# Achieving low-cost emissions targets

**There has been much discussion about ways to reduce the rate of atmospheric accumulation of carbon dioxide and other greenhouse gases. What are the key economic and policy issues concerning the timing of such efforts?**

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In thinking about ways to achieve a reduction in the emissions of greenhouse gases, it is crucial to distinguish between the timing of emissions abatement and the timing of policy action. As we discuss below, there are compelling arguments for implementing only relatively small $CO_2$ mitigation measures in the short term and delaying significant abatement to the more distant future, but this does not justify the absence of policy action now. On the contrary, it is vital to have a short-term abatement policy to bring about low-cost reductions in $CO_2$ emissions, even when most of those reductions will occur in the distant future.

We believe that a carbon tax is the most economically efficient and administratively flexible instrument for policy action now. Under a range of plausible economic assumptions, we show here that a carbon tax is a better instrument for generating a cost-effective abatement profile than subsidies to research and development for alternative, low-carbon sources of energy.

## Postponing abatement

Last year, Wigley, Richels and Edmonds[1] published a widely cited, influential article on the appropriate timing of emissions abatement. They examined several alternative models for mitigation pathways culminating in the same long-term concentration of $CO_2$ and concluded that, in general, overall abatement costs are kept to a minimum if the bulk of $CO_2$ abatement takes place in the more distant future rather than soon.

Wigley *et al.* offered four explanations for their conclusion. The first is the positive return on capital: capital growth would mean that fewer resources need be put aside today to fund future abatement. The second is that the capital stock for energy production and use may be long-lived. Delayed abatement would allow expensive production assets to be gradually replaced with fewer carbon- or energy-intensive new technologies after the older stock has reached the end of its economic life. The third is technological progress: new, energy-efficient technologies will be discovered and developed, hence the "availability of low-carbon substitutes will probably improve and their costs reduce over time"[1]. And fourth, carbon emitted sooner is exposed to natural removal processes for longer, so delayed abatement permits a larger total of cumulative emissions to produce the same long-term concentration target.

The main idea expressed by Wigley *et al.*, that society can economize on the costs of achieving targets for reduced emissions of greenhouse gases by deferring most abatement to the future, has won many adherents. But others (see, for example, ref. 2) contend that delay could be costly, as a commitment to reduce emissions now would be an important catalyst for technological progress that will ultimately lead to lower costs of abatement. Much of this disagreement can be overcome by distinguishing between emissions abatement and abatement policy. Although there are strong arguments to justify delaying the bulk of emissions abatement, we believe there are compelling arguments for short-term implementation of government policies to set in motion the economic adjustments necessary to bring about low-cost reductions in emissions.

## A carbon tax today

Climate-related damage from accumulation of $CO_2$ is a cost that, without government intervention, is not incorporated in the market price of fuels[3]. A carbon tax, if set appropriately, would allow market prices to reflect the full social cost of climate damage and give purchasers the incentive to economize on fuel use. In addition, because the tax would cause prices of carbon-intensive consumer goods to rise relative to other goods, it would give individual consumers the incentive to rely more heavily on less-carbon-intensive goods and services, and producers the incentive to develop alternatives.

Of course, other policies could be used to discourage or restrict the use of carbon-intensive fuels, for example, direct limits or caps, fuel-efficiency standards and mandated technologies or equipment. There have been many economic comparisons of these alternatives[4,5], but most tend to embrace the carbon tax as the most economically efficient and flexible instrument because it imposes fewer information requirements on policy-makers; it provides dynamic incentives; is relatively inexpensive to administer; and is relatively easy to adjust in response to new information (essential in climate assessment). Moreover, a carbon tax would bring governments revenues that could be used to finance cuts in ordinary income taxes, thereby helping to avoid inefficiencies associated with disincentives to work or to save. This ability to generate revenue would make a carbon tax much more efficient than limiting carbon use[6].

