due, for example, to differences in the suitability of alternative technologies that have lower carbon-intensity. The SMC of abatement to firms 1 and 2 is SMC_1 and SMC_2 respectively. Assume that the firms have the same social marginal benefit of abatement, SMB (which, recall, is the negative externalities from the output of carbon by each firm). A socially efficient outcome would require firms 1 and 2 to pay different prices for their permits (i.e. p_1 and p_2 respectively), resulting in abatement levels of b_1 and b_2 and a total demand for permits equal to $g_1=g_0-(b_1+b_2)$.

Figure 3. The market for tradable permits when firms face different costs of abatement



In practice, however, all firms face the same market price for permits. Therefore an aggregate abatement level would be chosen by government along with the implied level of permits, g_1, which in turn implies a permit price, p_0. This leads to abatement of b^*_1 and b^*_2 for firms 1 and 2 respectively. From society's point of view firm 1 does too little abatement because $b^*_1 < b_1$; and firm 2 abates too much because $b^*_2 < b_2$. Hence there is an efficiency loss to society equal to *wxz* from firm 1 and *nqo* from firm 2.

Now compare this outcome with the case where firms are given a fixed (non-tradable) allocation of permits equal to b_0 such that $2*b_0=b_1+b_2$. In this case firm 1 abates too much and firm 2 abates too little relative to the socially optimal level of abatement. The efficiency loss in this case is equal to *zyk* from firm 1 and *knm* from firm 2. These efficiency losses may or may not be greater than the efficiency losses where firms can trade their permits.

However, permit trading confers unambiguous gains if the SMB schedule is flat (which implies that the marginal gain from abatement does not depend on the amount of abatement that is occurring). In that case permit trading would ensure that the SMB equals the SMC for each firm. Students should verify this by drawing the diagram with a flat SMB schedule.

6. What if the costs of abatement are uncertain?

It was pointed out above that in principle a carbon tax and permit trading system can both deliver the optimal level of carbon abatement. As Weitzman[8] (1974) showed, however, this equivalence can break down when the costs of abatement are uncertain.

To see this, consider **Figure 4a** and **4b.** Here we simplify matters in one respect by assuming that all firms are identical. However we relax the prior assumption that the costs of abatement are known with certainty. Rather, SMC_2 is the government's view of the SMC of abatement while SMC_1 turns out to be the actual SMC of abatement. Suppose the government, having decided that SMC_2 is the SMC of abatement, allocates permits in order to produce the optimal abatement of b_2. If the true SMC turns out to be SMC_1, the permit price will be p_0. This creates an efficiency loss of *xyz*. Whereas a carbon tax of T, given the same miscalculation about the SMC curve, would imply a very much smaller efficiency loss because abatement would be only slightly lower than the optimal level (b_2 instead of b_1). (The efficiency loss triangle is too small to clearly show on the diagram.)

Figure 4a. Tax better than permits

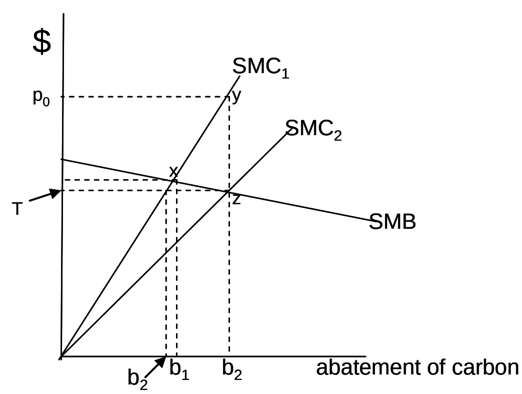
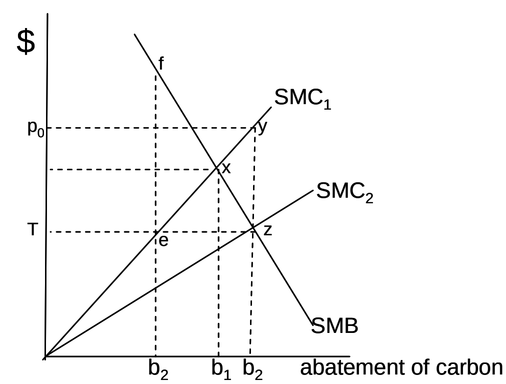


Figure 4b. Permits better than tax



Now consider **Figure 4b** which shows a steeper SMB schedule and flatter SMC schedules. As in **Figure 4a**, the triangle *xyz* is the efficiency loss under a permit system if the SMC turns out to be SMC_1 rather than SMC_2. A carbon tax of T, however, would imply a greater efficiency loss equal to *efx* because abatement would be b_2 which is much lower than the optimal level.

