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The development costs of the Stern Review findings – implications for building consensus on global strategies for climate change

A research paper prepared by ITS Global for the Australian APEC Study Centre at Monash University.

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Executive Summary

A new global consensus to tackle climate change

Since the G8 Summit in Germany in June 2007, there is consensus among the world's leading economies that a new global strategy to address climate change is required. The Kyoto Protocol has failed to secure the necessary global consensus to serve that purpose.

There also seems to be consensus that this work be conducted within the institution of the UN Framework Convention on Climate Change (UNFCCC), the parent Convention to the Kyoto Protocol, to which all major economies (and most nations) are parties.

A series of meetings are planned in the last quarter of 2007 with the aim of achieving agreement on a new global approach. Climate Change will be considered by APEC Leaders at the Sydney Summit in early September. Later in the month, a high level meeting will be held during the annual UN General Assembly and President Bush will separately convention a meeting of leading nations interested in climate change. Finally the thirteenth meeting of the Parties to the UNFCCC will convene in Bali in early December.

The aim this year is to secure agreement on the basis for a new global approach which can then developed. One ambition is to complete this by the time of the 2009 G8 Summit in Denmark. A reference point for parties to the Kyoto Protocol is expiry of the commitments by industrialized parties to the Protocol to reduce emissions in 2012.

No Consensus if strategies restrain economic development

Numerous studies show the high growth trajectories of the developing economies, particularly larger ones like China and India, will result in significant increases in emissions. Developing countries, China in particular, have made clear climate change strategies must accommodate development goals.

A pre-requisite for a new global consensus is that developing countries consider their development goals are protected.

The unacceptably high development cost of the Stern strategy

The analysis in the report by Sir Nicholas Stern which was commissioned by the British Government concluded that achieving the levels of reduction estimated in that report as necessary to stabilize the level of emissions of greenhouse gases in the atmosphere would ultimately be up to one percent of world Gross Domestic Product.

This report finds that a cost this dimension would translate into a cut in GDP in China of around 15 percent, 13 percent in India, 12 percent for most major economies and four percent of GDP for the United States. The impacts on ordinary people would ber greater, reducing money available for household expenditure by them by nearly 30 percent in China and between 15 and 30 percent for most developing countries. The estimate for the US is 11 percent and the average estimate in Europe is 6 percent.

Established positions suggest developing countries would consider these costs unacceptable.

Stern report divisive

It is impossible to see how a new global consensus to tackle climate change can be based on the cost model proposed by Stern. It will divide positions, not bridge them. A global consensus can only be built if it allows each country to develop a strategy on climate change which enables it to satisfy national economic goals.

Consensus requires a return to the economic development mainstream

The Stern reported overturned conventional thinking among economists who have studied the long term costs of measures to abate emissions and adapt to climate change. Stern argued that if strong action to abate emissions were not taken now, the cost to developing countries in the long run would be greater.

The long-standing conventional view among economists, as represented generally by William Nordhaus of Yale University, is the reverse: that costly action early would have a larger detrimental effect on the welfare of the world's people, particularly the poor, than taking modest action from the outset and leaving the costlier action to much later on when economies can afford it.

It was also reflected in the Copenhagen Consensus developed in 2004 among a group of the world's most eminent economist, including four Nobel laureates, who reviewed climate change as part of the set of the ten most serious challenges facing the global community in the immediate future (others included poverty, HIV/AIDS, poor sanitation, and ensuring food supplies). They rated global warming as a low priority (seventh out of ten) in the short term for strategies to direct global resources to alleviate the disadvantages suffered by the world's poor.

Consensus requires reality

Some will argue immediate action is required to reduce greenhouse gases. No immediate action, no matter how severe, will have that effect. Strategies to alter the levels of greenhouse gases in the atmosphere of necessity must be programs set out over one or two century timelines. Today's reality is that no effective global action is possible unless all the world's major generators of greenhouse gas sign on. A strategy which does not achieve that it is not practicable.

I. Contents

II. Introduction

This paper canvasses the key conclusions and policy recommendations of the Stern review of the economics of climate change undertaken on behalf of the UK Government. In doing so the paper analyses their implications of implementing those recommendations for a selection of developing economies. It compares the results obtained with a cross-section of OECD countries at different stages of their economic development.

