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TRADABLE PERMITS IN TRANSPORT?

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PREFACE

Article 16 bis was a last-minute addition to the Protocol negotiated in Kyoto in December 1997 at the third Conference of the Parties to the United Nations Framework Convention on Climate Change. It calls on the Parties to develop rules and guidelines for emissions trading 'for the purpose of meeting quantified emission limitation and reduction commitments'.

No concrete consideration has been given yet to the modalities of introducing a scheme for trading emissions in countries like Australia. It is therefore timely to identify at least some of the practical implications that any such scheme might have, if it were to be introduced at some time in the future.

Most of the literature on trading in greenhouse emissions has focused either on international aspects, or on general principles. Much of the literature is also incestuous, because the same examples of the limited number of existing (non-greenhouse) schemes tend to be drawn on in each article or book. Little has been written on the likely effects on various sectors of domestic economies. Even less has been written on the difficult issue of how to take account of carbon sinks.

By contrast, this Working Paper breaks new ground by identifying a number of practical issues that merit serious consideration if a workable scheme is to be implemented in the transport sector. Nevertheless, the authors are conscious of the strong likelihood that not all relevant issues have been addressed. Any comment would therefore be gratefully received.

The authors were Leo Dobes (principal author), Edwina Heyhoe, Joe Motha, and Ryan Perry. The Project Coordinator was Edwina Heyhoe.

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ABSTRACT

Tradable permits were a key, but last-minute issue, to arise out of the Protocol agreed in Kyoto. Much of the literature on tradable permits focuses on the international implications of tradable permits or on general theoretical issues. This paper focuses instead on the practical implications for the transport sector of a national or international scheme.

If an effective tradable permit scheme is to be implemented in Australia, it needs to take account of issues such as the fact that international transport emissions are currently recorded, but not attributed to specific countries; possible distortions, because the Kyoto Protocol targets only direct greenhouse gases; the need for compatibility with ‘green’ national accounts, and business accounting conventions for treating environmental assets and liabilities; and the need for scientific clarity on the calculation of CO_2 equivalents for long-term carbon sinks.

The high transaction costs involved in tradable permit schemes raise the question of whether a carbon tax may be preferable in the transport sector.

… AT A GLANCE

- The Protocol agreed at the December 1997 Climate Change Conference in Kyoto calls on the Parties to develop guidelines for trading in greenhouse emissions.
- Tradable emissions permits would entitle holders to emit a specified amount of greenhouse gases, denominated in CO_2 equivalents. By issuing permits to a quota level below that of current emissions, governments could reduce national emissions to meet internationally agreed targets. Trading of permits among holders would ensure that national emission targets were met at least cost.
- Tradable permits have been analysed widely (and positively) in the literature from a general and theoretical perspective. But virtually nothing has been written about the practical issues involved in implementing them in specific sectors such as transport. This Working Paper seeks to remedy that deficiency.
- By targeting only radiatively direct greenhouse gases, the Kyoto Protocol excludes carbon monoxide and nitrogen dioxide, both emitted by transport vehicles. Nor is any clarification provided on the attribution of emissions from international transport to individual countries; or whether such emissions would also be traded. Distorted behaviour could follow.
- Permits could be allocated to vehicle operators such as motorists or airlines, but it would be administratively cheaper to allocate them to the smaller number of fuel producers or wholesalers. Because they limit use of fossilised carbon, tradable permits would effectively ration the use of fuel. If wholesalers received free allocations on a ‘grandfathering’ basis, they would gain windfall profits.
- Consideration needs to be given to making any tradable permit scheme compatible with national ‘green’ accounts, and with business accounting conventions for environmental assets and liabilities.
- Creation of sinks (for example by planting trees) would be a means of gaining ‘credits’ that could be sold, or used to offset emissions beyond initial allocations of permits. Two major issues that probably need to be addressed in future negotiations are the numeraire of CO_2 equivalents and its scientific

determination, and the assumption of risk in the creation of sinks. Resolution of both issues would reduce uncertainty about tradable permit schemes.

- Given the relatively high administrative costs that would be incurred in implementing and operating a tradable permit scheme in the transport sector, it is valid to ask whether a carbon tax might not be a better alternative.

TRADABLE PERMITS IN TRANSPORT?

Concern about the potential effects of climate change has prompted a number of international conferences in recent years. One of the most influential has been *The Changing Atmosphere: Implications for Global Security* conference, held in Toronto in June 1988. The conference urged all governments to adopt action plans aimed at reducing annual carbon dioxide (CO_2) emissions to 20 per cent below 1988 levels by the year 2005. The outcome has since become known as the 'Toronto target'.

A Framework Convention on Climate Change (FCCC) was signed by more than 150 countries following the United Nations Conference on Environment and Development, held in Rio de Janeiro in June 1992. The FCCC does not contain a binding target, but calls on developed countries and others identified in Annex I to the Convention to adopt policies and measures with the aim of returning their greenhouse gas emissions to 1990 levels by the end of the present decade.

The first Conference of the Parties (COP1) to the Convention took place in Berlin in March–April 1995. It mandated negotiation of a new set of post-2000 (up to 2020) commitments for Annex I Parties, but no new commitments for developing countries. Australia argued that, in the light of rapidly increasing emissions from developing countries, there was a need for greater developing country involvement in emission reduction efforts, in order to ensure an effective global response. This position did not, however, receive much support.

A second Conference of the Parties (COP2), held in Geneva from 8 to 19 July 1996, resulted in a Ministerial Declaration calling for accelerated negotiations on the text of a new legal instrument, to be adopted at COP3 in Kyoto, Japan, in 1997. While Australia endorsed the Ministerial Declaration, it did not agree to the commitment that the outcome of the Berlin mandate negotiations would include legally binding targets, without the nature and content of the commitments being clear.

THE KYOTO PROTOCOL

Intense negotiations at the 1–10 December 1997 third Conference of the Parties in Kyoto resulted in agreement on the so-called Kyoto Protocol. The Protocol will be open for signature for twelve months from 16 March 1998. It will enter into force 90 days after 55 parties have ratified it, including parties that account for at least 55 per cent of the 1990 greenhouse emissions of Annex I countries.

Annex B to the Kyoto Protocol lists 39 countries and their different emission limits. By the 'commitment period' of 2008–2012, Australia is expected to reduce its emissions to a level that is no more than 8 per cent above those in 1990. (Emissions resulting from changes in land use are included.) Overall, the Annex I countries are to reduce CO_2 equivalent emissions of 6 specified greenhouse gases by at least 5 per cent below 1990 levels.

A last-minute addition to the Protocol was Article 16 bis, which provides that:

> The Conference of the Parties shall define the relevant principles, modalities, rules and guidelines, in particular for verification, reporting and accountability for emissions trading. The Parties included in Annex B may participate in emissions trading for the purposes of fulfilling domestic actions for the purpose of meeting quantified emission limitation and reduction commitments…

As indicated by Article 16 bis, details of any international scheme for emissions trading remain to be negotiated. Provision in Article 12 of the Protocol for a 'clean development mechanism' also envisages further elaboration. Clean Development Mechanisms (previously referred to as Actions Implemented Jointly) are intended to facilitate joint implementation of projects by Annex I and non-Annex I countries. For example, Australian public or private sector participants could agree with Malaysian partners to plant trees in Malaysia, or to transfer new technology, in order to achieve an overall global reduction in net emissions.

The Federal Minister for the Environment, Senator Robert Hill, is on record to the effect that:

> Australia supports emission trading in principle, recognising its possible contributions to improving the cost-effectiveness of emission reduction.
>
> ('Australia's International Policy on Climate Change', address to the American Chamber of Commerce in Australia, ANA Hotel, Sydney, 9 July 1997.)

It is therefore timely to consider the potential implications for transport, as well as other sectors of the Australian economy, of the possible introduction of tradable permits for controlling greenhouse gas emissions.

The literature has to date focused primarily on general principles (for example Hinchy et al. 1993), and on potential international arrangements. By contrast, this Working Paper focuses on the *practical* implications for the Australian transport sector if a tradable permit scheme were to be implemented in the future.

