Can international tradeable carbon dioxide emission quotas work?

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Can tradeable carbon dioxide (CO_2) emission quotas (TEQ) be an effective policy response to predicted global warming, as has been suggested by the Clinton administration? This raises a broad question of whether such a regime will achieve the desired policy objective. There is also a narrow question of whether a market in TEQ can be made to function, and if so, whether it would achieve a better outcome than feasible alternative policies. The major alternative policy instrument, as advocated by European nations, is a tax on CO_2 production.

This paper is based on previous publications on greenhouse issues by the Tasman Institute (1992, 1994a, 1994b, 1994c, 1994d, 1994e, 1995a, 1995b, 1996).

The policy objective

International greenhouse policy involves a complex interaction between:

- scientific assessment of the extent and the effects of global warming, and other effects of increased CO_2 in the atmosphere;
- economic analysis of the costs and benefits of global warming and of increased CO_2 in the atmosphere;
- the costs of greenhouse gas abatement, the removal of greenhouse gas from the atmosphere and the costs of treating effects rather than causes; and
- international policy negotiation and development.

There is considerable scientific uncertainty about the extent of possible global warming over the next century.[1] The global temperature records that NOAA satellites have produced since 1979 and corresponding readings from weather balloons have not shown any global warming. Furthermore, while the ground stations have revealed increases in global average temperatures over the same time period, those records:

- are restricted to land areas, while the satellite measures also cover the oceans;
- are more concentrated in the middle latitudes of the northern hemisphere — where the satellite measures also indicate some warming; and
- over-sample cities, which are seriously affected by 'heat island' effects.

Two of the most ominous predictions of global climate models are a possible sea level rise as polar ice melts and an increase in extreme weather conditions. These predictions are, however, even more uncertain than the possible rise in global average temperature.

Offsetting the possible negative effects of increased atmospheric concentrations of CO_2, plant growth will increase, as will plant resistance to deficiencies of water, light and nutrients. Increased plant growth will also support more animals.[2] Unlike the warming and other negative predictions, these beneficial effects are uncontroversial. They will also occur even if warming does not eventuate. If warming does occur, however, it is likely to extend growing seasons and increase average levels of rainfall, both of which will *enhance* the favourable effects of higher CO_2 on biological (and agricultural) productivity.

1 For a good summary of scientific issues, readers are referred to the volume published by the European Science and Environment Forum (ESEF) (1996).

2 See, for example, Sherwood B. Idso, ESEF (1996), pp. 28–33.

The *undesirability* of increased atmospheric concentrations of CO_2 is as much a matter of economics as of science, and there is considerable uncertainty about the economic analysis. Much more detailed economic, as well as scientific, modelling is required to conclude that the negative effects of an increase in CO_2 concentrations in the atmosphere will outweigh the positive effects.

The precautionary principle

In response to the uncertainties surrounding global warming, many environmentalists have invoked the precautionary principle to justify immediate action to control CO_2 emissions. A statement of the principle can be found, for example, in the Intergovernmental Agreement on the Environment (IGAE), signed in Australia (by representatives of the different levels of Australian governments) in 1992:

> *Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by:*
>
> *(i) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment; and*
>
> *(ii) an assessment of the risk-weighted consequences of various options.*

Ian Wills (1996) comments:

> *Who is to decide what constitutes 'serious environmental damage', what is 'irreversible', and on what evidence? How are 'risk-weighted consequences' to be assessed? The implied degree of discretion on the part of decision-makers would not seem to make for certain or stable environmental management rules. Nor is it clear why the IGAE specified 'serious or irreversible environmental damage' … Precautionary principle advocates give no reasons why we should worry about serious environmental damage which can be reversed, or irreversible damage that is not 'serious'.*

The precautionary principle is not a sufficient basis for action. The precautionary principle warns against delaying remedial action by requiring unreasonable standards of proof of benefit. It says nothing, however, about reasonable standards of proof in examining the effects of human activity. It also says nothing about the optimal trade-off between the use of different remedial actions (Tasman Institute 1995b). Policy needs a wider set of principles as a guide.

