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# Out of the Shadows: What's Behind DEFRA's New Approach to the Price of Carbon?

**A report to Friends of the Earth England, Wales and Northern Ireland**

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## 1. INTRODUCTION

DEFRA's (2007) "The Social Cost of Carbon and the Shadow Price of Carbon: What They Are, and How to Use Them in Economic Appraisal in the UK" sets the official UK government carbon price for use in internal decision-making at £25 per tonne of carbon dioxide equivalent ($CO_2e$) in 2007. The non-specialist reader could be forgiven for confusing DEFRA's old measure, the social cost of carbon (SCC), with its similar-sounding replacement, the shadow price of carbon (SPC). The SCC is the present value of future damages resulting from an additional tonne of carbon emissions; as DEFRA now points out, future damages, and hence the SCC, depend on future emissions. The SPC is the value of the SCC if future emissions are assumed to be on track to reach an optimal stabilization target.

Curiously, DEFRA's more sophisticated new method results in exactly the same carbon price as did its previous formulation, published in 2002. Using a social cost of carbon methodology, DEFRA (Clarkson and Deyes 2002:41) suggested a carbon price of £70 per tonne of carbon in 2000, or roughly £25/$tCO_2e$ in 2007[1].

Where the old SCC method estimated the sum of all future costs resulting from each new unit of greenhouse gases that we emit today, the SPC takes a very different approach. DEFRA's SPC methodology begins by making an optimistic assumption about the trajectory of the atmospheric concentration of greenhouse gases over the next few centuries. DEFRA calls the social cost of carbon estimated on the basis of this assumed stabilization trajectory the "shadow price of carbon" or SPC. The SPC is then used as a carbon price to create incentives for greenhouse gas abatement in government projects, thereby lowering emissions and helping to move the world onto a new stabilization trajectory. It's a chicken and egg conundrum: The assumed stabilization trajectory determines the SPC, and the SPC helps determine the actual trajectory.

In its latest spending review, the House of Commons Environmental Audit Committee (2008:19) expressed its dissatisfaction with what it called the "fatal circularity" of the SPC methodology:

> *[B]y assuming that action will be taken to ensure that the effects of climate change will be relatively mild, the paper concludes that the costs of climate change are relatively low. In doing this, however, it is setting a relatively low carbon price to be plugged into all Government decision-making today. The risk is that this will fail to discourage the approval of policies and projects that will lead to a growth in carbon emissions – and thus help to make it more difficult to achieve the stabilisation target that the paper assumes will be met.*

The shaky foundations for DEFRA's low carbon price are the subject of this critique. The next section addresses logical and technical problems with DEFRA's new methodology: the circularity of a carbon price that is set on the basis of an assumed future stabilization trajectory; the contradiction of an optimistic stabilization trajectory that leads to very little abatement; and an argument for not using Stern's discount rate while claiming that it is correct. The section concludes, on technical grounds, that DEFRA's SPC methodology is fundamentally flawed.

These technical issues are followed by a section detailing some of the more serious ethical concerns raised by DEFRA's methodology: whether a country need abate when it can rely on the abatement of others, and the meaning of equity in paying the global costs of abatement. The final section sets out conclusions and policy recommendations including a brief description of a different methodology that could be used to set an ethical and efficient UK carbon price.

## 2. TRAJECTORY-BASED CALCULATION OF THE COST OF CARBON

DEFRA's (2007) new SPC-based carbon price originates from the Stern Review's (2006) social cost of carbon for a path leading to stabilization at 550ppm $CO_2e$. Stern's year 2000 cost of carbon is £19/$tCO_2e$ for the 550ppm $CO_2e$ stabilization trajectory; on this basis DEFRA concludes that the appropriate SPC to set on the use of carbon in the UK is £25/$tCO_2e$ in 2007 (this includes a 2 percent increase for each year). DEFRA's analysis assumes that the world is and will be on the 550ppm trajectory; if any other trajectory were assumed, the result would be a different carbon price.

This particular price, DEFRA explains, is chosen to support the need for policies consistent with the global 450 to 550ppm $CO_2e$ target, set out in Stern, while insuring against the risk of underabatement by taking

1 Clarkson and Deyes' (2002:4) year 2000 carbon price was £70/tC * (12tC/44t$CO_2e$), or £19/t$CO_2e$; using DEFRA's (2007) inflation adjustment calculation, this would be £25/t$CO_2e$ in 2007.

the highest end of this range. To give the Stern's 450 to 550 ppm $CO_2e$ range of stabilization trajectories some context, a recent Tyndall Centre report states that the Climate Change Bill's plan to cut UK emissions 60 percent by 2050 is consistent with only a 650 to 800ppm $CO_2e$ target[2]. If DEFRA were to base its SPC analysis on the more pessimistic assumed trajectory of 800ppm $CO_2e$, the result would be a much higher carbon price creating incentives for much more abatement, and, eventually, the achievement of a lower stabilization trajectory.

In DEFRA's methodology, the lower (or better) the assumed stabilization trajectory, the lower the price of carbon. At first glance, this may appear contradictory – an impression that further analysis tends to support. DEFRA's argument goes like this: The carbon price is a value placed on future damages, and a lower stabilization target means lower future emissions and, therefore, lower damages. Yet when the price is viewed as an incentive for carbon reduction, a lower price means that a smaller amount of abatement, and more damages, will take place. This contradiction – an *optimistic* stabilization trajectory that results in less abatement – has its source in DEFRA's circular trajectory-based methodology, in which the assumed trajectory determines the carbon price, which determines the actual trajectory.

Three modeling choices – raising one big and two small issues – make DEFRA's carbon price lower than the widely advertised results of the PAGE model used by Stern.

- First, the big issue is that DEFRA's carbon price is based on an assumed 550ppm $CO_2e$ stabilization trajectory, while Stern's much higher carbon price of £65/t$CO_2e$ in 2000 is based on an approximation of the world's current business-as-usual trajectory[3].
- Second, DEFRA uses a different set of exchange rates (to convert dollars to pounds) than Stern; the exchange rate used in the Stern Review would increase DEFRA's carbon price from £19/t$CO_2e$ to £30/t$CO_2e$ in 2000.
- Third, DEFRA (2007:9-10) recommends a two percent "uprating" in each future year because "as time goes on, the damage comes closer, and is discounted less heavily; so its present value rises, increasing the SCC", as well as to reflect "the Stern Review's assessment of the rising incremental damage of each unit of carbon as temperatures rise." Chris Hope, the economist who created the PAGE model, has recommend uprating its resultant carbon price at 3 percent each year; DEFRA (2007:10) strangely attributes its choice of a lower rate to unspecified uncertainty. (One would expect uncertainty to justify higher, not lower, increases in future carbon prices.)

Although all three issues influence DEFRA's carbon price, our focus here is largely on the topic of trajectory-based costs.

The next stage for DEFRA is a comparison of its carbon price of £25/t$CO_2e$ to several studies of the marginal abatement cost for this same stabilization trajectory. The purpose of this comparison is to demonstrate that the carbon price set using DEFRA's SPC methodology is high enough to pay for the desired level of abatement. That is, it appears that a roughly similar result could have resulted from a calculation based on abatement costs. This, however, is not the logic behind the SPC. Like their previous social cost of carbon (SCC) method, DERRA's SPC is based on the cost of *damages from emissions* – it contains no information about the cost of *stopping or slowing emissions*. In contrast, abatement costs are based on estimates of how much it would cost to eliminate specific amounts of emissions.

Using DEFRA's uprating schedule, its carbon price would reach £32/t$CO_2e$ in 2020 and £39/t$CO_2e$ in 2030, well above the marginal abatement costs in two of the three studies considered. One study examined global abatement costs, or the cost of abatement assuming that all abatement opportunities around the world are available to the UK, and found marginal abatement costs for 2030 ranging from £27/t$CO_2e$ at

2 Anderson and Bowes (2007) report 600 to 750ppm $CO_2$; we've added a flat 50ppm to both ends of this range as a ballpark conversion to $CO_2e$.

3 Stern's (2006:287) PAGE model results in a carbon price of £65/t$CO_2e$ in 2000 in the business-as-usual scenario. An uprating convention of 3 percent per year, recommended by the designer of the PAGE model (as cited in DEFRA 2007:10), results in £75/t$CO_2e$ in 2007. For a comparison of the Stern and DEFRA exchange rates see DEFRA (2007:20).

450ppm to £17/t$CO_2$e at 550ppm[4]. Studies limited to those abatement opportunities available in the UK had contradictory results: one showed £25/t$CO_2$e to be an appropriate price for 2020 marginal abatement in the 450 to 550ppm range; in the other, UK marginal abatement costs would be significantly higher than the cost of global abatement opportunities. DEFRA (2007:8) concludes that "available evidence provides some indication that the [carbon price] is broadly in line with meeting the 450ppm goal providing full international abatement options can be exploited, although the figure will depend on the degree of abatement required to take place in the UK."

The bulk of the critique presented here takes DEFRA's choice of modeling parameters as given: the nuts and bolts of exchange rates and uprating are not the most serious problems in DEFRA's methodology. DEFRA's choice to set price incentives using an assumed stabilization trajectory, rather than the world's actual current trajectory, is the most important determining factor in the overall scale of the resultant carbon price. DEFRA's trajectory-based methodology combines a misinterpretation of shadow pricing with the power of positive thinking. The result is a carbon price that will provide scant incentive for UK greenhouse gas abatement and, therefore, fail to achieve its stated goal, a 450 to 550ppm $CO_2$e trajectory.

**A Lexicon of Carbon Price Names**
Many different names are given to carbon prices, usually based on the method used to estimate them. The following terms are used in this report:

**Carbon price** – A carbon price is a generic term for a value applied to each unit of carbon emissions, regardless of the methods used to determine this value. A carbon price can be set on the basis of the marginal abatement cost, the social cost of carbon, the shadow price of carbon, DEFRA's SPC, or some other estimation technique.

**Marginal abatement cost** – The marginal abatement cost (MAC) is an estimate of how much it would cost to reduce (or "abate") the next unit of carbon emitted. It is commonly assumed that the more carbon that is abated (that is, the lower the emissions) the more expensive it becomes to abate the next unit. The presumption is that the cheapest and easiest abatement techniques will occur first, leaving the more expensive techniques for the future.

**SCC** – The social cost of carbon (SCC) is the present discounted value of the future stream of costs resulting from today's emission of a new unit of carbon. Social costs are also called damage costs. The "present discounted value" is a way of making commensurate damage costs that will take place in different years. Future costs are discounted, or reduced in value; the further into the future a cost occurs, the less value it is given in present terms.

**Shadow price** – A shadow price is the price of a negative externality, or a negative environmental effect that is not included in a good's market price. The shadow price of carbon is determined by estimating marginal abatement costs and social (or damage) costs for a range of different emissions levels. The shadow price is the price at which the marginal abatement costs and social costs agree.

**SPC** – DEFRA's "shadow price of carbon" (SPC) is not, in fact, a shadow price in the classic sense of this term. Instead, the SPC is determined entirely by the social cost of carbon at an assumed stabilization trajectory. Marginal abatement costs are then, in very general terms, compared to the SPC to assess its accuracy. The SPC is determined by an assumed emissions level, while a true shadow price is determined by the intersection of marginal damages and marginal abatement costs.

This report refers to DEFRA's "shadow price of carbon" as the SPC, and refers to shadow prices, in their classic sense, as *shadow prices*.

4 Enkvist *et al*. (2007) in euros. An exchange rate of 0.67 was used to convert to pounds.

### Misinterpreting the Shadow Price

The starting point of DEFRA's analysis is the range of desirable stabilization trajectories determined by the Stern Review, 450 to 550ppm $CO_2e$. This range is then narrowed to a single target or assumed trajectory:

> *Within the Stern range, the tighter the emissions target, the lower the SCC [social cost of carbon] will be, since there will be less damage from climate change. Thus in Stern's suggested range, the SCC is highest for 550ppm $CO_2e$. Care is therefore needed in selecting the specific target on which to base the UK's SPC. If the SCC exceeds the required MAC [marginal abatement cost] for the given goal, this will lead to overachievement of the target. However, if the SCC is below the MAC for the expected stabilization goal – too little investment will take place.* (DEFRA 2007:4; original emphasis)

In DEFRA's SPC method, the stabilization trajectory determines the carbon price and therefore the level of abatement – a conclusion that is not consistent with the standard interpretation of the shadow price methodology.