Therefore the permit system provides the smaller efficiency loss the steeper is the MB schedule and the flatter is the SMC schedule. A tax allows firms to optimally adjust their level of abatement which is important if costs of abatement vary more than gains. Indeed, McKibbin in

[8] Weitzman, M.L. (1974) "Prices vs. Quantities', *Review of Economic Studies*, October, 41, 4, 477-91.

Stavins et al (2003)[9] argues that this is supported by the evidence which shows that the MB of greenhouse gases (CO_2, nitrous oxide, chlorofluorocarbons) is very flat because they remain in the atmosphere for such a long time (up to 200 years for CO_2). The first ton and the last ton in a given year will have very similar effects on the atmosphere. The evidence also suggests that the SMC curve is very steep. Nevertheless, the science is not completely settled on this and therefore we must consider the possibility that the true slopes are the reverse in which case **Figure 4b** would apply. In that case fixing the quantity of abatement and letting the price adjust is better than fixing the price and letting quantity adjust.

Other arguments have been advanced in favour of taxes over permits. First, taxes provide more flexibility in response to the business cycle. For example, a situation of weak demand for goods and services implies less demand for carbon and therefore a lower cost of abatement which in turn implies a higher optimal abatement level. A tax would allow firms to adjust to the lower cost of abatement, whereas with a fixed allocation of permits the permit price would simply be lower.

Second, permit prices can be very volatile which implies a more volatile inflation rate and, importantly, price volatility inhibits the incentives to invest in green technology. A tax on the other hand provides a clear price floor for carbon and hence a minimum return for any innovation.

Third, carbon taxes raise revenue that can be used to offset other inefficient taxes thereby cutting the economic costs of carbon abatement; and they can be used to compensate the poor who are hit disproportionately by higher fuel costs. However, this is not a clear advantage of a tax because in principle short term permits could be auctioned on a repeated basis which would raise revenue in the same way as a tax.

It is sometimes argued that a problem with a carbon tax is that it applies to all emissions, not just marginal emissions, which may represent a significant tax burden on firms. However, the same criticism could apply to permits if they are auctioned by government as opposed to being gifted to firms.

Another argument – in this case in favour of permits – is that trading of permits allows a given output of carbon to be produced where it has the highest value; or equivalently, that permits achieve a given level of abatement at lowest cost. There is an incentive to reduce the carbon intensity of production in order to release value by selling permits to those who value them more highly. In terms of **Figure 3a,** firm 1 wants to abate less than firm 2. So, compared with a fixed allocation of permits, firm 1 would want to buy permits from firm 2. The price adjusts to clear the total market for permits and both firms pay the common price which equals their respective marginal costs of abatement. Because they pay the same price which is also equal to their MC of abatement, their MCs of abatement are equalised. Equalising MC is an efficient way of allocating any fixed resource among uses with different marginal costs.

[9] Stavins, R.N.. Wagner, A. and Wagner, G. (2003) Interpreting sustainability in economic terms: dynamic efficiency plus intergenerational equity. *Economics Letters*, 79, 339-343.

However, the weakness in this argument for permits is that, for any given level of abatement, a tax per unit of carbon acts just like a permit price, because it is the price of producing carbon. Hence firms would equate the tax to the MC of abatement in the same way that they equate the permit price to the MC of abatement. The least cost outcome is similarly achieved with a tax, for any given aggregate level of carbon. In practice the difficulty with a tax is that the level of aggregate carbon cannot be known in advance. The tax would have to be adjusted over time by trial and error in searching for the target aggregate level of carbon. Whereas with a permit system the aggregate level of carbon is set *exante* and hence the target level of carbon is automatically achieved.

A way of bringing the permit and tax instruments closer is by designing a permit system that has the flexibility of taxes. This is the aim of the McKibbin hybrid model (see McKibbin in Stavins et al, 2005).[10] The idea is that the permit price would be capped by the government issuing sufficient additional permits whenever the permit price threatened to breach the cap. However these additional permits would have a short expiry date which would give the government the option of either re-issuing them if the permit price was still under upward pressure or not reissuing them if the price pressure had subsided. Hence the short term permits would act as a safety valve. This would address the problem of permit price volatility.