Principles for action

Tasman Institute (1996) has proposed that policies applying to environmentally negative emissions ought to be guided by three basic principles:

Knowledge: Rational judgement requires reasonable knowledge of costs (of remedial action) and benefits (in terms of net costs avoided). The expected costs of remedial action need to be lower than the expected net costs of inaction, where expectations are based on the best available current information.

Efficiency: Remedial action should reduce harmful environmental effects at the lowest possible cost or, equivalently, achieve the greatest environmental benefit for a given cost in terms of lost welfare.

Commensurability: The more expensive the policy option, the greater the level of certainty of achievable benefits required to justify it.

Implications of the above principles in the case of global warming include:

1. Major negative effects cannot occur before per capita incomes are much higher. It is very costly to reduce incomes now to prevent smaller *percentage* reductions in incomes many decades into the future. The net negative expected future effects therefore have to be quite large to justify even minor present control costs.
2. Delay should allow additional research to reduce uncertainty about the timing, nature and magnitude of possible effects of global warming. Future remedial action can then be based on better information as well as better technology.
3. Negative consequences of global warming, not energy use, nor even CO_2 emissions, are the primary target. Other measures, such as building dykes, could limit negative effects while retaining the beneficial effects of additional CO_2 in the atmosphere.
4. It may be possible to reduce warming at lower *net*[3] cost by controlling gases such as methane and chlorinated fluorocarbons instead of CO_2.
5. Even if reducing atmospheric CO_2 is desirable, reducing emissions could cost more than increasing absorption through reafforestation, increased industrial use[4] of CO_2, or concealing CO_2 in deep ocean currents or exhausted natural gas wells.[5] Efficiency requires equal marginal cost of *all* reduction *and* absorption measures.

3 The word net is needed to account for benefits associated with *increasing* the concentration of a gas.

4 John Emsley, ESEF (1996), pp. 34–40 notes that five million tons of CO_2 are commercially produced each year in the US, where CO_2 is now ‘one of the top 20 bulk chemicals’.

5 J. T. McMullan, ESEF (1996), pp. 51–9 discusses these and other options.

6. It is counterproductive to eliminate firms with low greenhouse gas emissions to favour firms with higher emissions per unit of energy used.
7. Historical activities are irrelevant except in so far as they provide information about the marginal costs of further adjustments.
8. Distributional concerns are not arguments for abrogating these principles. Such concerns should be dealt with by mechanisms specifically designed to address them.

No regrets policies

So-called ‘no regrets’ policies reduce greenhouse gas emissions while imposing no net economic costs, or perhaps even delivering net benefits. It would be irrational and unjust to require expensive measures before all such policies have been used.

The scientific and economic uncertainty, and the very long lead times for potentially serious effects, mean that *no* country can now justify taking anything other than no regrets policies. Furthermore, all countries should refuse to take costly control measures until all other countries have implemented all available no regrets policies.

Policies that increase the efficiency of energy use have been suggested as no regrets policies. However, greater energy efficiency may expand the demand for energy-intensive products and increase the demand for energy inputs. Furthermore, even if greater energy efficiency reduces greenhouse gas emissions, it may not be obtainable at zero cost. It is quite possible for energy efficiency to be too high. It is rational to save on energy as an input only in so far as the cost of alternative substitute inputs, or the sacrifice in product quality, is not too high.[6]

An example of a no regrets policy in Australia would be the removal of tariffs on imported vehicles. These measures would reduce the average age of cars and therefore also reduce CO_2 emissions per kilometre driven.[7] The policy would be no regrets because the economic benefits would be strongly positive. Australia also could take other measures to improve transport system efficiency. For example, removing restrictions that raise coastal shipping costs could reduce energy use and CO_2 emissions. Railway reform could also reduce energy demands and costs.