Greenhouse gas emissions constitute what economists refer to as a negative externality: The costs of climate change are very serious, but emissions are treated as costless in production decisions. Because the costs of emissions are missed or ignored, production that requires the emission of greenhouse gases seems to be much cheaper than it actually is. More of these goods are supplied in the market than there would be if a full accounting of costs were made; this means that prices are low, and as a result consumers buy more of these products than is optimal from the point of view of the social good.

If carbon had a price, or equivalently if goods that contained carbon were taxed, fewer such goods would be sold, and less carbon emitted. This process is called "internalizing the externality" or assigning a price to something that is being treated as costless (see Technical Note 1 for further explanation). But how can we calculate the correct "shadow price" to place on the externality so that society gets the greatest possible benefit?

In Figure 1, social costs increase with each additional unit of carbon emitted while abatement costs decrease with each additional unit of carbon emitted. The intersection of these two curves (or the simultaneous solution of these two functions) is called the equilibrium and is said to indicate an optimal level of pollution. (Following the marginal abatement cost curve from right to left, the more carbon we abate, the more expensive that abatement becomes.) Of course, such a solution can only be as accurate as the assumptions made in measuring social costs and abatement costs. This equilibrium level of pollution gives rise to a shadow price: the marginal damage cost (or social cost of carbon) and the marginal abatement cost at the "optimal" emissions level. Only at the equilibrium does the social cost of carbon equal the marginal abatement cost, which equals the shadow price.

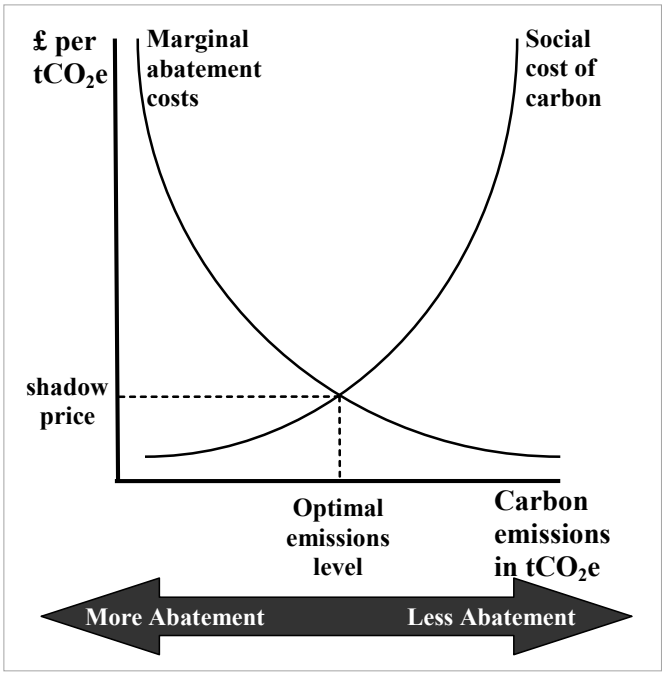


Figure 1: Determining the Shadow Price

**Equilibrium and the "Optimal" Level of Emissions**

There is no reason why damage costs would necessarily equal abatement costs at any particular level of emissions, however, since damage costs increase and abatement costs decrease as emissions grow, there will likely be *some* level of emissions for which the two kinds of costs agree. The neo-classical school of economics often attaches a special significance to this coincidence of damage and abatement costs. The "equilibrium" level of emission – where the damage and abatement cost curves agree – is very commonly treated as a goal or target, and is even called the "optimal" level of emissions. The equilibrium level of emissions is said to be desirable because:

- If emissions were higher than the optimal level, each new effort at abatement would create more savings in avoided damages than the costs of abatement. Producers would choose to reduce emissions to the optimal level.
- If emissions were lower than this level, each new effort at abatement would cost more than the possible savings in avoided damages. Producers would choose to abate less, or emit more, until they reached the optimal level.

The equilibrium level of emissions is "just right". While on the surface, this seems like a rational approach to decision making, reifying the equilibrium level of emissions tends to ignore questions of distribution. Social costs of carbon are net costs (costs to society less benefits to society). The segments of society that suffer the worst social costs from climate change will likely desire less emissions, and more abatement, than the "optimal" level.

DEFRA's shadow price of carbon (SPC) is not a true shadow price, in the sense that this term is commonly used in environmental economics. A shadow price, together with its associated optimal level of emissions, is the intersection of the social cost and marginal abatement cost curves (see Technical Note 2 for further discussion). Instead, in DEFRA's methodology, the SPC is the social cost of carbon at the assumed stabilization trajectory (see Figure 2). Using this approach, it is impossible to know whether the SPC is higher or lower than the true shadow price, or by how much, because the marginal abatement cost curve is not included in the assessment; as a result, there is no way to know whether the UK will abate an amount that is too much, too little, or just right[5].

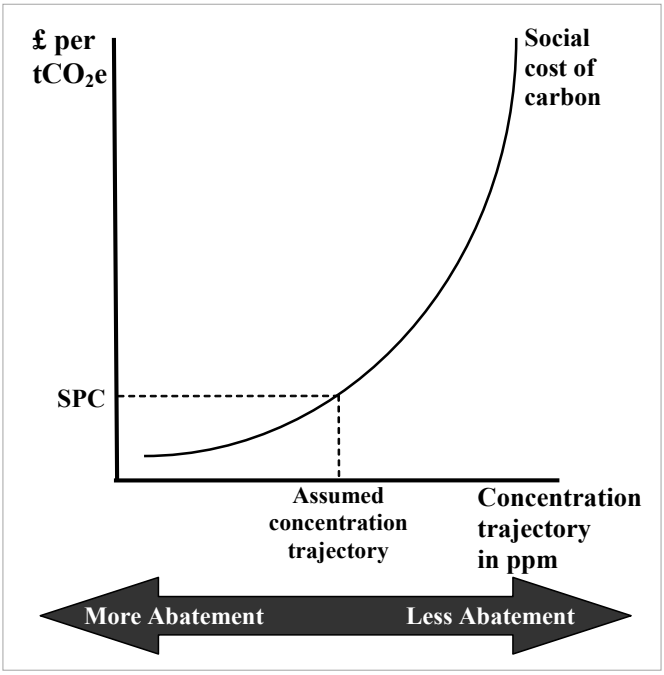


Figure 2: DEFRA's SPC Methodology

5 Later on in DEFRA's analysis, measurements of the marginal abatement cost at the assumed stabilization trajectory are considered, but the equilibrium condition does not determine the SPC.

While a carbon price can be set solely on the information contained in the social cost function, *the amount of abatement that it will buy is determined by the marginal abatement cost curve*.

Taken step by step, DEFRA's SPC methodology is as follows:

1. DEFRA chooses an assumed target stabilization trajectory that is consistent with successful global cooperation in greenhouse gas emissions abatement.

2. The social cost of carbon is estimated at the assumed global cooperation stabilization trajectory and called the SPC (see Figure 2).

3. The SPC is applied as a carbon price in policy appraisal. That is, DEFRA's carbon price will be assigned in appraisal of government projects *as if* they had to pay a charge for the carbon that they use. Decisions about the cost-effectiveness of these projects will then be made, taking into consideration the cost of carbon. (If the SPC was also applied in the market, private firms would have to make an analogous choice, either paying for or reducing their carbon emissions. Any cost-effective abatement – i.e., any reduction in emissions that could be achieved at a cost lower than the SPC – would then be profitable for businesses to carry out on their own. At present, however, there are no plans or proposals to actually impose the SPC on the private sector.)

4. So how much abatement would result from the application of the SPC as a carbon cost (in the private sector as well as the government)? The actual amount of abatement can be read from the marginal abatement cost curve at the SPC price. Producers would not abate any more than this amount (labeled actual emissions in Figure 3 below) because it would be cheaper to pay the charge to continue emitting carbon. (To the left of the actual emissions level, the marginal abatement cost is greater than the SPC.) Producers would not abate any less than this amount because it would be cheaper for them to abate a little bit more than to pay the charge. (To the right of the actual emissions level, the SPC is greater than the marginal abatement cost.) But nothing in DEFRA's method guarantees that the actual level of emissions will be the same as the targeted level.

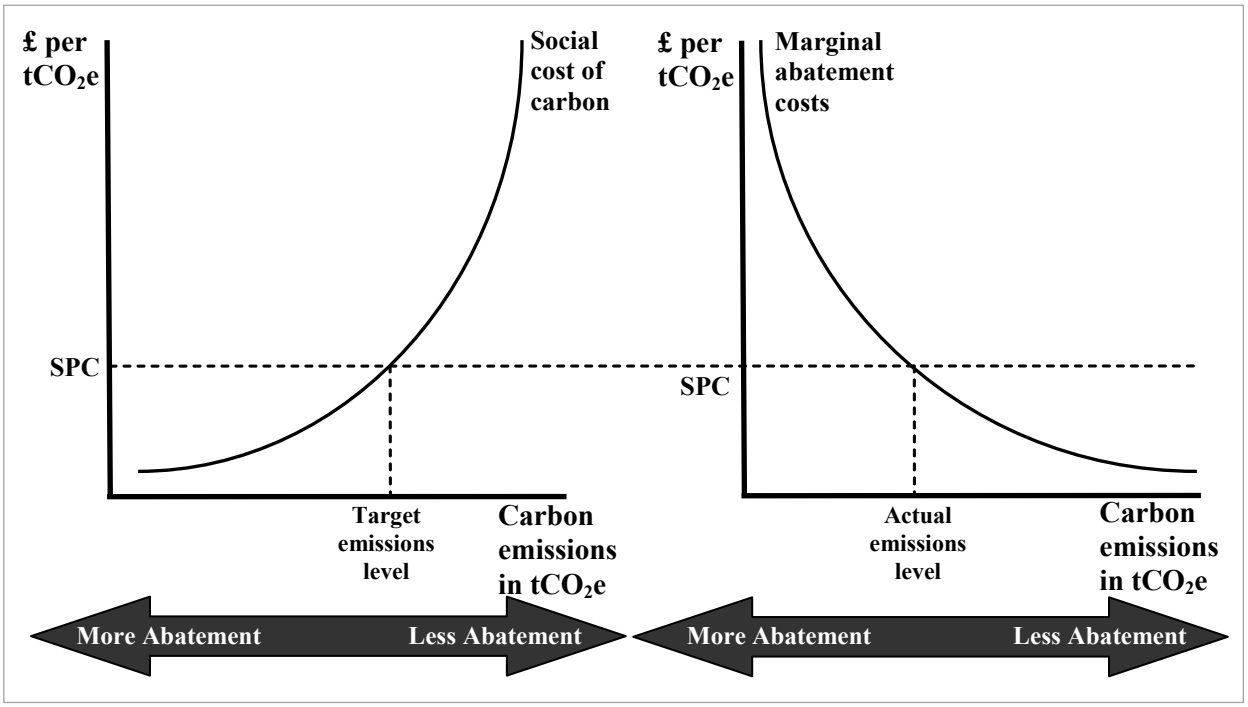


Figure 3: Determining the Actual Level of Emissions

In short, too high an assumed stabilization trajectory (that is, a pessimistic projection with high future emissions) leads to "too much" abatement. Too low of an assumed stabilization trajectory (an optimistic projection with low future emissions) leads to "too little" abatement. In somewhat more technical terms, if the assumed concentration trajectory is higher than the optimal level of emissions, then the SPC will be higher than the true shadow price (see Figure 4, and refer to Technical Note 3 for a more detailed explanation). For all SPCs that are higher than the true shadow price, actual emissions will be lower than the assumed emissions: too much abatement will occur. If, on the other hand, the assumed concentration trajectory is lower than the optimal level of emissions, then the SPC will be lower than the shadow price (see Figure 5). For all SPCs that are lower than the true shadow price, actual emissions will be higher than the assumed emissions, and too little abatement will occur.