An appropriately scaled carbon tax would also help to dictate the most efficient time-profile for abatement. We agree with Wigley *et al.*[1] that it is more cost-effective to defer to the future the bulk of carbon emissions abatement (relative to the path of emissions under an unconstrained 'business-as-usual' model). But this does not justify avoiding carbon taxes in the short term.

Economic analysis indicates that carbon tax rates should be set according to the 'marginal environmental damage' from $CO_2$ emissions. Most analyses imply a carbon tax rate that rises with time[3,7,8] to encourage the level of abatement to increase. Even a constant carbon-tax rate, though less economically efficient, is consistent with a rising time-profile for abatement because, as new technologies for emissions (or fuel) abatement are discovered and implemented, the profit-maximizing amount of emissions-abatement expands, even if the tax rate is constant. Thus, there is no contradiction between introducing carbon taxes now and a cost-effective time-profile for abatement.

Introducing the carbon tax now could be a key factor in inducing the technological change that justifies deferring most abatement to the future. Making carbon-based fuels more expensive provides incentives to research alternative energy-supply options. As emphasized in ref. 2, a carbon tax can also stimulate technological change by promoting "learning-by-doing". In the context of climate change, this means that experience with processes that reduce $CO_2$ emissions may lead to the discovery of cheaper ways to reduce emissions. In our view, introducing the carbon tax now would usefully exploit this phenomenon.

## Research subsidies or carbon taxes?

Does the fact that a carbon tax may stimulate research mean there is no justification for introducing a research and development subsidy as part of climate-change policy? A general economic principle is that governments should apply the policy instrument most closely related to a particular 'market failure'. As noted above, the central market failure in this case is the climate damage associated with combustion of carbon-based fuels. A research subsidy does not directly deal with this market failure because, unlike a carbon tax, it does not directly alter the prices of carbon-based fuels. If there were no other market failures to be concerned about, a subsidy would be unnecessary: the carbon tax alone would reduce the accumulation of $CO_2$ in a cost-effective manner.

But there *is* a second market failure —

failure in the market for research and development. It is well known that private investment in research and development can generate 'spillover benefits' that are enjoyed by parties other than the investor. Not all knowledge can be kept as private knowledge. Under these circumstances, companies tend to underinvest in research and development, mainly because they do not take into account the full social value (including the spillover benefits) when they make the investments. A government subsidy can correct this market failure, ideally by lowering a company's costs enough to allow it to expand its investment in research and development to the socially optimal level.

Does this argument imply that a carbon tax should be accompanied by a subsidy for research into alternative energy supplies? It depends. Economic theory suggests that a subsidy is appropriate wherever there are significant spillovers. If such spillovers arise in connection with virtually all industrial research investment, then the most economically efficient policy response is a broad-based subsidy for a wide spectrum of industries. On the other hand, if such spillovers are specific to investment in alternative energy supplies, then there is a basis for a more targeted subsidy. Although there are strong theoretical and empirical reasons to support a carbon tax, the case for a targeted research and development subsidy is less clear.

We have developed an economic simulation model for the United States[9] which we believe is the first large-scale, general equilibrium, economic model to take into account incentives to invest in research and development, knowledge spillovers, and the functioning of research and development markets. The estimated costs of reducing cumulative $CO_2$ emissions by 15 per cent in the 100 years after 1995 is shown in Table 1. A research subsidy alone never offers the cheapest way to meet the target reduction in cumulative emissions and indeed can be many times more costly than the other policies. Results from our model are sensitive to parameters that are highly uncertain; thus, we emphasize the qualitative pattern from Table 1, not specific numbers. These simulations support our view that a carbon tax is essential for cost-effective reductions of $CO_2$ emissions, and that this tax should be accompanied by a research subsidy only when there are spillover benefits from research and development.