Unfortunately, the lack of a detailed international agreement makes it difficult to be specific about a tradable permit scheme. For the purposes of discussion, it has been assumed that a scheme would:

- be national in scope—that is, it would include all sectors of the economy, and allow permits to be traded freely between them;
- encompass both sources and sinks;
- ensure fungibility of permits, possibly by expressing them in CO_2 equivalents, and avoiding time limits on their use; and
- preclude governments from regulating trading activity beyond allocation of new permits (probably on an annual basis), monitoring, enforcement, and Open Market Operations designed to alter the number of permits held by residents.

WHAT ARE TRADABLE PERMITS?

Governments can employ three major means to reduce externalities such as greenhouse gas emissions (BTCE 1998).

Regulatory, or 'command and control' approaches are the oldest and simplest way to control environmental damage. But regulations are highly arbitrary, may involve significant administrative costs, do not encourage reductions below official limits, and typically fall with equal force on all.

In the case of greenhouse gases, governments could impose a 'carbon' tax as an alternative means of reducing emissions by making fuel more expensive. But governments would need to guess to some extent the likely reduction that would be achieved by such a tax. Moreover, subsequent spending by a government of the revenue raised would transfer some of the benefits back to polluters, partially offsetting the initial reduction in their incomes.

A third option is to employ tradable permits. Tradable emissions permits would entitle the permit holder to emit a specified amount of greenhouse gases. By issuing only a limited number of permits, governments would be able to keep national emissions at or below a specified level (assuming no cheating by permit holders). In the case of greenhouse emissions, the level itself would be unlikely to be economically optimal, being set on the basis of international agreements, without regard to differences between countries in marginal costs of abatement. However, given a pre-determined emission limit, tradable permits allow polluters to choose the most cost-effective means of reducing emissions. They therefore combine the certainty of regulatory standards with the flexibility and cost-effectiveness of economic instruments.

Permits can be bought and sold. But governments will limit the number of permits to less than the current level of emissions (otherwise there would be no need to have permits). Permits will therefore command a price like any other asset or commodity in short supply. To meet permitted emission quotas, polluters would need to either reduce their current levels of pollution, or obtain sufficient emission permits from others.

Polluters able to reduce their emissions relatively cheaply will do so, rather than purchasing permits. Those polluters who face higher abatement costs will tend to purchase permits to satisfy requirements. In this way, reductions in emissions are made by those polluters who can do so at least cost (being compensated by polluters who face higher costs).

THE TRANSPORT SECTOR IS DIFFERENT

There is no theoretical reason why tradable permits should not be applied to emissions from the transport sector. However, the transport sector is different from other sectors where tradable permits have been used to date. These differences are salient to any discussion of tradable permits:

- 'Transport' is not homogeneous. The five major competing modes (road, rail, air, sea, and pipelines) use different fuels and vehicles. The output of pollution, including greenhouse emissions, is different for each mode. Four of the five modes can be further categorised into passenger (mainly private travel) and freight (largely the business sector), so there are significant differences in characteristics. The design of a tradable emissions permit scheme could differ for each mode and category, depending on the basis of allocation.
- Compared with other industries where tradable permits have been used to date, transport systems involve mobile, rather than fixed sources of emissions. Monitoring of emissions could therefore be more difficult or expensive.
- Although carbon dioxide forms about 85 per cent of the emissions from transport in general, other externalities are also generated. Noxious emissions (some of which are also greenhouse gases), traffic congestion, effects, noise and accidents are produced in ways that are not independent of the production of carbon dioxide. Focusing on carbon content alone could result in socially sub-optimal results. For example, reducing the amount of carbon emitted could raise the level of nitrogen dioxide emissions.
- Pricing in the transport sector is not particularly close to optimal. Although excise is levied on fuel, various selective rebates apply. Apart from a few toll roads in Sydney and Brisbane (and soon in Melbourne), passenger vehicles use roads without any charge save for a lump sum annual registration fee imposed by each State and Territory. While heavy vehicles attract road user charges, these charges do not clearly reflect the marginal damage caused to roads. Excise levied on fuel is primarily a revenue measure, and various selective rebates distort its effect. The lack of a coherent, economically rational charging policy means that the marginal principle currently plays little part in setting road user charges (BTCE 1997).
- The domestic transport sector provides a non-tradable service. Of itself, its output cannot be produced overseas as a substitute for domestic production of transport services. Unlike other sectors, it is therefore not vulnerable to potential 'carbon leakage' (explained below).
- Demand for petrol is highly inelastic.

HOW TRADABLE PERMITS MINIMISE ABATEMENT COSTS

Suppose that there are two people, Mr Smith and Ms Jones. Each emits 20 tonnes of carbon per year, so that 40 tonnes of carbon are emitted annually between them. Suppose also that the Government wishes to reduce their total annual emissions by 10 tonnes, to 30 tonnes. One way to do this would be to force both Mr Smith and Ms Jones to reduce their emissions by the same proportion, to 15 tonnes each annually. In one sense, this seems fair, because both are forced to reduce emissions by the same amount (in this case both in absolute terms and as a percentage).

But unless it costs Mr Smith and Ms Jones the same amount to reduce their emissions, this method could be needlessly costly. For example, Mr Smith's only way of reducing his emissions may be to catch a bus instead of driving his car to work, whereas Ms Jones may live close enough to work to walk instead of driving her car. Suppose it costs Mr Smith $100 per tonne (say in terms of the value of time lost in additional travel) to reduce his emissions, and that it costs Ms Jones only $50 per tonne. If Mr Smith and Ms Jones reduced their emissions by 5 tonnes each, the cost to each would be $500 and $250 respectively, leading to a total of $750 for the reduction of 10 tonnes.

Were a system of tradable permits to be introduced, however, this total cost could be reduced. The community as a whole (Mr Smith and Ms Jones) would save on resources used.

To limit total emissions to 30 tonnes, the Government could allocate 30 tonnes worth of permits. It could allocate 15 permits each to Mr Smith and Ms Jones (1 permit = 1 tonne). Now Mr Smith would probably be willing to buy permits instead of reducing emissions himself, so long as the price was less than $100 per tonne. Ms Jones would be willing to sell permits and reduce her emissions so long as the price was more than $50 per tonne. Suppose the market price was $70. Ms Jones would reduce her emissions by 10 tonnes (costing her $500), and contrive to emit 10 tonnes. She would also sell 5 of her 15 permits to Mr Smith for $350. Mr Smith would purchase Ms Jones' permits, and would not need, therefore, to reduce his emissions. The total cost of abatement would then be $500, less than the $750 cost were they both to reduce their emissions by the same proportion.

The sharing of costs between individuals depends on the initial allocation of permits. In this example, Ms Jones faces a net cost of $150, while Mr Smith bears costs of $350. However, the Government may decide that it would be more equitable to give Mr Smith 17 permits, and Ms Jones 13 permits (still 30 in total). Were the market price still $70, Ms Jones would still reduce her emissions by 10 tonnes (costing her $500), but would only be able to sell the 3 permits she holds for $210. She would bear a net cost of $290. Mr Smith, on the other hand, would purchase 3 permits from Ms Jones for $210, and would not need to reduce his emissions. The total cost for both is still $500, but the costs are shared between them in a different way.

Each of these points is important in assessing the potential effectiveness and practicality of a tradable permit scheme from the perspective of the transport sector. They need to be taken into account when considering the major attributes of tradable permits.

THE TARGET POLLUTANT

Annex A of the Kyoto Protocol lists 6 greenhouse gases that are to be counted as part of the abatement targets:

- carbon dioxide (CO_2);
- methane (CH_4);
- nitrous oxide (N_2O);
- hydrofluorocarbons (HFCs);
- perfluorocarbons (PFCs); and
- sulphur hexafluoride (SF_6).