7. Should we subsidise renewable energy production?

Imposing a carbon price is not the only way to abate carbon emissions. As supplementary measures, governments subsidise clean energy such as renewable energy sources (e.g. bio-fuels, wind and solar), so-called "clean coal" technology and carbon sequestration.[11] Subsidies can be direct cash subsidies to consumers and/or producers, or funding for research and development (R & D).

Cash subsidies distort the relative prices of abatement methods by making alternative energy sources artificially cheap, implying that a given abatement is not achieved at least cost. This reduces economic welfare as illustrated in **Figure 5.** In the absence of the subsidies the optimal abatement level of b_1 would be achieved at least cost by firms choosing to abate carbon up to the point where the social marginal benefit equals the social marginal cost. Subsidies distort the relative prices of abatement methods, implying that the costs to firms are not equal to the true social opportunity costs. This causes firms to adopt abatement methods that are not the true least cost methods. In **Figure 5,** firms replace least cost abatements of b_1-b_2 with higher cost methods b_3-b_1. The resulting social loss is the difference between the two areas under the SMC schedule: from b_1 to b_3 and from b_2 to b_1.

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[10] Stavins, R.N.. Wagner, A. and Wagner, G. (2003) Interpreting sustainability in economic terms: dynamic efficiency plus intergenerational equity. *Economics Letters*, 79, 339-343.

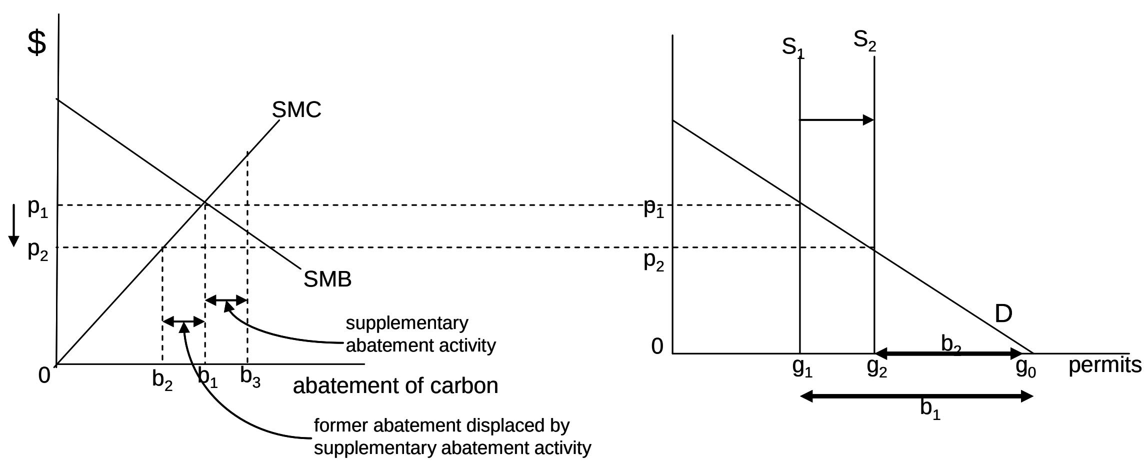
[11] Carbon sequestration refers to the capturing and storing of CO_2 emissions. Capture can be done through photosynthesis, either naturally (by planting trees and other vegetation) or artificially. Storage can potentially occur in the oceans and underground.

In addition to these costs are the standard deadweight losses from the taxation that is required to fund the government expenditure.

The case where supplementary abatement occurs through funding for R & D is a little more complicated. Technological breakthroughs can provide new low cost abatement methods. This would imply a shift of the SMC schedule downwards, which would lower the optimal carbon price and raise the optimal abatement level. This provides net economic gains to the extent that the R & D expenditure would not have occurred anyway through the private sector, and provided that the gains exceed alternative gains from the use of the funds (such as R & D in other sectors) and also cover the deadweight costs of taxation.

Figure 5. The effect of supplementary abatement policies

Figure 5a. **Figure 5b.**



Wrap up

This case study has illustrated a number of issues in the economics of carbon abatement using a framework that integrates the markets for carbon emissions, carbon abatement and carbon permits. The aim of applying the same framework to multiple aspects of the economics of carbon abatement is to deepen students' understanding of what is arguably the major public policy issue facing the world today; and also to deepen students' understanding of the tools themselves, which will enable them to apply the tools to other situations.