In an international context, reversing many trade protection policies may also be a global no regrets measure. For example, barriers to trade in steel may protect older, inefficient, energy-intensive plants against newer and more efficient plants.

6 For example, eliminating machinery and returning to more labour intensive production techniques would reduce electricity consumption but high wages would make the policy extremely costly. Similarly, greater use of plastics in cars might save energy but reduce the value of the product.

7 The number of kilometres driven is unlikely to increase enough to offset this effect.

Delaying action may be a more subtle example of a no regrets policy. Technological change is likely to reduce abatement costs, the costs of removing CO_2 from the atmosphere or the costs of mitigating or repairing damage caused by global warming.

Necessary conditions for tradeable quotas or carbon taxes to work

All governments have access to no regrets policies. More draconian policies, such as TEQ and carbon taxes, will not work, in the sense of reducing harmful environmental effects at the lowest possible cost, if governments do not first use all no regrets policies. Precipitate action on TEQ or carbon taxes also is inappropriate before further research has resolved the substantial scientific and economic uncertainties.

TEQ and carbon taxes also will not reduce harmful effects at the lowest cost if control of CO_2 in the atmosphere is not the best response to global warming. If controlling CO_2 levels is desirable, the marginal cost of reducing emissions into, and extracting CO_2 out of, the atmosphere needs to be equated across locations and activities. The marginal costs of current reduction or absorption measures should also equal the *discounted present value* of expected future marginal benefits.[8]

Tradeable emission quotas

In a TEQ regime, quotas are issued to emitters, who can then trade amongst themselves. High cost emitters can buy quotas from those with low costs until marginal costs are equal. The ability to sell quotas also encourages research into less costly control methods including new technologies.

By comparison, under ‘command and control’ policies regulators specify emission levels, and often the control technology, for each firm. Regulators then need to know the technological and other adjustment alternatives open to all firms. The marginal cost of

8 Let Q_t be the quantity of greenhouse gas in the atmosphere at time t, x_t the output of market goods at t, $c(x_t)$ the cost of producing x_t, $f(x_t)$ the output of greenhouse gas from x production, and q_t the greenhouse gas absorbed at cost $a(q_t)$. The quantity of greenhouse gas will evolve according to

(1) $Q_t = Q_{t-1} - q_t + f(x_t)$

Assume welfare depends positively on the consumption of x_t but negatively on the current level of greenhouse gas $U(x_t,Q_t)$, $U_{1t} > 0$, $U_{2t} < 0$ and let β be the time discount factor. Consumer goods output and absorption measures in each period would then be chosen to maximise

(2) $\Sigma_{t=0}\ \beta^t[U(x_t,Q_t) - c(x_t) - a(q_t)]$

Necessary conditions for a maximum in (2) are

(3) $U_{1t} - c'(x_t) + f'(x_t)[\Sigma_{i=0}\ \beta^i U_{2t+i}] = 0$

(4) $a'(q_t) = -\Sigma_{i=0}\ \beta^i U_{2t+i}$

From (3), the marginal cost of producing x should include the *present value* of future marginal costs (recall $U_2 < 0$) of the associated marginal increase $f'(x_t)$ in greenhouse gas. From (4), the marginal cost of current absorption activity also should equal the present value of future marginal benefits.

controlling pollution can be orders of magnitude larger for one firm than for another, while mandated technologies can be much more expensive than best practice.[9] Command and control approaches also tend to perpetuate existing technologies.

TEQ let individual emitters choose emissions levels within a framework of total emissions set by policy. Effective enforcement is essential not only to controlling total emissions but also for ensuring that quotas retain a positive market value. A TEQ regime also will not produce an efficient outcome unless organisations involved in sink activities can issue quotas.