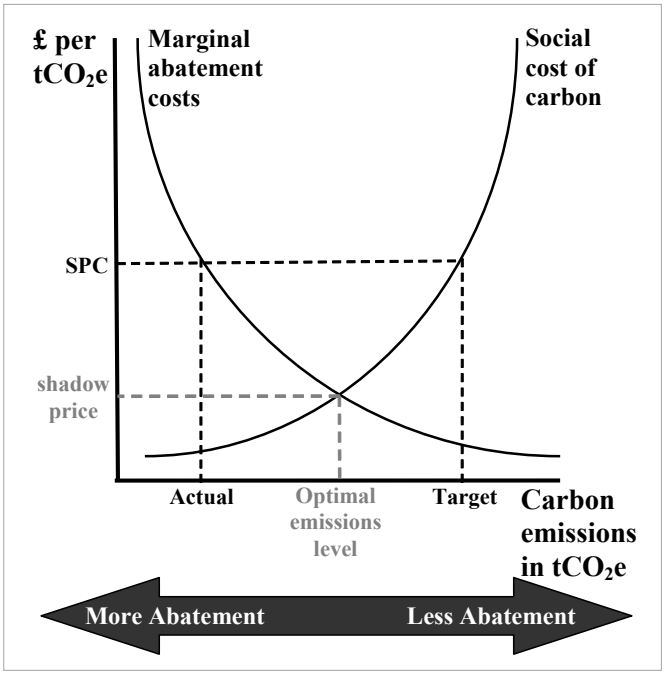


Figure 4: Too Much Abatement

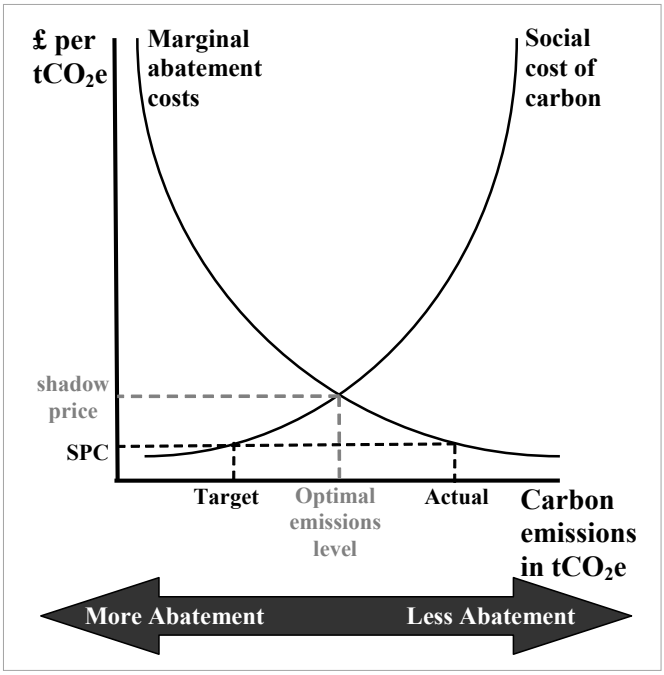


Figure 5: Too Little Abatement

It is on this basis that DEFRA (2007:4-5) chooses the 550ppm $CO_2$e concentration trajectory as its target, or expected value: "For this reason, and in order to be more certain that the UK is undertaking sufficient abatement to help achieve the stabilization goal, we believe it is prudent to adopt a SPC based on the [social cost of carbon] at the top of the 450-550ppm range." A lower assumed stabilization trajectory would risk too little abatement (see Technical Note 3).

Unfortunately, an assumed 550ppm stabilization trajectory does not completely insure against insufficient abatement: the optimal level of emissions could be higher than the target range, the actual social cost of carbon could be higher than the measured social costs, or actual abatement could be more costly than estimated. (See Technical Note 4 for a graphical analysis of each point.)

If the optimal emissions level (at the intersection of the social cost and marginal abatement cost curves) is higher than the targeted 450 to 550ppm $CO_2$e range – that is, if worldwide abatement measures would be more costly to society than the savings from avoided damages – then the SPC will be too low to provide incentives for the necessary amount of abatement. This contradiction is discussed in the next section of this critique: more pessimistic assumptions about the concentration trajectory indicate a higher SPC and more abatement, while more optimistic assumptions lead to less abatement in DEFRA's methodology.

Overly optimistic assumptions can lead to underinvestment in abatement in a second way. If the estimated social cost of carbon fails to include some actual current or future costs, the result is, again, a SPC that is lower than the true shadow price, and insufficient abatement. Accurate measurement of social costs is a problem not just in the use of DEFRA's SPC, but in the shadow price methodology more generally. Only the true shadow price can provide the correct incentives for a socially optimal result, but the social cost curve may be described incorrectly due to incomplete knowledge regarding the impacts of climate change. According to the Environmental Audit Committee (2008:18), "The strict monetary value given for the SPC will undoubtedly be an undervaluation, given that it explicitly excludes social costs such as those arising from mass migrations and local wars due to increased flooding and droughts." More generally, any estimate of social costs must necessarily be incomplete – it would be impossible to account for every future impact of climate change; values placed on social costs, therefore, always should be assumed to under-estimate true social costs.

In addition, because the estimation of social costs requires not just scientific knowledge but also value judgments, there could be said to exist an infinite number of "correct" social cost curves across a range of very different ethical perspectives. If Group A is more concerned about the well-being of those who are not a part of their immediate society than Group B, then Group A would perceive the optimal level of emissions to be lower. Group B's less inclusive notion of social costs would result in a higher optimal level of emissions[6].

A similar set of issues exists with regard to the marginal abatement cost curve. DEFRA (2007:7) discusses the likely possibility that a global marginal abatement cost function – based on the assumption that the world's least cost abatement options are available to the UK – would be lower than a strictly UK abatement function. More generally, if the costs of abatement are underestimated, the true shadow price will be greater than the SPC, and the investment in abatement that takes place will be insufficient to reach the socially optimal emissions level[7].

DEFRA's method attempts to triangulate the true shadow price by beginning with the Stern Review's cost of carbon at the optimistic 550ppm $CO_2$e concentration trajectory, and then reviewing the accuracy of Stern's estimate using data on global and UK-specific abatement costs. DEFRA's SPC will be equal to or greater than the true shadow price (assuring a minimum level of abatement consistent with the chosen stabilization trajectory) as long as worldwide abatement initiatives are strong, and actual damage and abatement costs are no higher than estimated costs. It will fail to create sufficient incentives if worldwide

6 On the role of values in the measurement of the social costs of climate change see Ackerman and Stanton (2008) and Ackerman, DeCanio *et al*. (2008).

7 The costs of abatement may be underestimated in practice, because many cost-effective investments in energy efficiency do not occur. Thus an analysis that acknowledges the current failure to adopt all cost-effective abatements would imply a higher carbon price, and would call for more investment to reach the optimal emissions level. However, the policy recommendation that flows from that analysis is to create incentives and programmatic support to implement the full range of cost-effective energy savings – which would lower the cost of abatement and, on DEFRA's logic, would lower the carbon price as well.

abatement initiatives are weak, damage or abatement costs have been underestimated, or Stern's target 450 to 550ppm $CO_2$e range of stabilization trajectories is too low or is no longer achievable.

**Uncertainty and the SPC**

It should be emphasize that both the estimated social cost of carbon and the estimated marginal abatement costs are uncertain – they cannot be calculated to any reliable level of accuracy. (There is no known probability, for example, that a £25/t$CO_2$e carbon tax will create sufficient incentives to meet the UK's carbon reduction goals.) DEFRA (2007:12) addresses the uncertainty of its carbon price by offering a "sensitivity range" of -10 percent to +20 percent, or £22 to £31/t$CO_2$e, for use in decision making. This choice of sensitivity range requires a noteworthy departure from DEFRA's earlier SCC methodology, where the range of -50 percent to +100 percent would be £12 to £50/t$CO_2$e for the current SPC. Neither choice of sensitivity range is based on a rigorous exploration of risk and uncertainty in the measurement of the social cost of carbon. Instead, the choice of these ranges involved judgment calls about how large a band of carbon prices DEFRA should consider in evaluating future policy options.

The old sensitivity range implied a relatively large degree of uncertainty about the cost of carbon; DEFRA's explanation of the new range indicates that the uncertainty is now much reduced, but offers no persuasive explanation of the change. According to DEFRA, the old, higher limit "has hindered decision making" – suggesting that there are some specific policy decisions for which a £50/t$CO_2$e carbon price leads to a different decision than £25/t$CO_2$e, while £31/t$CO_2$e might endorse the same choice as £25/t$CO_2$e. DEFRA does not elaborate on these decisions, and the different choices to which a higher cost of carbon might lead us. Given the uncertainties involved in estimating the social cost of carbon, how sure can we be that the decisions taken with a £50/t$CO_2$e carbon price would not lead to the better outcomes in terms of British welfare than decisions taken with a £31/t$CO_2$e carbon price?

Two important sources of uncertainty in DEFRA's calculation are omitted costs and benefits (discussed above), and double-counted costs and benefits. DEFRA's instructions for how to apply the SPC in the assessment of government projects includes a warning against double counting: "In producing policy and project appraisals we need to be careful to make sure that externalities are not counted twice. Where policy/project costs already reflect – wholly or partly – the social cost of carbon, only the remaining external part of the SPC should be added." Consistent application of this principle, however, requires a clear statement of which things would constitute double counting, and which would not. It is equally erroneous to exclude other internalized externalities in the effort to avoid double counting carbon. For example, energy and fuel taxes may be forms of internalizing the climate change warming externality, but if (as we believe) some fuel taxes are designed instead to internalize the externalities of congestion, nongreenhouse- gas air pollution, or other impacts, these should be counted as separate categories, parallel to the internalization of the carbon externality.

This adds particular complexity to the point made by DEFRA regarding the exclusion of taxes and transfers from a cost-benefit analysis. Economic theory does endorse the exclusion of these categories, if they are *not* enacted to internalize externalities. On the other hand, taxes and transfers (such as subsidies) that *are* designed to internalize externalities must be included, in order to "get the prices right." To rigorously apply this theory, one would have to collect complete information on costs and benefits, identify all taxes and subsidies that enter into the data, determine which are externality-based and which are not, and then exclude the nonexternality taxes and transfers. Opportunities for error in both directions – double counting and under-counting – are rife, and the claimed simplicity and transparency of cost-benefit calculations recedes ever farther into the distance.

### The Power of Positive Thinking

DEFRA's more pessimistic assumptions about the stabilization trajectory indicate a higher SPC and more abatement, while its more optimistic assumptions lead to a lower SPC and less abatement. This Orwellian accomplishment is the result of the implicit assumption that once a desired stabilization trajectory has been chosen, the UK must behave as though this is the world's actual current trajectory. Plainly, Stern's proposed trajectory of 450 to 550ppm $CO_2e$ and our current business-as-usual trajectory toward somewhere upwards of 800ppm are not one and the same. The following question emerges: Is it better to set price incentives that are consistent with our current circumstances, in order to deliver the climate outcomes to which we aspire – or incentives that are consistent with those desired future outcomes, as if we had already achieved them today?

The consequence of setting the SPC using the social cost of carbon implied by our current stabilization trajectory would be "too much" abatement (see Figure 6), but only if that same SPC were maintained well into the future. A policy of a high SPC today that gradually would be reduced as new energy-efficient technologies became commonplace would spur innovation sooner rather than later. Those countries that invest early in what will become the technology of the future will likely reap greater economic benefits than those that wait to adopt technology invented elsewhere[8].