The Protocol does not directly address the issue, but permits traded either nationally or internationally would presumably be denominated in terms of CO_2 equivalents of the radiatively direct greenhouse gases listed in Annex A. However, the International Panel on Climate Change (IPCC) does not currently give numerical values for the Global Warming Potentials of indirect greenhouse gases, such as carbon monoxide (CO). Due to the short atmospheric lifetime of most indirect greenhouse gases and the complex chemical processes involved in their effects, GWP values have not been assigned in the recent IPCC reports. If any scheme for emissions trading is to be fully effective, there must be an agreed methodology for calculating the CO_2 equivalent effects of the indirect greenhouse gases.

The gases listed in the Protocol do not include carbon monoxide (CO), which forms about 6 per cent of the total CO_2 equivalent emissions of passenger cars (BTCE 1996a, p. 377). Not itself radiatively active, CO is nevertheless considered to be an indirect greenhouse gas because it eventually oxidises to CO_2, aids in the production of ozone, and scavenges hydroxyl radicals which would otherwise remove methane (a direct greenhouse gas) from the atmosphere. The sum of these effects would have a greater Global Warming Potential than CO_2.

Carbon monoxide results from incomplete combustion in internal combustion engines. If it is not included in the gases targeted by a tradable permit scheme, it is possible that cars would be tuned solely to optimise fuel consumption, rather than to minimise total exhaust emissions. Emissions of the ‘indirect’ greenhouse gas CO could increase.

Equally important, CO is a noxious gas. In urban areas, up to 90 per cent of CO emissions are due to motor vehicles (BTCE 1995, p. 137). Any increase in concentration in urban areas could add to adverse health effects, particularly circulatory and respiratory disorders.

Targeting directly radiative greenhouse gases alone may also result in other perverse consequences. For example, catalytic converters reduce the output of noxious emissions such as CO and oxides of nitrogen (NO_x). Nitrogen dioxide (NO_2) is not only an ozone precursor but can cause lung damage, increased susceptibility to asthma, and damage to plants and buildings through acid rain. Three-way catalytic converters, which have been standard on Australian cars since 1988, reduce emissions of CO, NO_x and hydrocarbons. However, the use of catalytic converters can increase fuel consumption in cars. Some motorists could be unintentionally encouraged to disengage catalytic converters in order to reduce fuel consumption.

Transport vehicles produce three major indirect greenhouse gases: CO, non-methane volatile organic compounds (primarily hydrocarbons), and NO_x. Uncertainty created by omission of such gases from a tradable permit scheme may also have an adverse effect on the scheme. The prices of current permits may be discounted to allow for the risk of possible devaluation if other gases are introduced into a tradable permit scheme in the future.

A potential problem of some tradable permit schemes is the localisation of effects. EPAV (1995, p. 24) points out that in the case of a scheme covering noxious emissions:

> …permit purchasing patterns will be determined by the comparative emission reduction costs faced by individual emitters. It is possible that an individual firm, or a group of firms in close proximity to each other, may buy a large proportion of the available NO_x emissions permits and this might lead to localised pollution problems. The nature of dispersal of the pollutant to the particular airshed is also a factor in causing localised effects.

Not all emissions that affect radiative forcing (the determinant of the 'Greenhouse Effect') are fully miscible in the atmosphere. However, greenhouse gas emissions are generally more of a global, rather than a geographically local, concern. Nevertheless, it is possible that unforeseen localised effects could occur in terms of other transport externalities. For example, a greenhouse gas emissions trading scheme could induce residents of cities where public transport services are poor to buy (greenhouse) permits because of the lack of alternatives. Congestion, noise, or noxious emissions in such areas might increase.

THE TARGET POLLUTER

It is natural to think of a system of tradable emissions permits being directed at the users or producers of fuel. However, BIE (1992, p. 27) put forward two other possibilities, albeit in the context of pollutants from a non-greenhouse perspective:

- motor vehicle manufacturers could be permitted to build any combination of polluting or non-polluting vehicles, subject to an overall permit quota of total emissions. Under this system, producers of gas guzzlers would need to purchase permits from producers of fuel-efficient cars. Wang (1994) similarly proposes a marketable permit scheme for light duty vehicle manufactures, as a more efficient alternative to the ‘corporate average fuel efficiency’ system; and
- a tradable permit system based on commuters’ destinations. This strategy would work by defining the destination as the source of emissions, since it can be argued that a destination’s output is dependent upon the number of commuters travelling to it. Destinations such as businesses, theme parks, or beaches would effectively be required to reduce visitors’ vehicular emissions through strategies such as providing company buses, rationing parking spaces, imposing parking taxes, and so on.

These options are not pursued here on the principle that it is better to control the actual source of the pollution, rather than an indirect agent. The primary focus of this Paper is therefore on allocation of permits to either vehicle operators (motorists, etc.) or producers (or importers) of fuel.

A major unresolved issue in international negotiations that is particularly relevant to Australia is the attribution of bunker fuel used by ships and aircraft on international routes. To ensure that all fuel use is accounted for, the International Panel on Climate Change (IPCC), the principal body investigating greenhouse issues, recommends that countries should ‘record separately [from domestic usage] the quantities of fuel uplifted’ by international ships and aircraft (IPCC/OECD 1994, p. 1.11).

Unless an international agreement can be reached, fuel used by international transport would presumably be excluded from the ambit of any emissions trading scheme. The obvious distortion would occur, with trips to Bali or

Singapore becoming relatively more attractive than those to Darwin or Perth. Domestic emissions may fall, but total global emissions probably would not.

Where a country takes measures to reduce greenhouse emissions in a way that increases costs of production, then its exports (or domestic sales) of the commodity involved may become uncompetitive. If production is transferred to another, lower cost country which has not taken similar abatement measures, there is said to be emissions or carbon ‘leakage’. Where leakage migrates to a country which is less efficient in emission output, the net result of abatement measures taken in the first (abating) country may be a global increase in emissions.

Because domestic transport services are not traded internationally, ‘carbon leakage’ is unlikely to be a problem in terms of transport per se. However, it could affect other sectors (such as aluminium smelting) from which demand for domestic transport services is derived. If the country to which the aluminium smelter ‘migrates’ has an associated transport system that uses more fuel than would be used in Australia, concomitant ‘carbon leakage’ will also occur in terms of domestic transport services. Even in terms of domestic transport, therefore, an effective international tradable permits scheme requires that all countries (not just those in the Annex I group) accept emission reduction obligations.

ALLOCATION OF PERMITS

In theory, the initial assignment of permits will not affect economic efficiency. In practice, however, things are not that simple.

INTER-SECTORAL ALLOCATION

Permits for greenhouse emissions could, in principle, be allocated equally between sectors. For example, if Australian emissions in the 2008 to 2012 'commitment period' were expected to be 40 per cent above 1990 levels, then Australia could be bound under a ratified Kyoto Protocol to reduce emissions by 23 per cent from their expected levels (calculated using the following formula).

The agriculture, transport, energy, industry, tourism, and household sectors

$$\frac{5 \times 1.08 \times \mathit{1990emissions} - \mathit{2008to2012totalemissions}}{\mathit{2008to2012totalemissions}}$$

could be required to each reduce emissions by 23 per cent.

The inefficiencies of this option are obvious. Emissions should be reduced by a greater proportion where it is more cost-effective to do so. Overlap between transport and tourism or other sectors could also be a problem. The administrative costs of separate systems would probably be greater than for a joint scheme. And the greater the number of sectors, the more economically inefficient the system, because the opportunities for efficient trading of permits would be more limited within each (smaller) sector. The sectoral approach is therefore to be ruled out.

ALLOCATING PERMITS TO INDIVIDUALS

Allocating permits to individual motorists (or operators of trains, ships or aircraft) is attractive primarily because it would provide a direct incentive to reduce fuel consumption not only through choice of vehicle, patterns of travel behaviour (including mode choice) and residential location, but also through driving behaviour such as reduced acceleration.

But there are a number of disadvantages which would probably outweigh any efficiency advantages of allocation of permits to individual users of transport.

The most significant disadvantage would be the substantial implementation, administration, monitoring and enforcement costs incurred if individuals participated in the tradable permit market. Without a clear understanding of the scheme proposed, it is impossible to be accurate about costs. However, the following list suggests likely areas of expenditure, and, where available, estimates of the order of magnitude using programs with similar characteristics as proxies.