An efficient *intertemporal* allocation of reductions requires a path of total emissions that equates the marginal cost of control to the *present value* of expected marginal benefits. When there is uncertainty about the costs or benefits of emission control, efficiency therefore will require governments to adjust total emissions as the market price for quota changes. The regime also needs to allow 'banking' of TEQ so that current emission reductions can substitute for future reductions. Expectations about future TEQ prices will affect incentives to transfer reductions into the present or future, as well as incentives to invest in emissions reduction technologies or sink activities. Governments therefore need to specify in advance the *rule* they will use to relate issues of new TEQ to market prices.

The SO_2 market in the United States

The major example of a TEQ system is the market-based approach to reducing sulphur dioxide (SO_2) emissions in the United States instituted by Title IV of the *Clean Air Act Amendments* of 1990. Phase I of the SO_2 program (January 1995 to January 2000) affects 110 of the highest-emitting electricity generating units, although other plants and industrial sources can choose to participate. In Phase II, the program will expand to include most existing fossil fuel power plants. The Act aims to reduce annual SO_2 emissions by 10 million tons below 1980 levels by the year 2000.

The program has the following features:

- The Environmental Protection Agency (EPA) allocated allowances to producers based on past fuel usage, and EPA definitions of 'good practice' control technology. Allowances can be 'banked' by using them *after* the year of issue.
- *Except* where trades would violate local SO_2 standards, owners can sell allowances to market participants, brokers, speculators or environmental groups.

9 Estimates of the cost savings from trading rights to emit SO_2, as instituted in the 1990 *Clean Air Act Amendments*, range from $1 billion annually (Hahn and May 1994) to as much as $3 billion annually, or over 50 per cent of prior costs (General Accounting Office, cited by the CBOT, in 'EPA Acid Rain Program Environmental Benefits', available at http://www.cbot.com/acid.htm, April 1997).

- After 30 days following the end of each year, there is an automatic penalty of $2000 (adjusted for inflation) per ton of prior year SO_2 emissions in excess of the number of allowances. Excess SO_2 emission also must be recovered in a future period.
- Certified equipment, that is checked periodically for accuracy, has to measure on an hourly basis volumetric flow, opacity, and emissions of SO_2, NO_x and CO_2[10] from each unit. The results are reported electronically on a quarterly basis.
- The Chicago Board of Trade (CBOT) holds an annual *direct sale* that offers allowances at a fixed price of $1500 (adjusted for inflation), with qualified independent power producers (IPPs) given first priority to buy. This allows IPPs to ensure they have access to allowances needed to build and operate power plants.
- The CBOT holds an annual *auction* of unsold allowances allocated to direct sales. Private holders can also offer allowances at the auction. Subject to the constraint on local SO_2 standards, private parties are also free to trade allowances at any time.
- The EPA withholds approximately 2.8 per cent of the total annual allowances to supply the sales and auctions. Units from which allowances were originally withheld receive proceeds from allowance sales on a pro-rata basis. The sales are supposed to increase liquidity in the market, provide a price signal for private trades and ensure potential generators can buy allowances. The direct sales mechanism is also used to reduce emissions in early years of Phase I and allocate them to Phase II.
- Auction prices are not determined in the usual manner. Rather, the lowest sale offer and highest bid price are first matched, with the sale occurring at the *bid* price. Matches continue until all allowances have been sold, the number of bids is exhausted or the minimum price for the next allowance exceeds the purchase price of the next bid. Any allowances from the Reserve have a zero offer price.
- Sources not required to participate can enter the program by reducing emissions below their production levels in 1985, 1986 and 1987 using the ‘best available technology’.[11] They are allocated tradeable allowances equal to the reductions. The production base year 1987 was set two years prior to the introduction of the *Amendments* into Congress to eliminate incentives to raise output. Firms voluntarily opting-in cannot sell allowances if they subsequently cease production.