Two qualifications deserve mention. First, if research and development markets are already highly inefficient (for example, distorted by previous subsidies or taxes), then gauging the costs of new subsidies that should be applied to low-carbon energy sources becomes more complicated. Depending on the array of pre-existing subsidies,

**Table 1 Costs of 15% reduction in $CO_2$ emissions 1995–2095**

| Model | Carbon tax alone | Targeted R&D subsidy alone | Carbon tax plus targeted R&D subsidy of 10% | Carbon tax plus broad R&D subsidy of 10% |
|---|---|---|---|---|
| 1. No spillover from R&D | 0.94 | 8.52 | 1.02 | 1.18 |
| 2. Spillovers from R&D only by alternative energy industry | 0.66 | 5.98 | 0.60 | 0.78 |
| 3. Spillovers from R&D investment by all industries | 1.03 | 9.55 | 1.09 | 0.81 |

Figures are percentage reductions to the present value of GDP. All simulations involve carbon tax rates that increase at a rate of 5 per cent annually to the year 2075 and remain constant thereafter. The carbon tax profile is the lowest path of (rising) tax rates that leads to the 15 per cent reduction in cumulative emissions relative to the baseline model. Model 1 evaluates costs when there are no spillovers from research and development (R&D) investments. In this case, the cheapest way to attain the 15 per cent abatement target is through a carbon tax alone. Model 2 assumes that there are significant spillovers from investments in R&D by the 'alternative energy' industry (the non-carbon-based fuel industry). In this case, the combination of carbon tax and R&D subsidy to alternative energy is the more cost-effective way to attain the target. Model 3 assumes all investments in R&D involve significant spillovers. In this case, the least-cost policy involves a combination of carbon tax and broad subsidy to R&D.

the costs of a combination of carbon tax and subsidy might be higher or lower than suggested in Table 1, but this does not affect the general principle of our argument. Second, our model focuses on private-sector research (which may be publicly subsidized). Thus, our simulations do not directly address the effectiveness of research that is directly undertaken by the public sector.

## Political and other considerations

A carbon tax policy is likely to be less popular than subsidies for research into energy technologies, even though a policy consisting only of subsidies would not be the cheapest way to reduce emissions. A subsidy is more favourable to producers but a carbon tax is more attractive to general taxpayers (although some low-income groups are concerned about its potential regressivity). A research subsidy needs to be financed through other tax revenues, whereas a government can 'recycle' carbon-tax revenues to the benefit of general taxpayers (including lower-income groups). Discussions of policy options need to take into account these effects on the tax-paying public.

We have concentrated here on the issues of cost-effectiveness and economic efficiency. Of course, in the political arena there are advocates for other policy principles, such as the precautionary principle or the principle of stewardship. Our purpose is not to debate the relative merits of alternative criteria for policy choices, but simply show that a 'do-nothing' policy is difficult to justify, even according to a policy criterion endorsed by most economists.

A further important issue is the existence of uncertainty. One view is that it is premature to initiate policy action now, given the uncertainties about the extent of climate change and associated damage, whereas another is that postponing policy action would be much more costly in future if action were ultimately required. Recent analyses indicate that it is worthwhile starting policy action now, despite the uncertainties, provided that there are not prohibitively high 'sunk costs' (unrecoverable one-time costs) of introducing particular policies[10,11]. A carbon tax policy is attractive because it involves minimal sunk costs, suggesting that short-term action is warranted, and because it is flexible enough to allow adjustments as new information about climate change and the effectiveness of policy becomes available[12].

In conclusion, we support the view that it may be cost-effective to defer most $CO_2$ abatement, but we believe that policy action is needed now for cost-effective future abatement. A carbon tax (or other flexible, direct policy confronting the effects of fossil-fuel combustion) is an essential element of greenhouse policy. A research and development subsidy could be a useful complement to a carbon tax when there are research and development market failures. But the case for a subsidy (in terms of economic efficiency) rests primarily on spillover benefits from general research (or other research and development market distortions) and not on the prospect of environmental damage from atmospheric build-up of $CO_2$. □

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