- A centralised electronic system would be needed to handle the large number of transactions that would take place if every Australian (as well as operators of buses, ships, etc.) were allocated permits. The scheme would be of a similar scale to Medicare. There are currently about 10 million Medicare cards in circulation, with a unit cost of approximately $0.85, totalling about $8.5 million (M. van Teulingen, Health Insurance Commission, pers. comm. 30 January 1998). Additional cards would be necessary if business also required permits to purchase petrol;
- All fuel retailers and permit brokers would need scanning equipment. There are currently approximately 9 000 retail fuel outlets in Australia (M. Frewin, Australian Institute of Petroleum, pers. comm. 12 January 1998), and the scanning equipment used in the Medicare system has a unit cost of $907 (pers. comm. M. van Teulingen, Health Insurance Commission, 30 January 1998). The total cost of this equipment would be at least $8 million.
- Were permits to be allocated to every Australian resident, a large scale public education campaign would need to be undertaken to teach individuals how the system would operate. A campaign may be considered that would be of similar magnitude to the one conducted by what is now the Australian Communications Authority (formerly Austel), the regulator for telecommunications and radiocommunications, to educate the public about changes in phone numbers. It cost approximately $25 million over a five year period (M. Perreira, Australian Communications Authority, pers. comm. 20 January 1998).
- Recurrent costs to government would include annual ‘topping up’ of electronic permit accounts, general administration (lost cards, etc.) of the system, handling complaints and enquiries, fraud control, audit, monitoring of any sinks, and maintaining and upgrading equipment.

If permits in the transport sector were ‘grandfathered’ (issued free, approximately on the basis of past usage of fuel or kilometres travelled), special arrangements would need to be made for migrants, new car owners, new bus companies or train operators, and tourists. Car ownership per head, for example, has grown about 1.5–2 per cent per annum in recent years.

Grandfathering permits on the basis of vehicle ownership may not be the most equitable allocative mechanism. It may even lead to some perverse or unforeseen behaviour, such as non-car owners purchasing cheap cars simply in order to obtain free emissions permits. Possible alternatives include allocation of an equal number of permits to each Australian resident, or a government auction of all permits.

Some degree of equivalence would need to be established to facilitate exchange of permits between modes of transport. For example, how would a train passenger be allocated permits? And what if the train is only half full? The easiest method of overcoming this problem would seem to be to allocate permits to *operators* of all vehicles. Train operators, rather than individual travellers, would be required to buy and sell permits. Similarly, operators of ships, buses, aircraft, cars or trucks would be responsible for permits.

ALLOCATING PERMITS TO FUEL WHOLESALERS OR PRODUCERS

Allocation to fuel wholesalers, or producers, offers an alternative. Transaction costs would be lower. (Stavins 1995 suggests that the success of any tradable permit scheme may be dependent on transaction costs.) And the effect of rationing fuel through the quotas established by a tradable permit scheme would be passed on to all vehicle operators in the form of higher prices. Allocating permits to fuel producers would fit easily into a national scheme in which individuals would not need to hold permits for their day-to-day activities.

Commentators such as Cornwell, Travis and Gunasekera (1997, p. 19) warn that imperfect competition could result from allocation just to a few large participants. Because fuel producers and importers would be able to trade with other industries this is unlikely to be a problem, although regulatory vigilance would be required.

Grubb (1990, pp. 101–3) makes an important point about tradable permits for CO_2. Unlike the case of pollutants such as lead or SO_2, which form only a relatively minor component of relevant emissions, carbon cannot be removed from the fuel without changing the nature of the fuel. Control of carbon through tradable permits is thus equivalent to rationing fossil fuels.

Where there is no close substitute, demand for a fossil fuel is generally inelastic. (This is particularly true of petrol.) Any restriction in supply will increase price. If the initial allocation of permits is free and directed at wholesalers or producers of fuel, then large companies could reap significant windfall profits. Under this scenario, the share prices of the large oil companies might actually rise, contrary to commonly held expectations about the effect on them of greenhouse abatement measures.

If the Government sought to recover some of the fuel wholesalers' windfall gains through taxation, the companies would pass on a large proportion of the taxes to individual buyers. For example, Capital Gains Tax may apply if companies receive permits free and sell them later. Under current laws applicable to fishing licences it is likely that the tax would be payable on the wholesale price (P. Brady, Australian Taxation Office, pers. comm. 25 February

1998). Final prices of fuel would be higher than warranted solely under a theoretical tradable permit scheme.

If the initial allocation were not free, and permits were auctioned, then the price paid would presumably reflect the value to the buyer of any likely windfall gains. In this case, the Government would skim off the gains immediately and more fully. However, recycling of large revenues back to transport users through general Government expenditure and provision of services might not be optimal.

MARKET MECHANISMS

Imposing time limits on the use of tradable permits offers a convenient administrative mechanism for monitoring and controlling emissions on an annual basis. Tradable permits issued at the beginning of a year would simply expire at the end of the year, and new ones would be issued for the next period. Governments would be aware of the exact level of permitted annual emissions, assuming no cheating.

However, artificial time horizons do not appear to be necessary. Article 13 of the Kyoto Protocol permits the parties to claim credit in 'subsequent commitment periods' for emission levels below their 'assigned amount', including any shortfall due to the creation of carbon sinks (see below).

Time limits could generate large movements in fuel prices at various times of the year. If permits are valuable assets, they will tend to be used reasonably soon (unless there is an expectation of appreciation in real value), or be sold. Otherwise, the holder will incur an opportunity cost similar to holding cash at home rather than in an interest-bearing deposit. Time limits for using a permit would also be illogical from a global climate perspective, unless emissions today cause a different degree of Greenhouse 'damage' than emissions in the future. Indeed, there may even be global climate benefits in encouraging the postponement of emissions to which a permit holder is entitled.

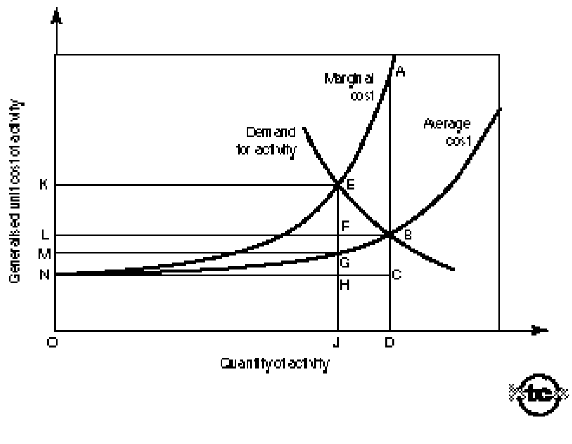
Allocation of permits to individual motorists and other vehicle operators would have the advantage of helping to create a wide market. But allocation to individuals would necessitate small denominations of permits for the whole scheme, to allow individuals to trade amongst themselves or with larger users. That is, major power stations would in theory need to be able to sell to, as well as buy from, individual motorists. In practice, middlemen would probably buy and sell small denominations in larger 'lots' or bundles. But in the absence of small denominations, prices would not be determined 'at the margin', resulting in a disjointed market and consequential loss in efficiency.

PRIVATE, PUBLIC AND SOCIAL COSTS

Social costs of an activity are those borne by society as a whole. They are the sum of the costs of resources used by individuals in that activity (private costs), and the value of any loss in the community's welfare due to the costs imposed by the activity on other individuals (public costs) who are not directly involved. If the opportunity costs of resources are correctly reflected in their market prices, then social costs differ from private costs by the damage caused by any externalities.