The program allows sources to choose their own method of compliance. They could reduce emissions by changing fuel quality,[12] reassigning production from dirtier to cleaner units, reducing generated electricity, or adopting fuel efficiency measures in addition to using scrubber technologies (as mandated under the old system). Changes in market prices could

10 NOx and CO_2 are also measured although they are not part of the program.

11 We have been told that oil refineries have chosen to enter the program.

12 Deregulation of the US rail industry may have reduced the cost of shipping low sulphur western coal.

affect many of these strategies. The program should also help achieve a given reduction in pollution at minimum cost by allowing pollution to be redistributed *across* producers. Already, the price of pollution allowances has begun to fall, while the allowance trading volume continues to increase from year to year.

Even so, the allowance market is much more complicated, and much less efficient, than it need be. The auction does not provide good information for private trades, and may limit the amount of trading that occurs through the auction mechanism.[13] State regulation of many electric utilities also has not encouraged allowance trades.[14]

Early in the program, uncertainty about regime permanence may also have inhibited trades. A firm with a high cost of control might have been reluctant to purchase additional allowances and increase pollution. If the old controls were re-instituted the purchased allowances would represent a waste of money. Conversely, a low cost firm might be reluctant to cut pollution and sell allowances for fear that a return to the old regime would see their pollution target permanently and substantially reduced.

A reluctance to abandon the command and control approach has also compromised the effectiveness of the SO_2 program. For example, the program retains:[15]

- adherence to EPA 'best practice' standards to determine initial allocations;
- controls on localised emissions in addition to an overall constraint;
- measures to prevent the courts regarding tradeable permits as genuine property rights — making them susceptible to confiscation without compensation; and
- restrictions on allowance trading from firms opting-in to the program, which reduce its attractions for them.

Fortunately, the CBOT has established a cash market for allowance trades. This will facilitate additional trading by reducing the transactions costs of making private trades. The CBOT has also recently begun futures and options markets in SO_2 allowances. Futures prices will allow firms to make better investment decisions about, for example, control technologies and fuel sources. Both futures and options contracts will also enable market participants to hedge the risks associated with future unforeseen changes in allowance prices. Deregulation of the electricity market in the United States should also increase

13 Hahn and May (1994) argue that the best pricing strategy for buyers and sellers 'is not clear'.

14 See, for example, Bohi (1994).

15 Rolfe and Nowlan (1993) discuss tradeable permit systems in chapter 5. They outline many of the equity, political acceptability and other concerns that no doubt lay behind many of these compromises. Rolfe and Nowlan advocate even greater restrictions on a permit trading system.

incentives for generators to pursue more efficient production strategies, including less costly means of controlling pollution output.

An international greenhouse gas TEQ regime

A TEQ regime has the potential to control greenhouse gases more efficiently than any feasible alternative. The SO_2 allowance market in the United States illustrates, however, that there are many practical problems associated with establishing a TEQ regime. An international market in greenhouse gas TEQ would need to solve similar problems, and several others besides, including:

- ***Coverage:*** It is difficult to ensure all greenhouse gas emissions are covered by a TEQ. For example, many sources are expensive to monitor. Policy proposals also usually pertain to CO_2 emissions while ignoring other greenhouse gases. TEQ for one greenhouse gas should be tradeable against TEQ for other gases. Optimising emission of a subset of gases from a subset of activities is most unlikely to achieve an efficient outcome. In addition, sinks are far more important for CO_2 than for SO_2. Investors in sinks need to be able to issue TEQ at the going market price.

- ***Verification and enforcement:*** Easily evaded quotas would be ineffective, in part because insecure property rights will have no market value. Emissions levels (and extractions by greenhouse gas sinks) therefore need to be verifiable and over-emitters need to be penalised. The SO_2 allowance market uses continuous recording by certified equipment, that is checked periodically for accuracy, with electronic reporting of results on a quarterly basis. Since most countries have serious problems enforcing property rights to land, for example, it is most unlikely they would effectively enforce TEQ rights. Differences in legal institutions would compound the verification and enforcement problems in an international TEQ regime.