III. Background

In July 2005 the UK Chancellor of the Exchequer commissioned a review of the economics of climate change headed by Sir Nicholas Stern, the Head of the Economic Research Service. Sir Nicholas handed his report of more than 550 pages to the UK Government in the following year (Stern 2006). Although it was drafted by a team of over 20 Government officials, the UK Government has described the review as ‘independent’.

On the basis of its review of the science of global warming, the Stern Review has estimated the economic benefits and costs of action to restrict the emissions of greenhouse gases (GHG) into the atmosphere from human activity.

For this purpose, the economic benefits of further action to reduce GHG emissions were taken to be the external costs from the emissions that would be averted by doing so. An external cost is one that producers and consumers do not take into account when deciding how much to produce and consume respectively. In that sense it is external to the parties who created it. In the case of GHG emissions, the external costs are the prospective economic impacts flowing from an increase in the concentration of such gases in the atmosphere and the consequential rise in global temperatures that it is expected to cause.

The Stern Review put these external costs at US$85 per tonne of CO_2 equivalent (CO_2-e) (Stern 2006, p. xvi). As for the costs of emissions abatement, the Review concluded that stabilisation of the level of GHGs in the atmosphere would cost countries not more than 1 per cent of GDP by the year 2050 (Stern 2006, p. xii).

The Review estimated the time-streams of benefits and costs over a period of two centuries and used a near zero discount rate to reduce them to their net present value. Having done so, it found that the net result was an ‘overwhelming’ case for ‘urgent’ action by all countries (Stern 2006, p. i). The Review also considered any delay would be ‘costly and dangerous’ (Stern 2006, p. xvii).

Following its publication, the Stern Review has been strongly criticised for its understanding of the science of climate change, overstating the economic benefits, understating the economic costs, and using a near zero real discount rate to estimate their net present value (see Byatt et al 2006 & Carter et al 2006).[1] In this respect the

[1] The discount rate chosen by the Stern Review is well below the rate that is officially recommended for use within the UK Government by the UK Treasury (HM Treasury 2003).

Review's estimates and its conclusions lie well outside those that have been reached in the mainstream economic literature on man-made climate change (Byatt et al 2006, Dasgupta 2006, Tol 2006 & Nordhaus 2007).

On the basis of its conclusions, the Stern Review recommended that all countries should impose a price for carbon by way of a carbon tax or a system of GHG emission permits. In either case, the policy measure in question should impose a level of restriction on man-made GHG emissions that would stabilise the concentration of GHGs in the atmosphere at no more than 550 parts per million. In its view, doing so was '…an essential foundation for climate-change policy' (Stern 2006, p. xviii).

IV. Results

The results of our estimates of the economic cost of imposing a carbon tax/emissions permit regime to the extent recommended by the Stern Review are set out in the Table below. The costs in the Table are the sum of the estimated losses in consumer surplus and the deadweight losses due to taxation interaction effects. They do not include the additional administration and compliance costs of the regime. Details of the methodology and analysis used in the report are set out in the next section

To provide a consistent perspective on the relative scale of these costs across the countries in question, we have expressed them as shares of GDP and of household consumption from the relevant national accounts. Expressing these costs as a share of household consumption reflects our expectation that most of the economic burden of implementation the Stern recommendations is likely to fall upon household incomes, rather than public services.

If Stern's valuation of the external cost of carbon is correct, these estimates provide a good first approximation of the loss of material welfare that is inherent in the comprehensive and immediate implementation of Stern's proposed GHG emission cuts. This loss is equivalent to the reduction in the broadest definition of the standard of living that everyone in those countries would experience as a consequence.