In figure 1, for any given level of activity OD, the vertical distance DB represents private costs (e.g. fuel, travel time, wear and tear on vehicle) and BA represents the public costs (the value of an externality such as greenhouse emissions). Total private costs for all individuals engaged in the activity are given by the area LODB, and the total public cost is represented as area ABE. A polluter can be required to 'internalise' a pollution externality by paying a tax or charge to reflect the additional costs to society from the externality. Imposition of such 'Pigovian' taxes, named in recognition of their first proponent, A.C. Pigou (1920), results in a socially optimal level of pollution. Apart from any administrative costs involved, a major drawback of Pigovian taxes is the difficulty of estimating the value, and hence the cost, of an externality at the socially optimal level. This problem is currently almost intractable in the case of 'carbon' taxes to reduce greenhouse emissions, because there is no scientific consensus on the effect or the likely damage in local areas.

FIGURE 1 ECONOMIC THEORY OF EXTERNALITY CHARGES



An alternative to a Pigovian tax GE in figure 1 is for governments to limit administratively the amount of the externality to the socially optimal quota OJ. If permits can be traded freely, a price equal to the Pigovian tax will be established automatically. Such tradable permits are not a panacea, because determination of the socially optimal level of an externality poses the problem of estimating its public cost. Because it is not known what the public costs of greenhouse emissions might be (or, conversely, the benefits of reducing such emissions), neither Pigovian taxes nor emission quotas can be set with any confidence. If tradable permits were to be established, emission levels would probably be determined by international political agreement rather than by estimating costs and benefits.

In theory, externalities can be addressed through a Pigovian tax that reflects public costs at an optimal point of production. Tradable permits are set in theory at the same point.

However, the transport sector is unlikely to be close to a point of market optimality, because of the absence of road user charges based on economic principles. Ideally, a Pigovian tax (or tradable permit scheme) should be introduced only after the imposition of rational road user charges. Of equal concern is the potential for distortion of the market mechanism where only one externality (greenhouse emissions) is addressed. It is not clear whether a tradable permit scheme without road user charges, or correction of other externalities such as noise and noxious emissions, will increase or decrease optimality. This is an area where more research would clearly be beneficial.

COMPATIBILITY WITH ACCOUNTING CONVENTIONS

Increasing attention has been given in recent years to revising current international conventions on national accounting. Conventional national accounts do not count factors such as clean air or old growth forests as part of a country's wealth. They include provision for depreciation of manmade assets, but not depletion of natural resources such as fish stocks, and record costs of cleaning up environmental damage as an addition to GDP, rather than a reduction in environmental asset values. An important issue in the production of 'green' national accounts is the attribution of environmental costs. Dutch farmers are reported (*Economist* 1993, p. 67) to have been annoyed because the costs of acidification and eutrophication from application of nitrogenous fertilisers were attributed solely to them in a set of satellite national accounts published by the Netherlands Central Bureau of Statistics. As with transport, it is not clear that environmental effects should be attributed automatically to the producers rather than the consumers of goods or services.

'Green' national accounts are not currently being reported in Australia (Sean Thompson, ABS, pers. comm. 24 February 1998). However, the major relevance of any future development of 'green' national accounting systems is that it would be administratively inefficient to adopt conventions different from those applied to a tradable permits scheme. As far as possible, the development of conventions in both should be coordinated at an international level.

Equally important is the need to maintain compatibility with business practice and accounting conventions. Transport companies and other businesses are generally subject to accounting standards. In recent years the accounting profession has devoted increased attention to standards for the treatment of environmental assets and liabilities (for example ICAA 1998). Establishment of any tradable permits scheme would require consultation and coordination with business interests to ensure compatibility.

MONITORING AND ENFORCEMENT

Adequate monitoring and enforcement would be vital to the success of any tradable permit scheme. In principle, the transport sector would not be likely to differ significantly from other sectors of the economy in requiring monitoring and enforcement to ensure that cheating did not occur. There would, however, be significant differences in the cost and difficulty of these tasks, depending on how the permit scheme operated.

Monitoring could become much more expensive and difficult if all vehicles were to be monitored rather than a relatively small number of fuel wholesalers or producers. In particular, compliance in the transport sector would require monitoring of fuel sales. Whether permits are allocated to individuals or to fuel producers/wholesalers and importers, governments would need to have reliable measures of fuel usage to ensure that fuel is not being consumed without permits.

It would be preferable to control and monitor actual greenhouse emissions, rather than exercising indirect control through fuel sales. However, annual emissions of greenhouse gases from cars cannot be measured accurately. Total fuel consumption estimates are usually based on average fuel consumption figures for different vehicle classes. A system that measures actual exhaust volumes is currently being tested by the US EPA (J. Haley, NRMA Limited, pers. comm. 11 February 1998).

Australian wholesale petrol prices are currently set at world parity on the basis of the Singapore spot price. A tradable permit scheme that included only Annex I countries would probably see Australian wholesale prices rise above those in Singapore because the scheme would limit supplies available to domestic consumers. It is difficult to know what might occur in such circumstances, but there would be some incentive to engage in black market practices if price differentials were large over a long period of time.

SINKS

A valid alternative to reducing greenhouse emissions is to increase the number of carbon sinks.

Carbon sinks are mechanisms that sequester carbon extracted from the atmosphere. Natural carbon sinks include trees (and other vegetation) which photosynthesise carbon dioxide into wood, and marine organisms that incorporate CO_2 as calcium carbonate ($CaCO_3$) in forms such as oyster shells. Article 6 of the Kyoto Protocol expressly provides for trading in sinks between Annex I Parties, and Clean Development Mechanism arrangements with non–Annex I countries are foreseen under Article 12.

BTCE (1996a, chapter 14) posited a scenario where wholesalers of transport fuels are required to reclaim the CO_2 emitted. Carbon dioxide could be reclaimed from the atmosphere through a range of measures, including pumping it under the ocean or into oil wells, freezing it, or storing it in tanks. Ormerod, Webster, Andus and Riemer (1993) indicate that planting trees is a relatively low cost option. Given the relatively large area of land available for planting trees in Australia, and because tree plantations yield revenues that can be set off against the cost of reclaiming carbon, BTCE (1996a, chapter 14) assumed that wholesalers of fossil fuels would choose forestry as a least-cost option to reclaim CO_2 if required to do so by governments.

Many analyses of arboreal carbon sequestration estimate only the amount of carbon that is stored temporarily. Such studies represent a so-called ‘buying time’ option, because they are based on only one cycle of growth and decay. BTCE (1996a, chapter 14), on the other hand, used a ‘steady state’ approach that assumed replanting of trees in perpetuity. The BTCE approach provided estimates of carbon sequestration on a permanent basis, and therefore permitted direct comparisons with abatement measures that result in permanent reductions in emissions. The BTCE approach was also more sophisticated than most studies because it employed three decay functions (to represent different wood products) rather than just one average function, included storage and loss of soil and root carbon, and took into account land availability, productivity, and cost.

However, a different approach is required to estimate carbon stored in sinks for the purposes of an emissions trading scheme. If tradable permits are issued on an annual basis (currently a common assumption in the literature), then the amount of carbon stored in a sink also needs to be estimated on an annualised basis, to ensure comparability. It is also essential to take into account the fact that tradable permits represent emissions in the current period (although holders could choose to delay usage), while carbon credits for sinks generally represent sequestration in the future.

ESTIMATING CARBON SEQUESTRATION ON AN ANNUALISED BASIS

Because emissions would probably be allocated on an annual basis, carbon credits would need to be issued for a matching time period. A major issue that requires resolution is how the credits would be calculated to ensure that ‘credits’ matched 'debits'. Four possibilities are explored below.

The ‘steady state’ approach

BTCE (1996b) and BTCE (1996a, chapter 14) present a methodology for calculating carbon sequestered in plantations. The ‘steady state’ approach implies that carbon is sequestered permanently, through repeated harvesting and replanting in perpetuity.

The concept used is analogous to a natural forest. Over a long period, a natural, unharvested (old growth) forest may be assumed to reach a state of equilibrium where the total amount of wood or carbon per unit area is, on average, constant. In this steady state (long run) equilibrium, the rate of growth (addition to the stock of wood) and the rate of decay (depletion of wood) would be equal.