- ***Stability:*** Tradeable quotas set up property rights in emissions. Judgements about enforcement, regime permanence and future changes in quota supply will affect the market value of quota. Property rights whose endurance is unclear have far less value than those with secure futures. The efficiency of the SO_2 allowance market has been compromised both by a reluctance to abandon the command and control approach and also by the restrictions preventing allowances from being treated as genuine property rights.

- ***Transactions costs:*** If the transactions costs of exchanging quota are too high, trading will be insufficient to minimise the cost of emission control. The CBOT cash, futures and options markets in SO_2 allowances have reduced transactions costs in that market. It would be more difficult to establish such formal markets on an international basis — including in developing countries. A related problem is that the market price of greenhouse quotas is likely to be below the price of SO_2 allowances, making it more important to reduce transactions costs.

- ***Allocation:*** Different allocation regimes have different distributional consequences. Allocation on a per capita basis would involve substantial income transfers from OECD countries, who would be net buyers of quotas, to non-OECD countries, who would be net sellers. Conversely, if recent historical emission levels determined quota allocations, rapidly growing economies would be large net buyers. A regime involving high international income transfers probably would not be feasible.[16] A simple auction system administered by an international agency also would be unacceptable if the revenue accrued to the agency. However, redistributing the funds would raise similar objections to the analogous initial distribution of TEQ.

Carbon taxes

Taxes on greenhouse gas emissions are the major alternative to TEQ. Although such taxes are often called ‘carbon taxes’, the terminology is misleading. The object of the tax is not carbon but oxides of carbon produced by hydrocarbon combustion.[17] Furthermore, CO_2 is not the only, nor necessarily the most important, greenhouse gas.

Since the aim of a carbon tax is to limit the damage from global warming, the regime should cover all sources and all sinks, including reafforestation and land clearing.[18] A carbon tax that does not reward carbon sinks with equal incentives is not sensible public policy. A carbon tax may also be less flexible than a TEQ regime because legislation needs to carefully define the activities that will attract taxes or subsidies.

A tax-based system may be preferable to a quantity-based approach when:

(i) marginal abatement costs and marginal climate damage are unknown; but

(ii) marginal abatement costs (Tasman 1992; Chisholm et al. 1994; Tasman 1994c) are expected to rise more steeply than marginal climate damage (Nordhaus 1991).[19]

Figure 1 shows that, under condition (ii) and for a given efficiency loss, the percentage variation in prices is much larger than the percentage variation in quantity. The expected

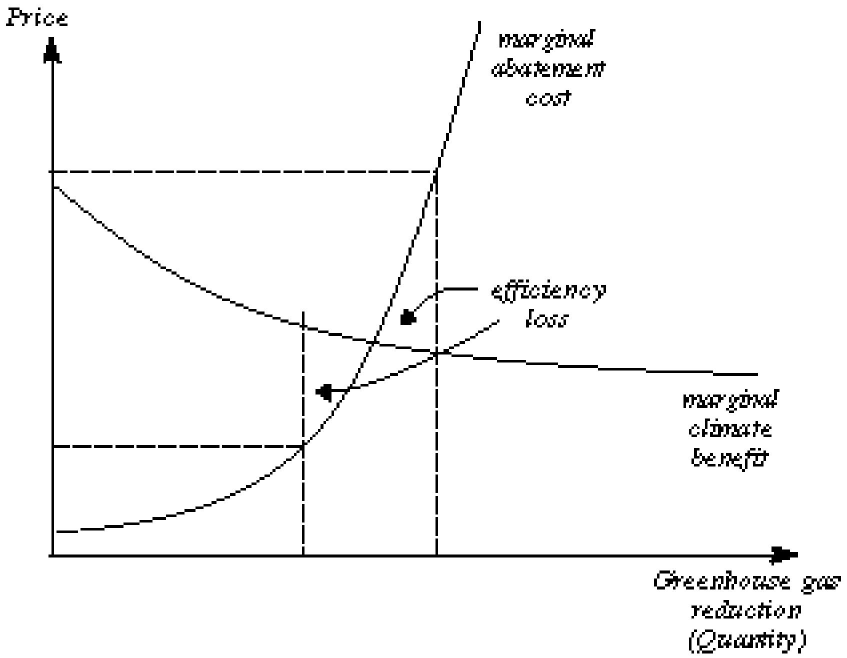
16 See UNEP Climate Change Fact Sheet 231 (http://www.unep.ch/iucc/fs231.html).