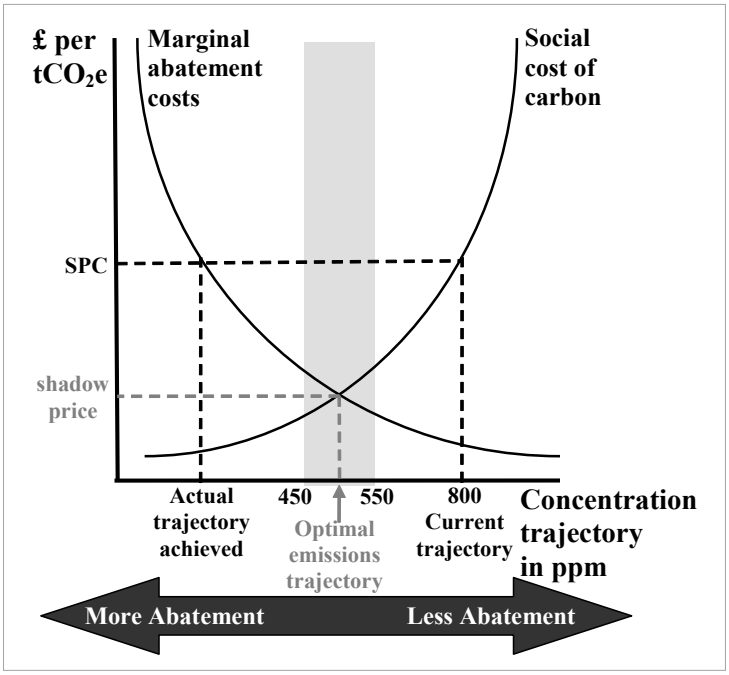


Figure 6: Incentives of the Current Trajectory

An important assumption underlying DEFRA's analysis is that it makes no difference whether the abatement occurs later rather than sooner – the stabilization trajectory's terminal concentration is the centerpiece of this methodology, while the shape of the stabilization trajectory is not considered (see Figure 7). Stabilization trajectories may be concave (like Trajectory A), wantonly emitting greenhouse gases until the last possible moment, or convex (like Trajectory C), taking a more cautious approach by investing early in abatement technology.

8 For a detailed treatment of this topic see *The Energy Journal* (2006) special issue on "Endogenous Technical Change and the Economics of Atmospheric Stabilisation."

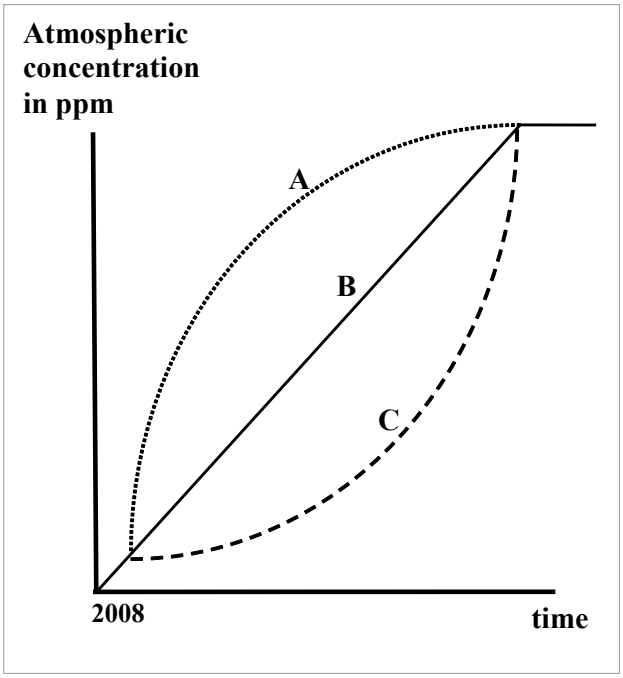


Figure 7: Stabilization Trajectories

Some of the best-known economic models of climate change recommend the former – a deliberate policy of waiting until abatement technology is cheaper in the future, assuming that the passage of time in and of itself reduces technology costs (Nordhaus 2007a; b). Experts on technological development advocate the latter course of action – investing early – citing the importance of learning by doing to both innovation and increasing technological efficiency[9]. The cost of new technology is determined by the stock of technology and the pace of innovation; it is only coincidentally correlated with the passage of time.

Moreover, a policy of waiting to reduce emissions clashes with the latest climate science, which implies that damages are greater from early emissions (Rhys 2008). The rate of reabsorption of carbon dioxide out of the atmosphere, into oceans, soil, and plants, is extremely low and may be decreasing. As a result, any increased emissions of carbon dioxide into the atmosphere will remain there for extraordinary lengths of time, far more than a century on average. So emitting carbon now rather than later simply means that the damages start sooner, but persist throughout the relevant time frame in which the climate problem must be addressed and resolved.

By focusing only on the terminal concentration, DEFRA ignores the macroeconomic ripple effects of new technology: job creation and less expensive production. The positive macroeconomic impacts of abatement are not included in Stern's social cost of carbon function. Nor do they appear to be included in the global and UK marginal abatement cost assessments cited in DEFRA (2007). Instead, the economic benefits that ripple from technological innovation are positive externalities missed by the SPC methodology.

Positive thinking is essential in setting goals for abatement – if achieving a better stabilization trajectory than the one we are currently on is impossible, why bother abating at all? But the connection between setting a stabilization goal and using that goal to set current incentives is underexplained in DEFRA's report, and the reason may be that DEFRA's methodology is poorly suited to its stated goals. Given the starting point of a 450 to 550ppm $CO_2$e target range of stabilization trajectories, there are at least two more obvious choices of methodology: the use of a vertical social cost function within the shadow price methodology and cost effectiveness analysis.

Any firm limit to emissions can be depicted as a vertical social cost function, or a social cost function that has a vertical section. Vertical costs are perfectly inelastic: there is no amount of money that society would accept to increase emissions beyond the stated limit; above the emissions limit, social costs are infinite (see Figure 8). When social costs are perfectly inelastic, any attempt to measure them with the

9 See *The Energy Journal* (2006) special issue on "Endogenous Technical Change and the Economics of Atmospheric Stabilisation."

goal of assigning a price to a negative externality (like a charge set on the use of carbon) would be both fruitless and unnecessary: all that matters in this case is an accurate accounting of the marginal abatement cost at the target emissions level. The resulting shadow price can then be used as an incentive, and it should be the "correct" price – the price that will cause the desired amount of abatement. Of course, if the marginal abatement costs have been measured incorrectly, the shadow price will fail to provide the correct incentives.

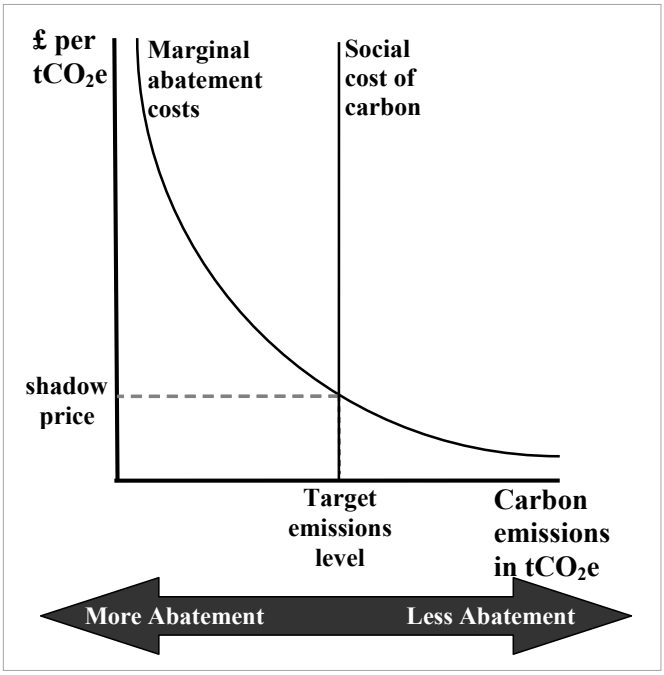


Figure 8: Vertical Social Cost Curve

Cost effectiveness analysis is a closely related approach that avoids the shadow price method's reliance on price incentives to do the heavy lifting. A cost effective strategy is the most efficient (or cheapest) means to reach a stated goal and is usually implemented through regulation. If the goal is a given amount of carbon abatement, than all possible abatement strategies would be listed along with a schedule of the expected marginal cost of abatement for each project at each possible level of abatement. It is unlikely that any one strategy will be sufficient to achieve the UK's entire abatement objective, but the least cost strategies could be employed first with gradually more expensive techniques (or whenever possible newly invented, even more efficient technologies) introduced over time. DEFRA (2007:14, 16-17) discusses the importance of cost effectiveness in the choice of which specific projects should be implemented first, but only in the context of the shadow price as incentive[10].

Global cooperation can still turn our current 800ppm $CO_2$e or more stabilization trajectory into a 450 to 550ppm $CO_2$e, but it will not be easy – and positive thinking is not enough to get us there. Realistic incentives can only be set based on current criteria, not on possible future conditions. DEFRA's SPC methodology mistakes wishful thinking for careful planning; a £25/t$CO_2$e carbon price – even if placed on all UK emissions and not just public entity emissions – will not create sufficient incentive for achieving a 450 to 550ppm $CO_2$e stabilization trajectory. The Environmental Audit Committee (2008:17) point out an

10 DEFRA (2007:17) express the concern that "a cost effectiveness ranking of policy options designed to reduce carbon emissions will invariably omit the large number of policy measures for which carbon abatement is not the primary goal, but which nevertheless have a significant influence on emissions. Many thousands of individual decisions across the public sector fall into this category – including decisions on the planning framework, infrastructure projects, the construction specification of schools and hospitals, and the configuration of transport projects. It is unrealistic to assume that all of these decisions can be reflected in, and influenced by, a single costeffectiveness analysis." DEFRA seem to assume that the entire price of infrastructure projects would be considered in ranking cost effectiveness. On the contrary, for all government projects or policies with a carbon impact, only the difference in price between higher and lower emissions specifications should be included in an accounting the marginal abatement cost.

additional concern in their recent review, "The overall risk is that the incorporation of a Shadow Price of Carbon into all policy decisions may actually lead to less thought being given to implications for climate change strategy, while simultaneously giving a false sense of assurance that the opposite is the case."

### DEFRA's Discount Rate

In addition to setting a low carbon price based on an assumed optimistic stabilization pathway, DEFRA extend their trajectory-based methodology to a corollary procedure regarding the discount rate. The import of DEFRA's approach is that the Green Book's 3.5 percent discount rate should be used instead of Stern's 1.4 percent discount rate in UK climate policy decisionmaking. The bigger the discount rate, the lower the present value that is placed on future costs and benefits. The costs of climate policy – investments that reduce the emission of greenhouse gases – begin today and continue at a high level in the near future, while the biggest benefits of climate policy (avoided damages) are expected to occur 50, 100 and even 200 years into the future. The choice of a large discount rate creates not only a bias for weighing impacts to the current generation more heavily than those of future generations, but also for weighing near-term costs more heavily than long-term benefits.

There are two reasons why the discount rate could depend on the future trajectory of economic growth and carbon emissions. First, the discount rate depends in part on the rate of growth of per capita consumption; faster growth leads to a higher discount rate. Second, the rate of pure time preference – the discount rate that would apply in the absence of economic growth – is much lower in the Stern Review than in the Green Book. The second is the more important and controversial point, expressing an ethical judgment about the welfare of present versus future generations.