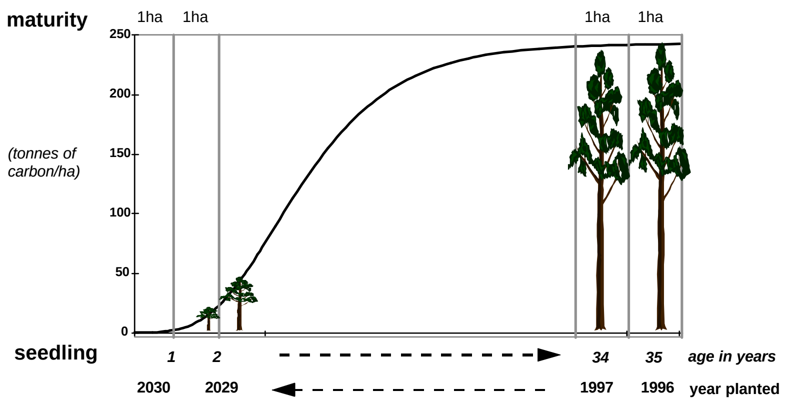
A natural forest comprises trees of different ages. In the case of plantations, individual annual plantings involve trees of identical ages, but the total plantation estate can be considered as if it were a forest of trees of mixed ages. Whereas trees in a natural forest will die at a biological limit, it can be assumed that trees in a plantation will be harvested at a commercially advantageous time (say 35 years). Immediate replanting of the felled area is required to ensure maintenance of the steady state equilibrium. The concept is illustrated in figure 2, which shows plantation strips of 1 hectare corresponding to one year’s planting, with each strip containing trees of uniform age. Taking all the strips together, even in a different sequence to that shown in figure 2, results in a ‘natural’ mix of tree ages.

The fact that timber is harvested, and that it decays in locations away from the forest (for example as paper), does not preclude envisaging the estate as a mixed-age natural forest. The difference between a natural mixed-age forest, and a forest in a ‘steady state’ plantation is that the steady state amount of carbon sequestered at any point in time in a plantation estate may be higher than in a natural forest.

In particular, the rate of decay of timber derived from a plantation is slower because timber stored as frames of houses, for example, decays more slowly than a log exposed to the elements in the forest. Further, commercially grown plantation timber is often cut closer to the time of greatest average growth rate rather than being permitted to grow more slowly to maturity. A greater amount of carbon is thus ‘harvested’ over time in plantations than in a natural forest.

Figure 2 illustrates the sequestration of carbon in standing timber. The estate shown is assumed to involve trees that are harvested at 35 years of age. At the end of the year 2030, the largest trees (planted in 1996) are harvested. The ‘1996’ area is replanted during 2031. (A new area is also planted in 2031 to soak up emissions from fuel used in that year.) At the end of 2031, the ‘1997’ plantation is harvested; it is replanted in 2032 and a new plantation for year 2032 emissions is planted at the same time.

FIGURE 2 SEQUESTRATION OF CARBON IN PLANTATIONS



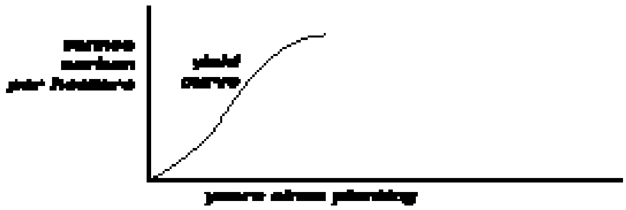
Source BTCE(1996a, p. 243).

Carbon credits based on a steady state approach are conceptually valid in terms of climate change effects, and therefore permit comparisons with permanent reductions in emissions. In practice, however, they would raise serious questions about compliance and enforcement, because those receiving credits would need to guarantee that replanting would continue into the indefinite future. This is clearly impracticable.

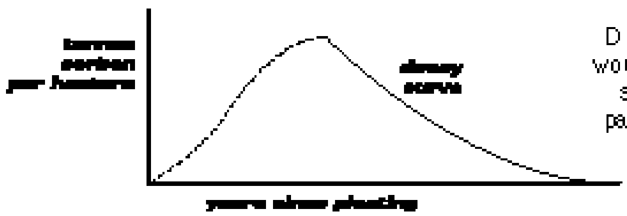
Annual accrual budgeting

An alternative that would facilitate monitoring of sinks, and would ensure that emissions (debits) roughly matched sequestration (credits) within the same time period, would be to account for both on an annual basis.

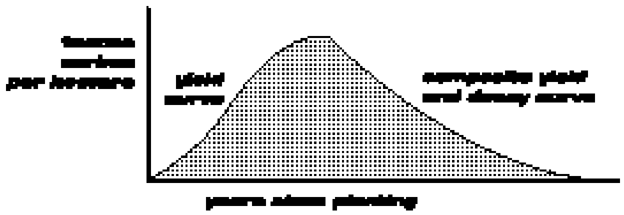
ESTIMATING SINGLE-CYCLE SEQUESTRATION OF CARBON



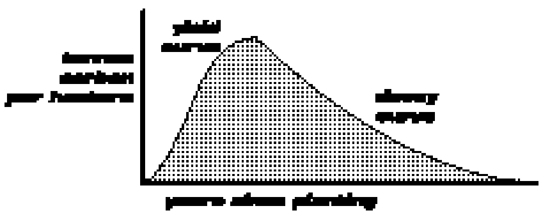
Illustrative sigmoidal yield curve representing tree growth, either to maturity, or harvesting.



Decay curve of wood product. Decay curves for different wood products would be represented by curves of varying slope. For example, the decay curve for paper products would have a steep slope while the curve for treated timber would have a more gradual slope.

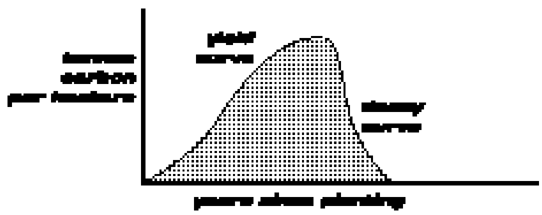


The area under the composite yield and decay curves represents the carbon sequestered over the lifetime of the trees and products derived from them.



OPTION 1

A steep yield curve and gradual decay curve represents a fast growing species such as *Pinus radiata* used as timber for house construction.



OPTION 2

A gradual yield curve and an abrupt decay curve represents a slow growing species such as river red gum *(Eucalyptus camaldulensis)* used for firewood or newsprint.

Note Total carbon sequestered in both options is approximately equal as represented by the areas under the curves. However, for the purpose of carbon sequestration, option 1 may be preferred to option 2 if the compliance risk involved during a shorter growing period is lower.

Emitters of greenhouse gas emissions could be required to plant trees, and to demonstrate at the end of each annual accounting period that a certain amount of carbon had been sequestered during the year. A credit would be issued for the certified amount. That is, credits would be granted before corresponding emissions occurred, but the time separating the two would be relatively short.

While this approach is attractive from an accounting perspective, it fails to take into account subsequent decay of timber produced (and hence re-emission into the atmosphere of the carbon sequestered). It is conceptually invalid, because permanent emissions of carbon would be credited with only temporary sequestration.

Delayed emissions

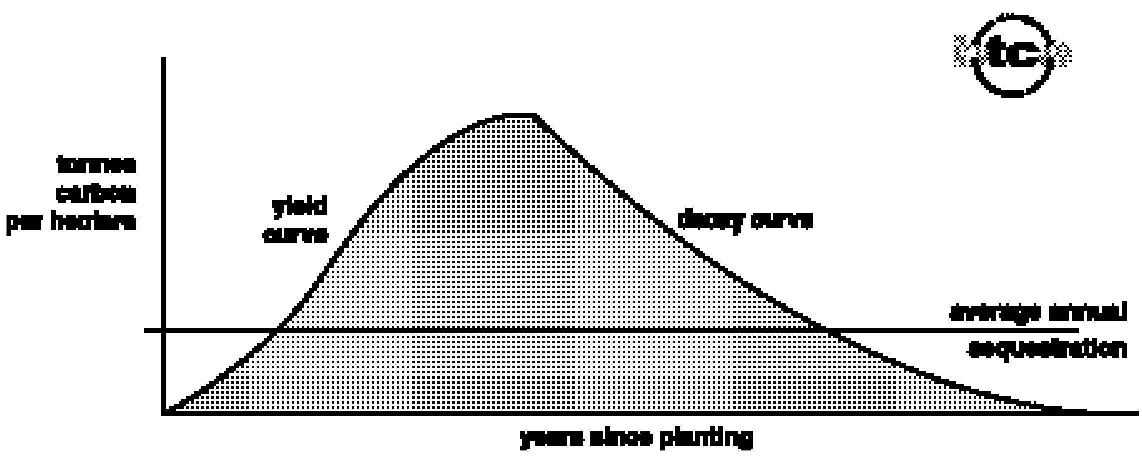
A third major approach would be to grant credits only after a forest had been harvested, and the use (and hence decay rate) of the wood products fully determined and certified.