17 We already have carbon taxes of a sort. Energy consumption, which most OECD countries already tax highly, is a necessary input to CO_2 production. Indeed, taxes on petroleum products in Australia had an equivalent carbon tax value of almost $A75 per tonne in 1990 (Tasman 1994b). Since income taxes and welfare payments encourage non-market activities at the expense of market activities that use more energy, the whole tax and welfare system also can be seen, in part, as a ‘carbon tax’.

18 Piers Maclaren et al. (1993) and Tasman Institute (1994e) have looked at emissions accounting for pine plantations.

19 The slope and position of the two curves is not known. However, available evidence suggests that the costs of climate change flatten out fairly quickly after initial effects and are flat around current emission levels under a wide range of assumptions about the effect of emissions on concentrations, and concentrations on temperature changes. Costs of emission cuts rise comparatively steeply.

Figure 1: **Targeting price or quantity**



costs of a given percentage error in achieving the target are therefore higher for a mistaken quantity than for an equally mistaken price. It becomes more important to guarantee an emissions price and allow quantities to miss abatement targets.

A bureaucratic argument for taxes is that they are relatively simple to administer. A focus on administrative simplicity leads, however, to poor policy. The *effects* of a policy should be the primary concern. Furthermore, while transactions costs are a relevant consideration, government costs are no more important than the compliance costs and efficiency losses[20] borne outside the government bureaucracy.

Another consideration is that the history of taxation does not inspire confidence in government restraint, economic rationality or simplicity. Tax instruments, like regulations (Krueger and Duncan 1993), become entrenched and more complex over time. Tax rates also inevitably increase due to 'fiscal demands' and the imperative for politicians to spend money regardless of outcomes. One cannot be confident that a carbon tax would bear any connection with the level required to achieve an efficient emissions target. A TEQ regime

20 Common and Hamilton (1994) claim that *replacing* the payroll tax in Australia by an explicit carbon tax would produce efficiency *gains*. Their results rely, however, on the counter-factual assumption that the supply of capital is constant while labour supply is perfectly elastic (so labour supply matches labour demand increases with no change in real wages). A carbon tax substantially reduces the return to capital in the model, but the assumption of a constant supply of capital implies that investment remains unaffected. This is unrealistic in a world capital market where even minor changes in expected returns can produce massive capital flows. Similarly, the large 'dividends' from the removal of the payroll tax follow from the assumed highly elastic labour supply. In the longer term, however, labour supply is relatively inelastic, and certainly more inelastic than capital supply.

that does not transfer revenue to governments may be more likely to be evaluated on efficiency grounds alone.

Conclusion

The current state of greenhouse science does not justify costly control measures. In addition, there are many ‘no regrets’ policies that could be implemented before anyone needs to make sacrifices in the name of preventing possible global warming.

As a method of further controlling CO_2 emissions, a TEQ regime would be preferable to command and control procedures. It is also likely to be preferable to a carbon tax, particularly if it facilitates increased use of sinks. The great danger with a carbon tax is that the desire of politicians to raise more revenue is likely to supplant the emissions control function. However, many practical problems have to be solved before an international TEQ regime could be implemented. Fortunately, the best scientific evidence implies that we have plenty of time before solutions to these problems might become necessary.

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