Table: Economic Cost of Cutting GHG Emissions in Developing Countries

Country	Economic Cost of GHG Cuts (low estimate) (US$b)	Economic Cost as Share of GDP (low estimate) (%)	Economic Cost as Share of Household Consumption (low estimate) (%)	Economic Cost of GHG Cuts (high estimate) (US$b)	Economic Cost as Share of GDP (high estimate) (%)	Economic Cost as Share of Household Consumption (high estimate) (%)
China	275.7	14.3	34.4	318.7	16.5	39.8
Saudi Arabia	28.87	11.5	27.7	33.3	13.3	32.0
Vietnam	5.1	11.3	27.2	5.9	13.0	31.4
India	71.0	10.6	25.7	82.1	12.3	29.7
Thailand	16.5	10.2	24.7	19.1	11.8	28.6
Indonesia	24.7	9.6	23.2	28.5	11.1	26.8
Malaysia	11.0	9.2	22.3	12.7	10.7	25.8
Poland	17.8	7.1	17.0	20.6	8.2	19.7
Taiwan	18.9	5.9	14.2	21.8	6.8	16.4
Philippines	4.9	5.7	13.7	5.7	6.6	15.9
South Korea	36.2	5.3	12.8	41.9	6.1	14.8
Bangladesh	3.0	5.0	12.2	3.4	5.8	14.1
Singapore	5.2	4.9	11.8	6.1	5.6	13.6
Sri Lanka	0.9	4.4	10.5	1.0	5.0	12.2
Canada	41.8	4.2	10.2	48.4	4.9	11.7
Brazil	24.5	3.7	8.9	28.4	4.3	10.3
US	411.5	3.5	8.5	475.9	4.1	9.8
Spain	24.0	2.3	5.5	27.7	2.7	6.4
Germany	59.3	2.2	5.2	68.6	2.5	6.0
Hong Kong	3.5	2.1	5.1	4.0	2.4	5.9
Italy	34.8	2.0	4.9	40.3	2.3	5.6
Japan	90.5	2.0	4.7	104.6	2.3	5.5
South Africa	23.4	1.7	4.0	27.1	1.9	4.7

Sources: IEA 2007, IMF 2007, Taiwan National Statistics 2007 & UN Statistical Division 2007.

Costs as a share of GDP

Of the 23 countries that we examined, China had, by far, the largest economic cost of GHG abatement as a share of GDP with an average of just over 15 per cent, equivalent to around US$300 billion a year in aggregate. China was followed by Saudi Arabia and Vietnam each with carbon costing just over 12 per cent of GDP. This was equivalent to an aggregate cost of around US$31 billion per year for Saudi Arabia and some US$5.5 billion a year for Vietnam.

In very large part these results reflect the relatively heavy reliance of these three countries on coal and crude oil. For example coal accounted for more than 70 per of Chinese primary carbon energy consumption in 2004, while the Saudi Arabian and Vietnamese economies relied more or less exclusively on coal and crude oil products. For India, Thailand, Indonesia and Malaysia, the average economic cost of GHG abatement fell in the range from 10 to 12 per cent of GDP. For the Philippines, Bangladesh, Sri Lanka and Brazil, the average cost amounted to between 4 and 10 per cent of GDP. Of the remaining eight countries analysed, only South Africa had an average cost of GHG abatement that was under 2 per cent of GDP.

If the Stern Review is correct in its evaluation of the benefits of GHG abatement, these results suggest strongly that the Stern Review has very substantially underestimated the economic cost of implementing its recommendations. On the other hand if the Review is correct in its estimate of the economic cost of abatement, then it has substantially overestimated its economic benefits.

Costs as a share of household consumption

When the economic cost of GHG abatement is expressed as a share of household consumption, the pattern is similar but the equivalent shares are naturally much higher. As indicated previously, this measure reflects our expectation that most of the economic burden of implementation of the GHG abatement regime recommended by the Stern Review is more likely to fall upon household incomes ultimately, rather than on public services.

China had by far the largest share, on average (37 per cent), followed by Saudi Arabia (30 per cent) and Vietnam (29 per cent). In part, these results reflect the relatively small share of GDP that accrues directly to households in those countries, or alternatively the relatively high share of delivered as public services.

The results for India, Thailand, Indonesia and Malaysia were somewhat lower but the cost of GHG abatement was still in excess of 24 per cent of household consumption, on average. The Philippines, Bangladesh, Sri Lanka and Brazil had an average of between 9 and 15 per cent. Of the other countries, all had an average share that was over 4 per cent.

These results dramatically highlight the extent of the political economy challenge for these countries in seeking to implement the recommendations of the Stern Review. Any serious attempt at implementation would require broadly based public support for the very extensive structural changes that would be required of households and of industry. The scale of the economic sacrifice that the average citizen would be expected to make immediately for a benefit that would not to be realised for many generations strongly suggests that the Stern recommendations are fundamentally flawed and therefore utterly unrealistic from a political economy perspective.