Monitoring and enforcement would be made easier, but the risk of obtaining credits would be borne entirely by the plantation owner. However, it is likely that the additional (regulatory) risk of potential changes in government policy and the uncertainty of predicting the value of tradable permits or corresponding credits 30 or more years into the future would make this approach commercially unattractive.

The 'buying time' benefit approach

An approach that takes account of the enforcement aspect, the need for simple accounting, and the temporary nature of sequestration in a single planting cycle is illustrated in figure 3.

FIGURE 3 CARBON SEQUESTRATION OVER A PLANTING CYCLE



While a plantation of trees that is harvested without continued replanting will not sequester carbon permanently, it will remove it temporarily from the atmosphere. (For this reason, the option of planting trees is often referred to as a ‘buying time’ approach.) For the period that the carbon is absent from the atmosphere, radiative forcing is reduced by a calculable amount. That is, the physical ‘benefit’ in terms of the greenhouse effect can be determined.

Plantation owners could be bound contractually to harvest their trees only after they had reached a certain size. They could also be bound contractually to ensure (a certification process could be required) that merchantable timber was used in pre-specified ways so that future decay rates could be estimated with some confidence.

Knowledge of the total amount of carbon sequestered over time, and the decay rates involved, would provide sufficient information to determine the amount of carbon removed (temporarily) from the atmosphere over a given period of time. The average annual carbon sequestered can be determined by dividing the area under the curve (figure 3) by the number of years from planting to total decay.

The average annual amount of carbon sequestered could be credited as soon as a plantation was established, because of the contractual undertakings obtained.

Conversion of the average annual carbon sequestered to some measure of contribution to reduced radiative forcing would permit calculation of CO_2 equivalent credits on an annual basis. Further work may be required on the concept of Global Warming Potentials (discussed below), but the average annualised ‘buying time’ approach would make accounting mechanisms reasonably simple.

THE PROBLEM OF A LONG-TERM GREENHOUSE NUMERAIRE

Consistent with the Kyoto Protocol, it has been assumed above that both emissions and sinks would be measured in CO_2 equivalents, in order to permit trading of permits. Article 5(3) of the Protocol stipulates that CO_2 equivalents are to be calculated using the GWPs accepted by the IPCC.

However, a major issue that needs to be addressed at an early stage in international negotiations is whether the same GWPs can be used to estimate the CO_2 equivalents of emissions and sinks. The question is important if tradable permit markets are to work satisfactorily. However, no work appears to have been carried out to date on expressing sinks in terms of CO_2 equivalents (M. Jackson, Greenhouse Challenge Office, pers. comm. 2 March 1998).

The earth absorbs radiation from the sun. This energy is redistributed by atmospheric and oceanic circulation and radiated to space at longer ‘terrestrial’ or 'infra-red' wavelengths. On average, for the earth as a whole, the incoming solar energy is effectively balanced by outgoing terrestrial radiation.

Any factor which alters the radiation received from the sun or lost to space, or which alters the redistribution of energy within the atmosphere, and between the atmosphere, land and ocean, can affect climate. (Increased absorption of energy in the atmosphere due to an increase in greenhouse gas concentrations is one mechanism which can increase the retention of energy within the global atmosphere.) A change in the energy available to the global earth/atmosphere system is termed radiative forcing. (Adapted from IPCC 1996, p. 14.)

Contributions of various greenhouse gases to radiative forcing can be expressed in terms of indexes of GWP. A number of different indexes have been proposed, but none is entirely satisfactory (IPCC 1994, chapter 5). The most commonly used measure (including by the IPCC) of the relative potential of a specified emission of a greenhouse gas to contribute to a change in future radiative forcing (that is, its GWP) is expressed as the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace gas expressed relative to that of 1 kg of a reference gas. (It is important to note that GWPs are a relative measure of radiative forcing, not of any resultant temperature changes.) In other words, the greenhouse potency of a gas such as methane (CH_4) is measured relative to the IPCC's reference gas, an idealised CO_2. A GWP is thus the ratio of the absolute warming potential of the gas in question to the absolute warming potential of the reference gas.

But this approach has a number of important limitations in terms of developing a system of tradable permits:

- It is not possible to derive a single atmospheric response time function for the lifetime of CO_2 because it is made up of a series of response functions. There is also some uncertainty about each of these response functions. Further, these response functions vary over times as CO_2 concentrations change, the status of the terrestrial biosphere changes, and (potentially) ocean circulation changes. This means that, over time, 'actual CO_2' will behave a little differently from the idealised CO_2 which provides the reference point for other gases. As a consequence, 'the numerical values of the GWPs of all greenhouse gases are likely to change, perhaps substantially, in the future simply because research will improve the understanding of the removal processes of CO_2' (IPCC 1994, p. 215).
- There is no specific time period over which GWPs should be calculated. It is common to use a 100 year time horizon, but GWPs are often also expressed in terms of 20 and 500 year horizons, although the various gases have different atmospheric lifetimes . Choice of time period is a policy decision that depends on whether it is considered that the anthropogenic greenhouse effect needs to addressed urgently or not (IPCC 1994, p. 229). International agreement is clearly required regarding use of a common time horizon.

- Scientific uncertainty about the direct Absolute Global Warming Potentials of various greenhouse gases is estimated at about ±35 per cent (IPCC 1994, p. 221). (Some gases have indirect effects on radiative forcing that arise largely from atmospheric processes. These indirect effects ‘are difficult to characterise adequately, thereby limiting the ability of current models to calculate the potentially important indirect contributions of many gases’. IPCC 1994, p. 214.).
- Although GWPs are based on the results of complex models that assume that future concentrations of greenhouse gases remain constant (IPCC 1994, p. 210), the radiative properties of CO_2 are particularly sensitive to changes in atmospheric concentration. ‘Thus, the forcing for a particular incremental change of CO_2 will become smaller in the future, when the atmosphere is expected to contain a larger concentration of the gas’ (IPCC 1994, p. 218). (Similar considerations apply to methane and nitrous oxide.) IPCC (1994, p. 219) estimates that the Absolute Global Warming Potential of CO_2 would on average fall by about 15 to 20 per cent if atmospheric concentrations of CO_2 doubled (projected for near the end of the 21st century).
- GWP indexes are based on the 1990 atmospheric concentrations of greenhouse gases. However, this approach does not take into account reductions in emissions from successful tradable permits schemes, introduction of new technology, etc.

Article 5(3) of the Kyoto Protocol envisages regular revisions of GWP values, but states that ‘any revision to a global warming potential shall apply only to those commitments under Article 3 in respect of any commitment period adopted subsequent to that revision.’

Uncertainty about future GWP values would therefore be unlikely to seriously affect trading in emission permits. Unless unused permits could be banked (and attract economic income greater than market rates of interest), they would be likely to be used up relatively soon after being issued.

However, the generation of carbon sinks would extend over a much longer time period than use of emission permits, and probably well beyond the 2008–2012 current ‘commitment period’ specified in the Kyoto Protocol. The uncertainties that would exist about the value of credits for carbon sinks could well be a significant disincentive to their creation.

RISK

Tradable permits would presumably be issued for current emissions. But carbon credits would be granted for the creation of sinks in the future. A major difference between them is therefore the issue of risk. In particular, who should bear the risk of non-delivery of a sink, and how?