In describing the appropriate application of its carbon price to UK government project assessment, DEFRA (2007:14-15) give instructions regarding the use of discount rates:

> *The Stern approach is appropriate in assessing the current generation's willingness to pay to avoid the impacts of climate change in the future – this is a non-marginal decision – and that is therefore what the [carbon price] used in current decision-making should reflect. However, most (perhaps all) individual policy decisions which impact on our emissions are at the margin. In assessing the present value of future streams of costs and benefits, therefore, the approach described in the Green Book should be used.*

Once a particular trajectory has been set or is treated as if it were set – as is the case in DEFRA's trajectory-based method – all decisions are marginal, that is, based on small incremental changes. While this may be true within the confines of DEFRA's model, in the real world the future stabilization trajectory is not set and most decisions are not marginal. In an imaginary future in which the big decisions that define the pace of overall global emissions reduction had all been taken, and the world was already locked onto a path headed for a relatively low stabilization target, then perhaps the DEFRA approach could apply to the remaining, second-order decisions about exactly how to implement the later stages of the carbon reduction plan. If on the other hand, the world is far from making a firm commitment to sufficient carbon reduction (as unfortunately appears to be the case), then the crucial decisions facing us today are precisely the big non-marginal investments that will determine which trajectory we are on. For this primary, "trajectory-defining" stage of decision-making, there is no doubt about the profound intergenerational implications of today's choices. Thus the Stern approach should replace the Green Book / DEFRA approach for the foreseeable future, until and unless we are comfortably on a path to the lower stabilization targets.

The Treasury response to questions about the shadow price of carbon concurs with DEFRA, and rejects the criticism of the Green Book's higher discount rate:

> *The comparison between the discount rate used by the Stern Review and that set out in the Green Book is a separate issue. The figure used by the Stern Review was different for several reasons that would make it inappropriate to use for standard appraisal of public sector projects... The Stern Review set out to assess, from a global perspective, the effects on the welfare of current and future generations of very large and for all practical purposes, irreversible changes to the environment, resulting from pollution induced climate change. The standard Green Book assessment of the economic costs and benefits of expenditure proposals, is rarely concerned with such major changes to the wealth and welfare of future generations.*[11]

11 Eagle (2007:68-9)

DEFRA asserts that climate change policy decisions are made at the margin, but marshals neither a logical case nor a body of evidence to support this claim. DEFRA's argument against Stern's discount rate amounts to this: it is valid everywhere but applicable nowhere.

***** ***** *****

DEFRA's trajectory-based methodology depends on a set of interrelated ideas. The assumed stabilization trajectory sets an SPC that is used to create an incentive for abatement. The chosen trajectory must be optimistic – if a pessimistic result is expected, than abatement isn't worthwhile. The chosen "global cooperation" trajectory is described only in terms of its terminal concentration; the pace at which we approach that concentration is not considered (nor is varying the carbon price to vary the pace). The result is a low carbon price that will create only small incentives for abatement in the short-run. The next section of this critique considers the reasoning behind DEFRA's methodology.

## 3. THE FEAR OF ABATING TOO MUCH

Why not abate a little bit more? Why not set a higher carbon price than the one based on the presumption of perfect global cooperation so that more abatement takes place sooner rather than later, or just in case social costs are going to be much worse than estimated? DEFRA warns against overinvestment in abatement, but never specifies its exact dangers. How much should we worry about a future economy that has too much capital invested in efficient energy generation, or in household and industrial conservation measures?

The higher the SPC, the more abatement is undertaken in the UK. DEFRA's (2007:4) choice of methodology emphasizes the importance of not abating too much:

> *Adopting a SPC higher than this range would imply a presumption by the UK (or any other country) that other countries would not move to achieve a goal of 550ppm $CO_2$e or lower. With the UK accounting for only 2 per cent of global emissions, even more aggressive UK action could not compensate for lack of commitment elsewhere. Using a higher SPC in investment appraisal than implied by a path to 550ppm $CO_2$e would induce additional, more costly abatement measures in the UK, so that the UK undertook greater reductions in carbon emissions than would be efficient to contribute to a 550ppm $CO_2$e goal or lower. More generally, it would be incorrect to choose a SPC based on a SCC which current evidence places outside the suggested range.*(original emphasis)

Over-investment in universally shared goods – a stable climate, a cleaner atmosphere, and cheaper energy bills for all – is a probably not one of the top of concerns of the British electorate. The climatic benefits associated with the abatement of greenhouse gas emissions have the characteristics of pure public goods: A better climate is non-rival (my enjoyment of it in no way impinges on yours) and non-exclusive (it is very difficult to exclude any person or group from enjoying the benefits). Like all public goods, greenhouse gas abatement tends to be undervalued and underprovided in the formal economy – or to put this a different way, production decisions are made as if emissions were costless.

The market, left to its own devices, fails to provide a socially optimal amount of public goods. If the best possible result for society is to be achieved, an adjustment must be made to the "free market" solution. Governments have a variety of policy tools at their disposal that can transform the free market solution into a socially optimal solution, for example, regulations that limit various actions, taxes that change our price incentive to buy or to produce a product, and permit systems that both set limits and change prices.

DEFRA (2007) is an effort to set the parameters for a proposed climate policy tool strictly for use by the UK government. DEFRA's carbon price, they argue, will create a sufficient incentive for abating an unspecified amount of UK emissions that will be consistent with fair participation in global efforts to achieve an atmospheric stabilization trajectory of 550ppm $CO_2$e. The actual policy tools – regulation, taxes, tradable permits – are not at issue in DEFRA's report.

The need for a fair level of participation in global climate initiatives, but no more than what is fair, is an important element of the SPC methodology. In response to questions from the Environmental Audit Committee, the Treasury (Eagle 2007:68) offered this rationale: "[T]he higher the value assigned to the SPC, the greater the costs that must be borne by society in seeking to avoid dangerous climate change. Therefore in setting the SPC Government must consider at what point the costs of climate change (that are avoided through carbon mitigation policy) begin to be outweighed by the costs of implementing the policy itself." To this the Committee (2008:20) replied, "[This] point, that had the SPC been set at a higher level

it might lead to such an aggressive programme of emissions cuts in the UK that this would outweigh the future costs of climate change, betrays a short-termist view that fails properly to comprehend the risks of failing to act in time."

By conflating "equal" with "fair"[12] DEFRA has sought to balance the risk of having to pay more than what is equitable with the risk of a worldwide failure to abate enough emissions to avoid a climate catastrophe. The logical sequence of the choices made in performing this high-wire act is as follows: If other countries don't abate, the UK's efforts at abatement will have no effect; therefore, the only possible reason to abate is if other countries are also abating. As long as a sufficient number of other countries are in fact abating, the UK should abate in accordance with the "global cooperation" SPC. DEFRA's fear of abating too much seems to stem from two sources: the problem of collective action and the problem of allocating fair shares to the burden of abatement.

### Solving the Collective Action Problem

Initiatives to reduce greenhouse gas emissions with the goal of slowing climate change would seem to suffer from the classic problem of collective action articulated by Mancur Olson (1965:2):

> *If the members of a large group rationally seek to maximize their personal welfare, they will not act to advance their common or group objectives unless there is coercion to force them to do so, or unless some separate incentive, distinct from the achievement of the common or group interest, is offered to the members of the group individually on the condition that they help bear the costs or burdens involved in the achievement of the group objectives…These points hold true even when there is unanimous agreement in a group about the common good and the methods of achieving it.*

Because the benefits of public goods are available to all, there is a strong incentive towards "free riding", or enjoying the benefits without paying ones share of the costs. Olson (1965:50) goes on to explain that the collective action problem is particularly intractable when individual contributions to pay for a public good are so small, and the group is so large, that any one individual's contribution would not be missed.

Indeed, most countries' current greenhouse gas emissions and expected future emissions are quite a small share of the world's total emissions, and any one country's efforts at abatement – with a few notable exceptions – would not be missed. The UK, for example, as the world's eighth most prolific emitter of carbon dioxide, has the potential to abate 2 percent (its entire share) of global emissions. Assuming that most other countries engage in significant abatement, the UK's failure to do so would have little direct impact on future climatic conditions.

And so the question arises, what should a rational, self-interested country do? Surely the greatest net benefits would come from free riding: the UK would pay none of the costs of abatement while reaping all of the benefits of a better future climate. The crux of the collective action problem is that in the absence of a separate incentive or sanction contingent on each country's efforts at abatement, not just the UK, but every country would be better off free riding.

DEFRA assumes that the UK will not free ride, unless too many other countries appear to be free riding. The choice of a SPC for use in the UK, and therefore the amount of abatement that will take place in the UK, depends on other countries efforts at abatement. A stronger set of abatement initiatives worldwide implies a lower UK SPC and less UK abatement. A weaker set of abatement initiatives implies a higher UK SPC and more UK abatement.

Beyond some lower threshold, however, DEFRA's (2007:4) line of argument suggests that weak abatement initiatives in other countries indicate that the rational course for the UK would be to set the SPC at zero: "In order to conclude that it is worth acting, each country needs to be confident that enough other countries are committed to a similar goal…Whether [current and emerging initiatives are] consistent with the stabilization goal advocated by Stern is not yet clear, but for the purposes of decision making in the UK this is the most reasonable assumption to make."

By this logic, there are only two possible outcomes: the world successfully cooperates to reach an optimal stabilization trajectory; or the world fails to cooperate. If global cooperation is going to succeed, the UK chooses a low SPC and thereby creates an incentive for some – perhaps too little – abatement. But if global cooperation is going to fail, the UK should not create any incentives for abatement, "In order to conclude

12 See next sections for more on this point

that it is worth acting, each country needs to be confident that enough other countries are committed to a similar goal." Outside of a narrow band of very optimistic concentration trajectories, the problem of collective action would seem to dictate that the effective UK SPC should be zero, the no abatement price. DEFRA's willingness to free ride if others free ride narrows the set of solutions available in its model.

In neo-classical economic theory, the obstacles to the success of collective action stem from two assumptions. First, "rational" individuals are self-regarding and therefore make decisions purely on the basis of their own self-interest. Second, no institutions exist that can assign sanctions or rewards on the basis of each individual's participation in the collective action. These assumptions, when applied to the problem of coordinating international cooperation in the abatement of greenhouse gases, raise two important questions. Will countries act out of selfregard, or out of regard for others? And, will international negotiations about abatement result in an agreement that has teeth, or in an agreement that is unenforceable and unenforced?

Even if the UK acts purely out of self-regard, it is not at all obvious that abdicating responsibility for abatement in the hope that no more than a few other countries will do the same is the rational course of action. If the expected cost of a failure of international cooperation is high enough, then the UK should participate regardless of the negligible direct effect of its own abatement[13]. More specifically, if the costs of catastrophic climate change are – or are believed to be – very large in comparison to the total cost of paying for the abatement necessary to reach a desirable stabilization trajectory, the rational country should abate vigorously and immediately. Indeed, if the costs of a climate catastrophe were large enough, a rational country would pay not only for its own abatement, but for the abatement of other countries as well.

It also may be the case that the UK should abate because its participation would lead other countries to do the same, or because early investment in new technologies would have wider economic effects (positive externalities) not accounted for in damage or abatement functions. The knock-on effects of setting a positive example – or alternatively, of shaming other countries – amplify each country's own abatement efforts; paying for one unit of abatement in the UK may be the cause of more than one unit of abatement worldwide, effectively lowering the marginal abatement cost function. DEFRA (2007:9) raises this point: "The UK Government's position on leadership may affect the SPC desirable for the UK. Attaching value to leading on climate change mitigation – whether as a contribution to reaching global agreement, or to gain some first-mover advantage – increases the UK's willingness to pay…Leadership may…be demonstrated in the willingness to take unilateral action in order to spur global agreement." It is also the case that in signing the UNFCCC – which cites "common but differentiated responsibilities" – the UK and other developed countries have agreed lead the way with abatement efforts. However, no additional "value of leadership" is added to DEFRA's proposed SPC.

If instead the UK acts out of its regard for others, then its higher social cost function, would indicate a higher SPC and more abatement (see Figure 9), as argued earlier in this critique. This same logic holds true when considering the degree of regard that the UK has for members of its own society that are or will be disproportionately impacted by climate change. The social cost may (but need not be) measured as the sum of damages *and* benefits across all individuals. This means that if Group A benefits from climate change, or from the economic activities that result in the production of greenhouse gases, while Group B suffers damages, the net social cost may be very small (Boyce 2002). Similarly, if damages are measured in proportion to affected groups' willingness and ability to pay to avoid them, then damages to poorer groups will have little effect on the scale of social costs. There is nothing deterministic about a social cost function; the prices that it generates are subjective, and are very strongly impacted by its designers' feelings about the value of damages to poorer and richer groups, and the value of damages to future generations (Ackerman and Heinzerling 2004; Ackerman and Stanton 2007; 2008).