V. Estimating the economic cost for developing countries

We estimate the economic costs for a selection of developing economies of imposing a carbon tax/emission permit regime *a la* Stern.   The analysis was carried out on the basis of the Stern Review's own valuation of the external cost of carbon. It therefore broadly reflects the degree of restriction on man-made GHG emissions that Stern recommended.

Our estimates were based on data for 2004 as it was the latest year for which internationally consistent data on primary energy production and usage were available from the International Energy Agency (IEA 2007) for the countries in question. We used GDP estimates for the countries in question published by the International

Monetary Fund IIMF 2007). Data on the composition of GDP were sourced from the United Nations Statistical Division (2007).

We have compared the results for these developing countries with equivalent estimates for a broad cross-section of OECD economies at different stages of economic development. The non-OECD economies included in the analysis were: Bangladesh, Brazil, China, Hong Kong, India, Indonesia, Malaysia, the Philippines, Taiwan, Thailand, Saudi Arabia, Singapore, South Africa, Sri Lanka, and Vietnam. The OECD economies were: Canada, Germany, Italy, Japan, Poland, South Korea, Spain, and the United States of America.

In doing so we have sought to take into account the behavioural responses to the imposition of the Stern carbon tax/ permit regime.[2] Its effect on energy prices will be rather dramatic — we estimate that it would have increased the real price of crude oil imports into the US in 2004 by more than 100 per cent. The more carbon-intensive the fuels, such as black and brown coal, would experience even higher price rises.

Such price rises would strongly discourage those activities that make use of carbon-based energy sources, while strongly encouraging those that make use of alternative energy sources. Their net effect on the economy, particularly over the long run, is substantially less certain but depends upon:

- the responses of domestic and industrial energy users to the changes in the relative prices of energy;
- the fiscal impacts of the increased public revenue from the carbon tax/permits regime;
- the public administration and private compliance costs imposed by the carbon tax/permit regime on government and on the private sector respectively.

Each of these factors will be assessed in turn.

Responses of energy users

The responses of energy users to these policy-induced changes in energy prices will be a range of adjustments in their use of energy:

- an increase in carbon-based energy efficiency;
- a switch to less carbon-intensive energy sources; and
- a cessation of lowly valued activities that use carbon-based energy relatively intensively.

The responses of energy users will vary with the time horizon. Other things being equal, the longer the time horizon, the greater is the scope for energy users to adjust their use of carbon-based energy. Over the medium term, their scope to do so is considered to be relatively limited. This limitation reflects the size of the stock of carbon-based energy-intensive industrial plant and equipment and household appliances that exists in most economies (Robinson 1988). The greatest scope to do so will be evident over the longer term, with the emergence of replacement

[2] The behavioural responses due to such a regime will depend on how comprehensively its provisions are applied in the first place. Logically the fiscal/regulatory discouragement given to GHG emissions should extend to an equivalent encouragement for all forms of GHG capture and storage in 'carbon sinks', such as forestry and vegetative cover. In many instances, expanding a 'carbon sink' is a much more cost-effective solution than cutting back the GHG signature from an activity.

technologies that make less intensive use of carbon-based energy or substitute it completely by alternative primary energy sources.

The nature and the extent of each of these adjustments will depend on the prospective costs and benefits of the various alternatives that each energy user is able to anticipate at any given time. These cost and benefits will, in turn, depend upon the time horizons over which they expect their responses to have to occur.

While there is evidence of a potential to improve *energy efficiency*, there are also significant transaction costs in realising them. These transactions costs are a reflection of the pervasive uncertainties that surround the choice and implementation of technical efficiency enhancements. They often make the investment of significant search costs to identify appropriate improvements an economic proposition from the perspective of the energy user (PC 2005).

The scope for energy users to *switch to alternative energy sources* critically depends on the costs of substitution, which tend to reduce as the time available for the adjustment lengthens. The sooner the substitution has to be made, the greater the economic costs will tend to be. For example countries with buoyant economic growth, significant proven reserves of natural gas, and an excess capacity in a well-developed infrastructure for its transmission and distribution, will be able to switch from coal to gas for electricity generation and industrial usage, at relatively low cost. Even in these cases, however, there will be additional costs to be incurred — such as from the premature replacement of long-life plant and equipment that would have continued in service had Stern's recommendations not been implemented.