The major sources of risk in terms of carbon sinks appear to be:

- sovereign risk arising from changes in the number or terms of the international treaties and agreements on climate change;
- regulatory risk due to changes in (domestic) government regulation. Examples might include responses to new scientific findings, regulation in related areas (e.g. noxious emissions in urban areas) that indirectly affect output of greenhouse emissions, introduction of road user charges that affect the amount of fuel used and hence the price of tradable permits;
- force majeure risk—the usual example is a forest fire that destroys a sink, but could also include developments such as a war that cuts off petrol supplies so that tradable permits remain unused, with their prices falling;
- compliance risk—a major consideration in the case of carbon credits (for example, making sure that wood is used for the purpose for which it was certified as a store of carbon, such as the frame of a house); and
- market risk—if every greenhouse emitting sector resorts to planting trees, the future price of timber may fall so low that it will be commercially unviable to actually harvest the trees (and to store the harvested carbon) as planned. While carbon would still be stored in the living plantation, decay rates would be faster.

Substantial further analysis is required in this area, because there do not appear to be any readily apparent answers at present. However, possibilities for further consideration include:

- use of binding long term contracts with a relevant government agency to deliver sinks;
- attaching conditions to land use (including covenants on title in the case of sale) where land is designated as being under plantation;
- government-owned plantations, either managed by the private sector on behalf of the government, or paid for up front by those seeking to buy carbon credits;
- compulsory insurance that covers force majeure risk;
- reduction of carbon credits by the CO_2 equivalent (determined at current market prices of tradable permits) of insurance against fire, or non-delivery, with the government subsequently assuming compliance and force majeure risk; and
- encouragement of development of secondary markets that offer financial options on future delivery of sinks.

CARBON SUBSTITUTION EFFECTS

The analysis above assumed that trees planted to obtain carbon credits would be used after harvesting for manmade products such as paper or as building materials. Most analyses represent the decay of such uses in terms of one ‘averaged’ decay function, although a more sophisticated approach (as in BTCE 1996a, chapter 14) is to use several decay functions.

An increased availability of wood in Australia or globally in response to trading of emissions permits and carbon credits is likely to be reflected in lower prices of timber. To the extent that the supply of timber increased, there would be more opportunities for substitution of wood for concrete and steel, particularly in flooring and frames of residential buildings.

Concrete and steel production require fossil fuel inputs, and production of concrete itself produces CO_2. Substitution of wood for concrete and steel would therefore indirectly sequester carbon to the extent of any fossil fuel not used. Maclaren (1994, p. 14) cites estimates by Honey and Buchanan (1992) indicating that 59 gigajoule is required to manufacture one tonne of structural steel, compared with only 2.4 gigajoule per tonne of treated timber.

Wood is also a renewable source of energy which can be substituted for fossil fuels. (There has recently been a renewed interest in coppicing as a means of increasing the rate at which biomass can be generated for use as fuel—Read 1994.) To the extent that less fossil fuel is used, the use of replaceable firewood represents an ‘opportunity benefit’ in reducing greenhouse emissions. The amount of fossil fuel conserved by burning wood represents an additional benefit from forestry, apart from any (temporary) sequestration of carbon during the growth phase of the trees.

In cases where plantation timber is used in ways that conserve fossil fuels that would otherwise have been consumed, the credit issued for the carbon sink generated by a plantation should be augmented by the greenhouse emissions avoided. In practice, however, a ‘moral hazard’ problem could arise if those seeking augmented credits were enticed to make false claims about what they would have done in the absence of the timber.

‘GREENFLEET’ AND THE KYOTO PROTOCOL

Schemes already exist where motorists offset emissions by having trees planted on their behalf. Although trading does not occur, such offsets schemes are analogous to the concept of carbon credits being used to extinguish emission obligations. They differ from the concept of tradable permits because they seek to recapture all the carbon emitted, rather than just a proportion.

The Stanley Foster Foundation in Gippsland has been the driving force behind the ‘Greenfleet’ scheme under which motorists voluntarily pay $25 with their annual registration in return for the planting of 7 trees. The figure of 7 trees per average car per year is based on the ‘steady state’ analysis in BTCE (1996a, chapter 14). Voluntary labour (particularly the Scout Association) is used to plant trees, but farmers make their land available for free. Although farmers benefit from the tree plantings through windbreaks, shade for cattle, reduced insect pests because of birds, reduced salinity where water tables are kept down, etc, they bear the opportunity cost of making land available. The Greenfleet scheme was launched by the Premier of Victoria, the Hon. J. G. Kennett MP, in September 1997.

A similar scheme run by the supermarket chain Tesco in England involves small levies on petrol purchases at the pump. Trees are planted in Uganda on behalf of motorists. It has even been suggested by the scheme's officials that 'babies could be bought climate-care warranties by godparents. More could be bought on the child's 18th and 21st birthdays…' (Nuttall 1998).

It is not clear, however, from an initial reading of Article 6 of the Kyoto Protocol, whether such schemes, being voluntary rather than government-initiated, would qualify as part of a country's reductions. It could be argued that they would have occurred anyway and are therefore not 'additional to any [reduction] that would otherwise occur'.

If an official tradable permit scheme reduced incentives to participate in voluntary schemes, it is possible (though unlikely on present participation rates) that emissions would actually increase. Greenfleet and the Tesco scheme are conceptually aimed at recapturing all of the carbon emitted by motorists. Tradable permits would only aim to reduce some of the greenhouse gases emitted. If highly popular voluntary schemes were discouraged because of the introduction of emissions trading, at least some motorists would end up producing higher net emissions.

IS A CARBON TAX PREFERABLE FOR THE TRANSPORT SECTOR?

BTCE (1996a, p. 144) showed that a carbon tax of $1000 per tonne of carbon ($273 per tonne of CO_2) imposed on cars could achieve a reduction in greenhouse emissions of up to 56 million tonnes (cumulative from 1996 to 2010) for a negative social cost, due largely to a reduction in congestion costs. (Achieving larger emission reductions would result in positive social costs.) This represents an 11.2 per cent reduction in CO_2 emissions in the transport sector.

A carbon tax that reduced emissions by this magnitude would almost double the current price of petrol. It would also be effectively directed solely at CO_2 emissions. If the carbon tax reduced travel, then N_2O emissions would also fall. If it only improved fuel efficiency, then N_2O emissions may not be reduced. Because N_2O does not contain carbon, it could not be targeted directly through a carbon tax.

However, the administrative costs of a carbon tax would be negligible compared with a tradable permits scheme. Its level could in practice be determined roughly on the basis of ruling prices for tradable permits internationally.

Further consideration of the relative merits of a tradable permit scheme is clearly required, at least for the transport sector.

ABBREVIATIONS

ABS	Australian Bureau of Statistics
BIE	Bureau of Industry Economics
BTCE	Bureau of Transport and Communications Economics
$CaCO_3$	calcium carbonate
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
COP1	First Conference of the Parties to the Convention on Climate Change
COP2	Second Conference of the Parties to the Convention on Climate Change
COP3	Third Conference of the Parties to the Convention on Climate Change
EPAV	Environment Protection Agency (Victoria)
FCCC	Framework Convention on Climate Change
GWPs	Global Warming Potentials
HFCs	hydrofluorocarbons
ICAA	Institute of Chartered Accountants in Australia
IPCC	International Panel on Climate Change
N_2O	nitrous oxide
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
OECD	Organisation for Economic Co-operation and Development
PFCs	perfluorocarbons
SF_6	sulphur hexafluoride
SO_2	sulphur dioxide
US EPA	United States Environmental Protection Agency

REFERENCES

ABBREVIATIONS

ABARE	Australian Bureau of Agricultural and Resource Economics
AGPS	Australian Government Publishing Service
BIE	Bureau of Industry Economics
BTCE	Bureau of Transport and Communications Economics
EPAV	Environment Protection Authority, Victoria
ICAA	Institute of Chartered Accountants in Australia
IPCC	Intergovernmental Panel on Climate Change
OECD	Organisation for Economic Co-operation and Development

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