13 Olson (1965:34) discusses this possibility as a special case wherein the individual's "personal gain from having the collective good exceeds the total cost of providing some amount of that collective good… In such situations there is a presumption that the collective good will be provided. Such a situation will exist only when the benefit to the group from having the collective good exceeds the total cost by more than it exceeds the gain to one or more individuals in the group."

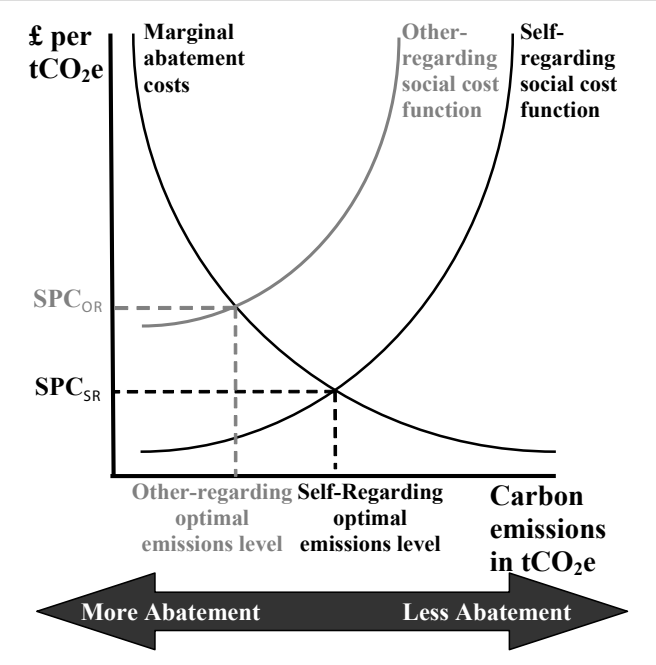


Figure 9: The Other-Regarding Social Cost Function

Finally, any remaining obstacles to collective action to abate greenhouse gases could be resolved by an international agreement on emissions that has a practicable enforcement mechanism. Even with a public good, like emissions abatement, where individual contributions are small enough, and the number of groups members is large enough, so that any one country's abatement would not be missed, a system of sanctions and rewards unrelated to the public good itself but awarded on the basis of participation has the potential to neutralize the problem of collective action. The participation of the two countries – the United States and China – whose individual contribution to abatement *would* be missed is, of course, essential to the successful achievement of any low stabilization trajectory.

Collective action in emissions abatement is only a problem if many countries are entirely selfregarding and the costs to each country of a failure of global cooperation are thought to be relatively small. As long as countries either have some regard for others or the costs to each country of climate catastrophe are perceived as large, the "rational" country should engage in a level of abatement consistent with a desirable stabilization trajectory. Even if some countries are still tempted to be free riders, a system of incentives or sanctions tied to actual abatement can overcome any obstacles to collective action.

### Allocating the Burden of Abatement

If the amount of abatement indicated by the SPC is the UK's fair share, then investing in additional abatement would be inefficient: the UK should pay no more and no less than what is equitable. But what evidence do we have that the SPC level of abatement is the fair level?

Generally, in a shadow price analysis, everyone is assumed to pay the same price per unit of negative externality; DEFRA (2007) makes no indication that they have a different allocation mechanism in mind[14]. The foundation for this type of analysis in economic theory is "Pareto optimality" – a result in which no one can be made better off without making someone else worse off; this is the notion of social welfare adopted by the neo-classical school of economic thought. In a Pareto optimal result, marginal cost equals marginal benefit for every agent. In shadow price analysis, "fairness" is achieved, along with the aggregate

14 DEFRA's plan to use their SPC only for internal decision-making purposes does not contradict this assumption. By setting their limited-purpose carbon price using the social cost of carbon for the entire society, DEFRA implicitly assumes that all other uses of carbon will respond to the same carbon price (even though there is no economic incentive to do so). Unless all UK greenhouse gas emissions – public and private – are assigned DEFRA's carbon price, there is no reason to think that this incentive effect will reduce British emissions to the desired level.

optimal level of abatement, when all agents incorporate the shadow price on each new unit of emissions in their production decisions.

DEFRA's choice of equal costs per unit of new emissions as the fair allocation of costs is a troubling one. The problem of climate change is not just a function of current and future emissions. Past emissions remain in the atmosphere for decades, and the UK's contribution of 5 percent of cumulative global emissions is relevant to any determination of equity in paying the costs of abatement (WRI 2005). A second, related consideration is the stock of wealth that the UK and other industrialized countries have amassed as a result of past emissions. Having depleted a global sink in the pursuit of wealth, should not the holders of that wealth have some special responsibility to clean up their emissions? The fairness criterion of Pareto optimality, and of shadow pricing, takes the initial endowment of wealth to be exogenous to the workings of the model; that is, it begins from the current moment, fresh, and unencumbered by awkward questions regarding who caused the mess in the first place.

In the case of global greenhouse gas abatement initiatives, some justification is necessary to explain why equality should be construed as equity. In the international arena, fair allocation of the cost of abatement is often thought of in terms of "contraction and convergence" wherein countries first converge towards equal per capita emissions (not to be confused with equal costs per unit of emissions), and then contract those emissions each year.

Anil Agarwal and Sunita Narain (1991) make the argument that equity in climate change policy requires a consideration of per capita entitlements to the earth's capacity to absorb greenhouse gases. In this way, the negative emissions of the poor (in comparison to their entitlement) become an asset. The allocation of property rights to the "world's carbon budget" – the maximum emissions that can be absorbed – could also incorporate cumulative emissions, although Narain and Riddle (2007:409) note that "an equitable allocation of the world's carbon budget that took historical emissions into account would provide the industrialized countries with so little space for reform as to be politically unfeasible."

Baer, Athanasiou, and Kartha (2007:15) argue that it is too late to talk about equal per capita emissions rights, since there is so little remaining opportunity for carbon emissions if the world is to avoid dangerous climate change:

> *[E]ven if industrialized country emissions were suddenly and magically halted, the dramatic emissions reduction demanded by the climate crisis would still require the developing countries to urgently decarbonize their economies, and to do so while they were still combating endemic poverty. This conclusion – a direct consequence of the implacable mathematics of our vanishing emissions budget – is not only the core of the physical challenge, but also the crux of the international political impasse that has overtaken the negotiations.*

They argue instead for "greenhouse development rights," based on the principle that low-income individuals – not countries – should be exempted from sharing the costs of a global emergency program for carbon reduction. They suggest an income threshold of $9000 per capita, in purchasing power terms, as the point at which people should be expected to start contributing to climate protection costs. Making this idea concrete, they introduce the Responsibility and Capacity Indicator (RCI) for the purpose of fairly allocating the cost of abatement without stifling development in poor countries.

The RCI combines each country's emissions since 1990 with its "capacity" to pay for abatement, a function of its population with incomes above the $9000 threshold (and the extent of their incomes above the threshold). Using this method, high income countries are assigned a collective share of 78.5 percent of the global costs of climate policy; the EU's share is 26.6 percent, and the UK's 4.3 percent.

Such innovative approaches to climate equity and development, however, are absent in DEFRA's analysis. DEFRA's implicit assumption that equity is equivalent to equality in the shadow price of future emissions disregards both the UK's responsibility for cleaning up its past emissions and its responsibility for redressing global poverty – a burden that can be construed to result from a long history of colonialism or as simple moral decency from those who have plenty to those who have little.

Equity is of concern not only in the choice of SPC, but also in the application of the SPC and in the division of its revenues. DEFRA (2007:1,10) states that the SPC should be used in "policy and investment appraisals across UK government" and "incorporated consistently into all analysis to support decision-making." Applying a carbon price only to government projects cannot have a general effect on the UK economy or achieve the desired level of abatement (even if were set far above the SPC indicated by the

social cost of carbon function). To attach an abatement incentive to every unit of greenhouse gases emitted in the UK, the carbon price must be applied in the market, most likely as taxes or permit prices:

- *Taxes*: When implemented, the carbon price can take the form of a per unit tax on carbon applied at some point in the production chain – when the carbon enters the country or is taken from the ground, for example, or at the moment of consumption by the final user. A fine that polluters are confident will be charged for every unit of carbon emitted would have an identical incentive effect.
- *Tradable permits*: An incentive system could also take the form of emissions permits; these can either be purchased for the carbon price per unit of emissions, or can be given away (or sold at a discount). A permit system can be structured to sell as many permits as are desired in the marketplace at the carbon price, or some lower amount of permits. If a ceiling below the desired number of permits is set, the effect will be the creation of a valuable asset for permit holders, especially those who have low-cost abatement options at their fingertips; it is very likely that permits will be resold on a secondary market at a price higher than their price at issue.

Either way, the practical institution of a carbon price implies the creation of a stream of revenue. If the carbon price is based on the true shadow price (the price at which the social cost of carbon and marginal abatement cost curves agree), then the revenue generated will be equal to the shadow price times the optimal emissions level (see Figure 10). The area below the shadow price and to the left of the optimal level of emissions (areas A and B combined) is the total revenue from taxes or permits; the area underneath the marginal abatement cost and to the right of the optimal level of emissions (area C) is the total cost of abatement. *The total abatement cost is not paid for with total revenue from taxes or permits, unless a separate arrangement has been made to do so*. Instead, firms voluntarily choose to pay for abatement because it is cheaper for them than the tax, fine, or permit. Firms then pass abatement costs on to consumers as retail price increases.

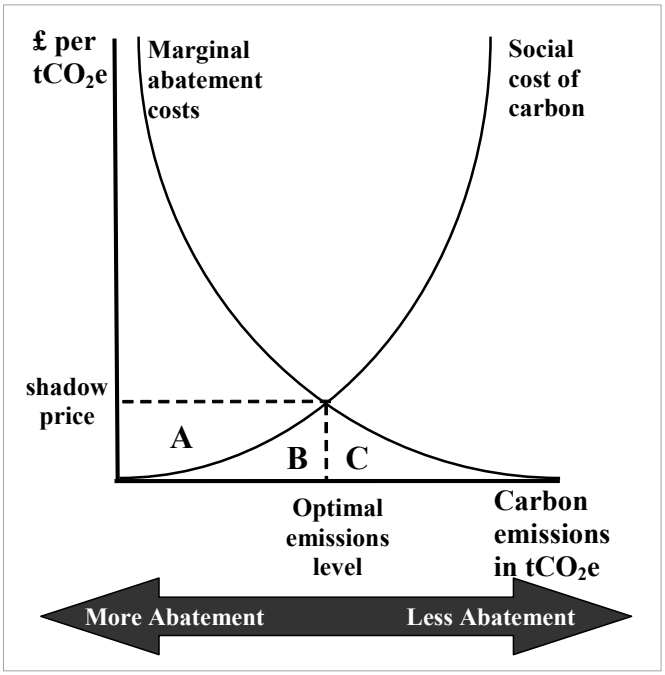


Figure 10: Total Revenue from Taxes and Permits

There is a third area of interest in Figure 10: the area underneath the social cost function and to the left of the optimal level of emissions (labeled B). This is the total social cost – the damage to society from the emissions that are allowed to continue. The total revenue can go to pay for these damages – at home or abroad – or it can go to offset abatement costs or it can go to some other purpose entirely. If, for example, permits are given away, the total revenue is in effect given to the favored firms. Schemes in which "green taxes" replace the income tax are another illustration. Note that if A = C, which is plausible

but not guaranteed, then the revenues from taxes or permits (A + B) would be just enough to pay for both the damages and the abatement costs (B + C).