At present most of the currently available alternative energy sources are significantly more expensive than the carbon-based sources being used at present. In most sectors of the economy, the scope for the substitution of energy sources is either very limited or non-existent, at least in the short to medium term, and the economics of the longer term possibilities are still clouded in significant uncertainty. In large part this reflects the inherent uncertainty over the direction and pace of future technological progress in the wake of the imposition of a carbon tax/ permit regime.

Background research commissioned by the Stern Review to assess the costs of prospective abatement technologies admits the extent of this uncertainty (Anderson 2006). Nevertheless, the Review's estimates of the GDP forgone by its recommendations do not fully reflect the results of this research. For example Stern's estimate of the economic benefit of GHG abatement is less than 40 per cent of the average cost per tonne of the abatement technologies assessed in the background research. In this regard it is particularly notable that the 20th Century has not seen the emergence of any significant new sources of energy, other than nuclear power and even there the economics have yet to be clearly established.

To quantify the extent of the net economic cost of these impacts on energy users we have drawn on the results of recent empirical research from the economic literature. This involved using empirical estimates of the sensitivity of aggregate primary energy demand to changes in prices and incomes, which were made during the 1990s (Al-Mutairi & Eltony 1995, Bentzen & Engsted 1993, Dahl 1992, Hodge 1999, Hunt & Manning 1989 and Jones 1994). These estimates related to countries at different stages of economic development, used the most robust econometric techniques that were available and obtained statically reliable estimates of the price and income parameters of energy demand.[3]

These empirical demand relationships provide a measure of the collective value that energy users place on the energy they consume at different price levels. This measure is called their willingness to pay. The difference between their willingness to pay and what they actually paid for a given quantity of energy is called their consumer surplus. Consumer surplus is a measure of the net economic benefit that was obtained from the quantity consumed. These concepts and how they were estimated in this context are outlined in further detail in the Box.

As outlined in the Box, the imposition of a carbon tax/emissions regime would produce an immediate cut in the consumption of carbon-based energy. Other things being equal, this would involve a net loss in consumer surplus for energy users as a whole in each of the countries where the tax/emissions regime was imposed.

[3] Four of the five studies cited above used the error correction modelling approach developed by Engle and Granger (1987). This is designed to avoid the co-integration errors that are often encountered when undertaking ordinary least squares (OLS) regression analysis of time series data, such as energy demand.

Box: The estimation of consumer and producer surplus

Welfare economics is the discipline devoted to the estimation of the net benefit of an activity from the perspective of the community as a whole. It represents a highly developed methodology for measuring the effects on the well-being of all individuals from changes in the prices and quantities that are produced and consumed. It does so by measuring the effect of a change in terms of the *economic surplus* — that is, sum of the *consumer surplus* and the *producer surplus*.

The price charged for each unit of a good or service that a consumer purchases is generally the same but that the value of each unit to the consumer varies — in terms of what the consumer would have been willing to pay for it. Typically the greater the total amount consumed in a given period, the lower the value of the marginal unit to the consumer. . The difference between the consumers' valuation of each of these units and the amount actually paid for them is the *consumer surplus*.

There is an analogous situation for the producers of the good in question. The *producer surplus* is the excess of the revenue received over the sum of the marginal cost of supplying each unit of the good in question. It is a measure of the profit that the producer earns in excess of the normal rate of profit, which is the minimum that the producer would have been prepared to accept from their investment in suppling the good in question. Where there are no barriers to the entry of new producers, such excess profits ten to be competed away by the new entrants bidding up the supply prices of key resources.

The consumer and producer surplus in a market are illustrated in Panel A. There the market price is determined by the intersection of the demand curve (D) and supply curve (S). At equilibrium, the price charged is P* and the amount consumed and produced is Q*. The consumer surplus is represented by the shaded triangle (abP*). The producer surplus is represented by the area above the supply curve that is bounded by the market price (P*). This is the hatched area (acP*).