The eventual use of the revenue matters not at all to the resulting optimal level of emissions from a given shadow price, but it matters very much to the incidence of social impacts. If, as Ronald Coase (1960) famously pointed out, property rights are well-defined and no significant transaction costs exist, an efficient allocation of resources will result even when there are externalities. "Coase's Theorem" is often taken to mean that externalities will correct themselves without government interference, but a closer reading leads to the opposite conclusion: Coase believed that the assignment of property rights was very often incomplete and that transaction costs – the costs of negotiation or of hiring representatives to advocate on one's behalf – could be very large.

In the problem of climate change, it is a lack of property rights to the atmosphere that permits the continuing existence of an externality[15]. This property right can be thought of as a right to pollute, or conversely as a right to not have one's environment polluted upon. The UK government's act of instituting taxes, fines, or permits creates a set of property rights, which may be assigned in accordance to any one of a number of different allocation mechanisms:

- If the right to pollute or not pollute belongs to the UK government, then a tax, fine, or permit fee will be collected and spent however policy makers see fit.
- If the right to pollute or not pollute belongs to firms in accordance with how much they have emitted in the past, then permits will be given away to the biggest polluters (as was the case with the EU Emissions Trading Directive through 2007). If the government sets a limit on the number of permits in circulation, then some rights to pollute are held by firms and some by the government. When firms attempt to pollute beyond the domain of their permits, the government can assert its rights by assigning fines.
- If the right to pollute or not pollute belongs to the UK people, then a "Sky Trust" mechanism, as suggested by Barnes and Breslow (2003), may be put in place to collect money on an equal per unit emissions basis and distribute the revenue on an equal per capita basis; this system would have the additional benefit of off-setting the regressive character of carbon pricing. (Poorer households spend more, as a share of their income, on carbon than do richer households, but if the revenue per capita is returned the net impact is progressive: a benefit to the poor and a cost to the rich.)
- If the right to pollute or not pollute belongs to the all the world's people equally, then a global Sky Trust mechanism is called for, collecting carbon taxes and distributing the revenue on a per capita basis worldwide (Hultman and Kammen 2007).
- If the just assignment of these property rights has something do with cumulative emissions, the stocks of wealth gained from those past emissions, and the inescapable connection between energy use, development and poverty, a more complex allocation mechanism will be necessary.

It matters very much who pays the shadow price and how the revenues are allocated.

Cost effectiveness strategies, too, can differ in the incidence of costs and benefits. If government pays for projects to be completed then the incidence of the costs depends entirely on the source of the revenue used. Of course, if the government is paying the full cost of the abatement projects, then the property right to the use of any new technologies developed belongs either the UK government or to the UK people. Patents for innovations made possible with public funds should belong to society at large, not to grant recipients. If firms undertaking abatement projects on the public shilling desire the resultant patents, then the expected value of patents should be a factor in the marginal abatement cost function of any project.

Cost effectiveness strategies, however, need not be paid for by government. Environmental policy can be implemented by what neo-classical economists sometimes deride as "command and control." In the context of cost effectiveness, a command and control policy would determine which abatement strategies were the least expensive, and institute regulations that either banned or mandated certain actions, technologies or substances. Over time, stricter regulations could be put in place forcing higher cost abatement strategies.

15 Garett Hardin (1968) called this the tragedy of the commons, but James K. Boyce (2002) has pointed out that the real tragedy is one of open access (a lack of enforceable rules – whether formal or informal) and not simply a result of common ownership.

For example, if one of the least cost options were getting rid of all incandescent lightbulbs, then a law banning their sale would be costless to the government, save any transaction costs accrued in the passage or enforcement of the regulation. Where technologies have a longer life – power plants, for example – enforcement would be more costly. The incidence of the transaction costs would depend on the source of revenue used.

In the planning and design of an abatement strategy for the UK there are important questions to be answered regarding how (and if) price incentives will be collected and how (and if) they will be redistributed. Unless unlimited permits are given away to firms (a policy that would have no price incentive effect), the application of DEFRA's SPC to the UK economy as a whole would result in the collection of a pool of revenue. This revenue then will be spent to mitigate the ongoing social costs of emissions not abated, to offset the cost of abatement necessary to reach the target emissions level, or for some unrelated purpose. Any of these uses for the revenue could be regressive or progressive; there is also a distinction to be made between progressivity on a national scale and progressivity on a global scale. The full social impact of DEFRA's SPC cannot be known outside of the context of a detailed abatement policy that includes incentives, mechanisms, enforcement and redistribution of revenue.

## 4. CONCLUSION AND POLICY RECOMMENDATIONS

The size of the SPC, or carbon price, is primarily the result of DEFRA's decision to base it on an assumed stabilization trajectory instead of the current stabilization trajectory. DEFRA's choice to set the carbon price by matching Stern's social cost of carbon at the fairly optimistic goal of 550ppm $CO_2$e will result in significantly weaker incentives to reduce emissions than would Stern's business-as-usual carbon price. From our critique of DEFRA's circular approach to setting a carbon price, four main conclusions follow.

*First, the UK need not build its climate policy around the fear that other countries will fail to abate.* It is certainly true that if no one else is abating, then UK abatement serves no purpose: Climate change is a global problem that needs a global solution. But every country has a strong incentive to abate and the UK should do whatever it can to abate its own emissions and to spur abatement in other countries.

Obstacles to collective action will apply to international greenhouse gas abatement initiatives only if many countries perceive their costs in the event of a climate catastrophe to be small in comparison to their abatement costs and many countries act entirely out of self-interest. The UK has an incentive to act – despite the fear that other countries will free ride, and even in the absence of international enforcement mechanisms – as long as expected costs to the UK of business-as-usual global emissions are perceived as high, the UK sees its role as a leader in climate policy as having political importance, the benefits of early investment in the innovation and early adoption of new technology are expected to be high, or the damages from climate change to those outside of the UK or those who will suffer disproportionately within the UK are given a noticeable weight in an accounting of social costs.

*Second, the UK need not build its climate policy around the fear of investing too much in abatement.* Ending up with too many solar panels is hardly a serious hardship, especially when compared to the competitive benefits of being a leader in the development of green technologies. The idea that setting a carbon price higher than the proposed SPC would constitute overabatement rests on the assumed fairness of equal worldwide payment per unit of new emissions, but equality and equity should not be conflated. UK's responsibility for climate change extends beyond its current emissions, and should include consideration of its historical emissions, the stock of wealth that it has built on the foundation of those emissions, the UK's current very high per capita emissions compared with other countries, and the absolute impediment to the eradication of poverty that a high carbon price would create for the least developed countries.

*Third, the pace of abatement matters.* DEFRA's SPC provides no incentive for early innovation or for early adoption of green technologies. The pace of abatement will determine not only the UK's share of benefits from technological change – like job creation, lower prices and higher profits – but may also impact on the world's ability to reach its desired stabilization trajectory. Technology advances through learning by doing, not by waiting for prices to fall from the passage of time. DEFRA has advanced no rationale for maintaining a steady (with a slight uprating) carbon price over time. A high initial carbon price could spark UK innovation and early adoption of technology.

*Fourth, an accurate, realistic and compassionate estimation of the social cost and marginal abatement cost functions is essential if the carbon price is to be set at the intersection of these curves.* An explicit understanding that the social cost of carbon is a subjective treatment of values would be especially useful in judging its accuracy. The best-informed choices about the social cost of carbon only can be made in

the context of a complete policy that details who will pay the cost of carbon and how the carbon revenue will be spent. DEFRA's current plan fails on all of these counts: the treatment of the social cost of carbon is deterministic; no information is given regarding the incidence of the carbon price; and no indication is made of how carbon revenues will be spent.

If instead the carbon price is to be set based on a target stabilization trajectory, as proposed by DEFRA, then the social cost of carbon must be treated as vertical – this is, as if there were no price at which society would accept a higher level of emissions. In this formulation, the accurate and realistic measurement of the marginal abatement cost becomes paramount. Abatement costs will change rapidly as new technology is created, and any decisions based on estimated future abatement costs must be frequently revisited and revised.

DEFRA's SPC methodology is rife with questionable, surprising, and under-explained assumptions and procedures: The SPC is based on an assumed best-case trajectory, instead of on realistic current conditions; a different exchange rate and uprating convention is used from that of Stern; Stern's discount rate is put aside in favor of a higher rate; and the SPC relies on a social cost function that can only claim to be a partial accounting of damage costs. Each of these choices errs in the same direction – towards a lower carbon price.

DEFRA's choice of setting incentives to meet an assumed future stabilization trajectory, instead of the actual current trajectory, is the key feature determining the value of its shadow price of carbon. A view of the success of worldwide abatement through rose-colored glasses can only lead to an overly optimistic price tag for the UK. DEFRA's methodology is flawed and should be replaced by one that can provide a system of fair incentives that will make it possible for the UK to achieve its abatement goals.

The Environmental Audit Committee's (2008:20) assessment of the SPC came to a similar set of conclusions:

> *We recommend that it be reformed, so that instead of assuming that global climate change goals will be met, it is based on the costs of climate change on a 'business as usual' trajectory of emissions. Furthermore, given the inherent difficulties in putting a price on climate change, the Government's first priority in deciding on the merits of potential policies and construction projects ought to be deciding how they affect UK carbon budgets, and only secondly on what the monetary value of resulting carbon emissions would be.*

The design of an abatement policy that is both equitable and efficient would require the following steps:

- Decide on the UK's fair share of global abatement and a set a target timeline for UK emissions abatement. Note that this share is in no way limited by the UK's current level of emissions.
- Treat the social cost of carbon as vertical, or perfectly inelastic, at the target; this will obviate any need for measuring social costs.
- Establish a realistic schedule of marginal abatement costs that takes into account a projected increasing cost schedule, and institute a carbon price via taxes or permits that is at least the level of marginal abatement costs at the target emissions level. A higher carbon price will be an incentive to spur UK innovation and early adoption of new technology. If a sufficiently high price is adopted – and it appears that a realistic carbon price could be quite high at present – it will spur greater investment in energy efficiency and renewables, and greater innovation in emission-reducing technology. Over time, these trends will tend to lower the carbon price, as it becomes cheaper to finish the job.
- Supplement and steer the market incentives of the carbon price with government policies that fund or mandate least cost technologies.
- Spend the carbon revenue to offset regressive carbon prices and to mitigate the social costs of ongoing climate change, at home and abroad.
- Frequently reexamine the UK's fair share of global abatement, the marginal cost of abatement, and the best use of the carbon revenue.

In the end, the right amount of UK abatement depends on moral judgments. In order to determine the UK's equitable contribution to abatement and to mitigating the social costs of climate change that will not be avoided through abatement, it will be essential to decide on an explicit set of values to act as a foundation for UK climate policy.

## TECHNICAL NOTE 1: UNDERSTANDING EXTERNALITIES

An externality (or external cost) is a side-effect that results from the production of a good but is not included in the price of that good. Externalities can be negative – like air pollution from a power plant – or positive – like the water and carbon sequestration services performed by farms. In the case of a negative externality, the price of the good only reflects the production costs that producers actually have to pay, and not the costs imposed on society by the good's production. Goods that require the use of fossil fuels in their production result in the emission of carbon dioxide, a negative externality, but the damage caused by climate change is not a factor in setting the price of fossil fuels nor in the price of goods made with fossil fuels. The result of the externality, in economic terms, is a price that is too low and, therefore, more of the good being sold than would be in the public's best interest.

In Figure TN1.1, there are two different marginal cost (or supply) curves – a private marginal cost curve that represents just the costs to producers, and a social marginal cost curve that represents the costs to the entire society (including the costs to producers). The vertical difference between these two curves is the negative externality. The market price is usually assumed to be found at the intersection of the marginal cost (supply) and marginal benefit (demand) curves. If producers need only concern themselves with their own direct production costs, than the market price will be $P_{private}$, at the intersection of marginal benefits and social marginal costs; at this price, $Q_{private}$ units of the good will be sold.

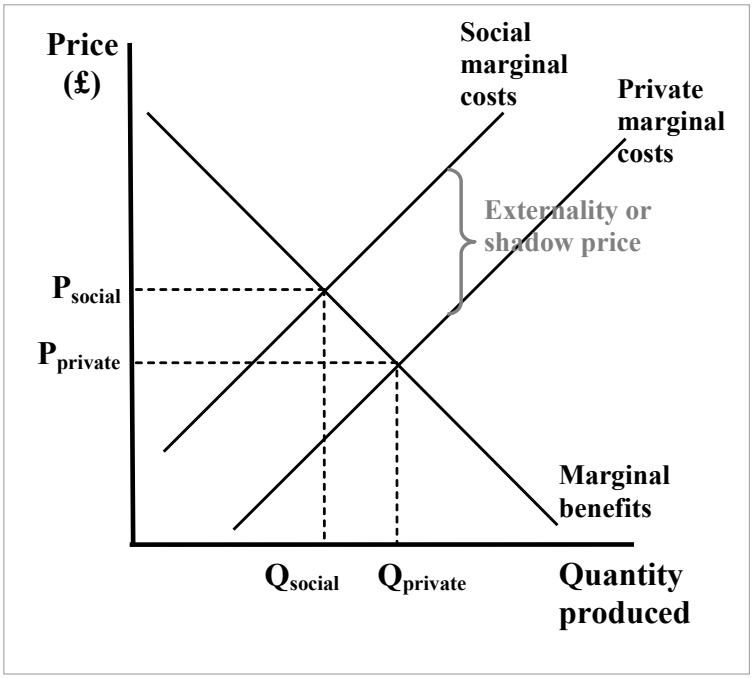


Figure TN1.1: Internalizing an Externality

If producers considered all costs to society, and not just the costs that they themselves face, then the market price would instead be $P_{social}$, at the intersection of marginal benefits and social marginal costs; at this higher price, only $Q_{social}$ units of the good are sold. If a negative externality exists, the price will be too low and more of the good will be sold than would be the case if the externality were considered in setting the market price.

The process of raising the price of a good so that it bears its total social costs is called "internalizing the externality". When a tax, fine or permit (in our example, a carbon price) is placed on the purchase of the good – or on the relevant, polluting inputs – producers' marginal costs *become* the social costs. If the goal is to have no more than the socially optimal amount of the good sold, then the carbon price should be equal to the size of the externality.

The shadow price methodology (not to be confused with DEFRA's SPC methodology) discussed in this report is a method for estimating the size of the externality and the correct carbon price to place on greenhouse gas emissions so that no more than the socially optimal amount of emissions is released into the atmosphere.

## TECHNICAL NOTE 2: TOO FEW UNKNOWNS

DEFRA's shadow price of carbon (SPC) is not a true shadow price, in the sense that this term is commonly used in environmental economics. A shadow price, together with its associated optimal level of emissions, is the intersection of the social cost and marginal abatement cost curves.

The problem with DEFRA's SPC methodology is too few unknowns. An exogenously determined level of emissions, *and* the social cost of carbon function, and the marginal abatement cost function cannot all be used to determine the shadow price. Any two of these data points together determine the other one at equilibrium. Attempting to solve this set of equations for the SPC, given an exogenously determined level of emissions, will have one of two possible results:

(1) If the assumed level of emissions was determined by an earlier solution of these exact same damage and abatement cost functions, or if by coincidence the true optimal level matches this result, then the SPC will be "correct", that is, it will equal to the true shadow price, or the marginal damage and marginal abatement costs at the target level of carbon.

(2) If instead the assumed level of emissions is anything other than the level indicated by the intersection of the damage and abatement functions, then the SPC will be incorrect, and no true shadow price will be generated.

The shadow price, by definition, is the price at which marginal damage costs are equal to marginal abatement costs; this is the only price that can accurately internalize the externality. If a level of emissions is chosen for which marginal social costs are not equal to marginal abatement costs, the correct shadow price will not be determined. And there is no reason to believe that any price other than the correct shadow price will successfully adjust consumer and producer's incentives to achieve the socially optimal level of emissions.

## TECHNICAL NOTE 3: TOO MUCH ABATEMENT

Too high an assumed stabilization trajectory (a pessimistic projection with high future emissions) leads to "too much" abatement, where "too much" abatement is any amount of abatement greater than the optimal, or equilibrium, amount. In Figure TN3.1, the assumed concentration trajectory is higher than the optimal level of emissions, and the SPC is higher than the true shadow price. For all SPCs that are higher than the true shadow price, actual emissions will be lower than assumed emissions: in other words, "too much" abatement will occur.

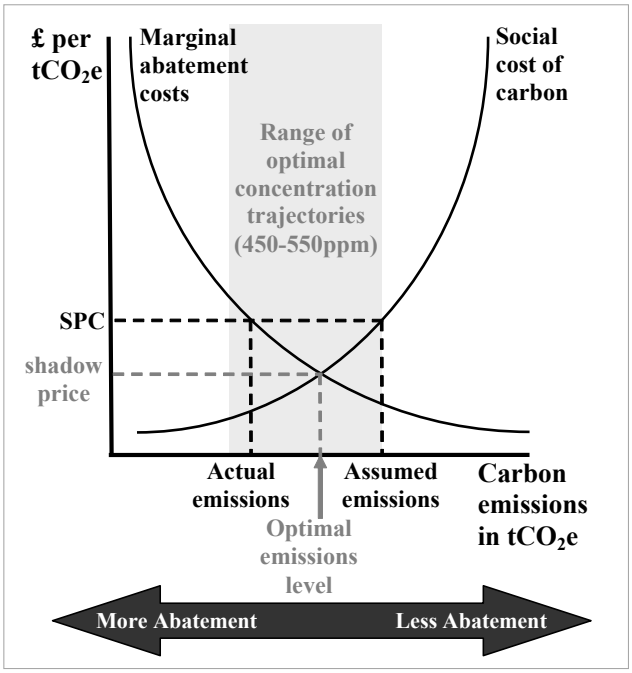


Figure TN3.1: UK Abates Too Much

DEFRA chooses 550ppm $CO_2e$ from Stern's range of 450 to 550ppm $CO_2e$ with the goal of avoiding the possibility of under-abatement. The lower the assumed stabilization trajectory, the less actual emissions take place. (Imagine, in Figure TN3.1 above, a reduction in assumed emissions. As assumed emissions move to the left, the SPC falls, and actual emissions – which are read from the marginal abatement cost curve – increase.) Note that DEFRA's method does not reveal the optimal level of emissions. In order to avoid emitting an amount greater than the optimal level, DEFRA chooses the highest value in their range; this creates an incentive for the most abatement possible *in their range*. Assuming an even higher stabilization trajectory would lower actual emission still more.

## TECHNICAL NOTE 4: CAUSES OF INSUFFICIENT ABATEMENT

Unfortunately, an assumed 550ppm stabilization trajectory does not completely insure against insufficient abatement: the optimal level of emissions could be higher than the target range, the actual social cost of carbon could be higher than the measured social costs, or actual abatement could be more costly than estimated.

In Figure TN4.1, the optimal emissions level is higher than the targeted range – as if worldwide abatement goals were more optimistic than would be required for marginal damages to equal marginal abatement costs. As a result, the SPC is too low to provide incentives for the necessary amount of abatement.

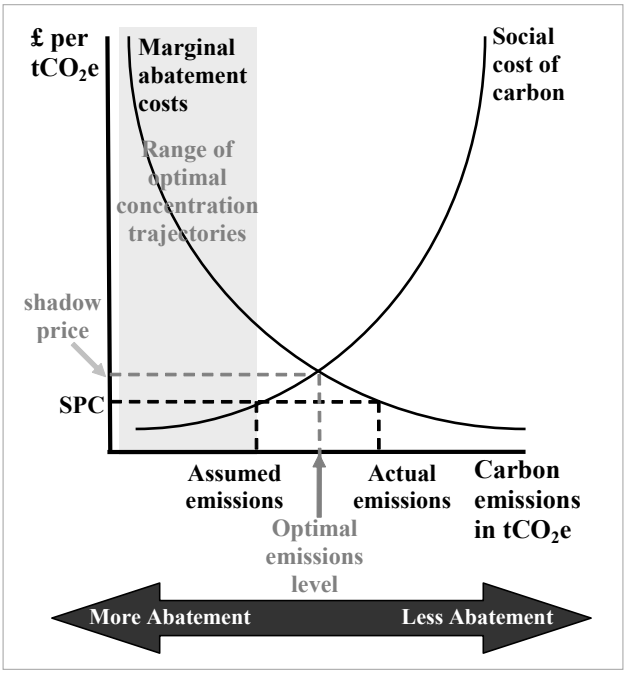


Figure TN4.1: Overly Optimistic Trajectory

In Figure TN4.2, the estimated social cost of carbon fails to include some actual current or future costs. The result is, again, an SPC that is lower than the true shadow price, and insufficient abatement.

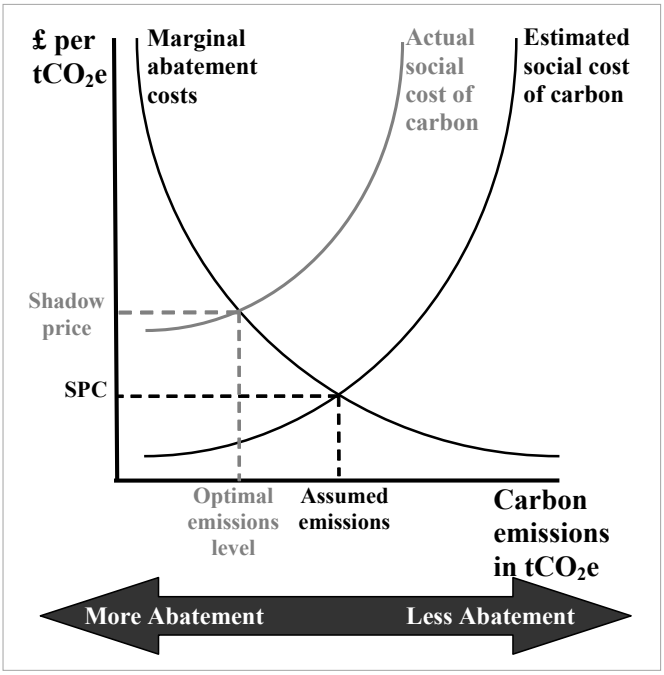


Figure TN4.2: Overly Optimistic Social Costs

In Figure TN4.3, the costs of abatement are underestimated. The true shadow price will be greater than the SPC, and the investment in abatement that takes place will be insufficient to reach the socially optimal emissions level.

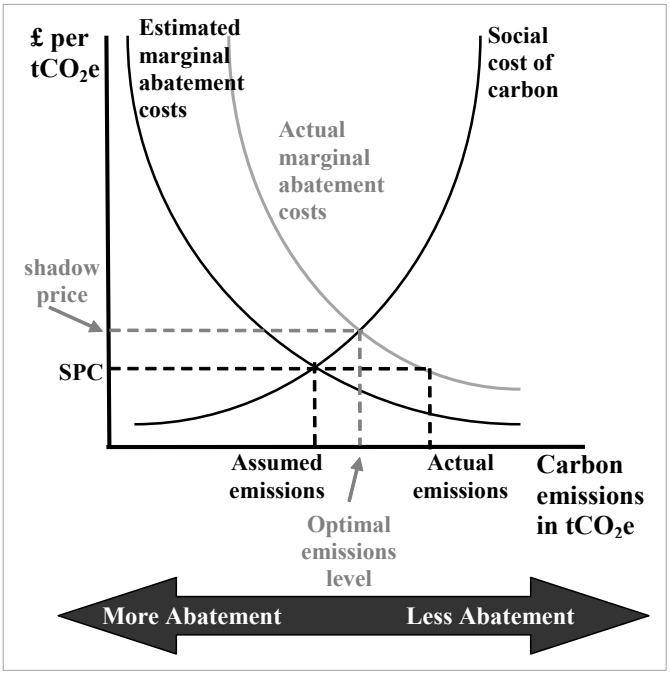


Figure TN4.3: Overly Optimistic Abatement Costs

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