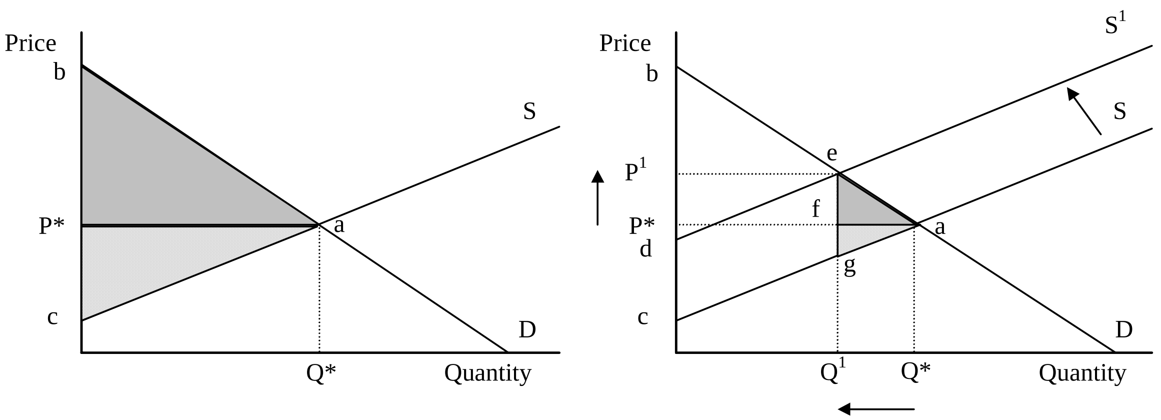
In this example the benefit to the community as a whole is the sum of consumer and producer surpluses. The size of the consumer and producer surplus depends on the slopes of the demand and supply curves for the good in question, that is on its own price elasticity of demand (Єd) and its prices elasticity of supply (Єs). For example, a steeper demand curve (one that is more price inelastic, or less responsive to price) than that depicted in Panel A would result in a larger consumer surplus, other things being equal, and *vice versa*. An equivalent relationship holds for the producer surplus.

When the demand and supply relationships are linear, the consumer surplus is mathematically equivalent to P*Q*/2Єd and the producer surplus to P*Q*/2Єs, where P and Q are respectively the price and quantity of the good or service that is purchased in the period in question.

Now consider a situation in which the supply of the good or service in question is subject to an exogenous change, say the introduction of a new tax or regulation on its production, such as a carbon tax or a regime to regulate GHG emissions. In principle any regulatory regime can be expressed in terms of an equivalent tax rate.

This is illustrated in Panel B, where the effective specific tax rate imposed by the change is eg. As a consequence, the supply curve shifts to the right — from S to S^1. This means that the product or service is now more expensive to produce at every level of output. The market price rises to P^1 and output falls to Q^1. Consumer surplus is now given by the triangle ebP^1 – a smaller area than the original consumer surplus. Similarly, producer surplus is now smaller, measured by the triangle edP^1. The rectangle bounded by P^1 e and eg (not shown in full) represents the income lost by consumers as a result of the change, either in the form of tax revenue to the government or economic rent to the owners of emissions permits (if the government auctions these permits, it will tend to be the ultimate beneficiary of this additional income).

Either way the change results in deadweight losses in consumption and production. These are the consumer and producer surpluses that are permanently foregone as a result of introducing the regulation/tax on GHG emissions. The deadweight consumption loss is represented by the shaded triangle (aef) in Panel B and the lost producer surplus by the hatched triangle (agf). The sum of these two triangles (age) represents the net economic cost to the community as a whole of the regulation/tax.



Panel A **Panel B**

By using empirical estimates of the relevant demand relationships, we have calculated the losses of consumer surplus that energy users would have experienced in 2004 had the Stern recommendations been fully implemented in that year. Specifically we have used the upper and lower bounds of the empirical price sensitivity estimates to produce a high and a low estimate of the loss of consumer surplus. Doing so helps to ensure we have broadly captured the uncertainty inherent in the empirical estimates.

For analytical convenience, we assumed that the relevant aggregate energy demand relationships are accurate over the range of energy price changes that are implied by the extent of the Stern carbon tax. Although the relationships are unlikely to be linear, we expect that this assumption will generally tend to underestimate the loss of consumer surplus.[4]

Although the loss of consumer surplus provides a good first approximation of the direct economic cost of higher energy prices for households and businesses, it does not capture the indirect impacts that are due to fiscal, public administration or compliance costs of the Stern recommendations.[5] These are taken up in the next two sections of this paper.

Fiscal impacts

Introducing a tax on GHG emissions will generate considerable public revenue. As the Stern carbon valuation would have the effect of doubling the price of crude oil, the revenue gain would be very substantial for most of the countries analysed.

For a given impact on GHG emissions, the scale of the income transfers under an emissions permit regime would be of a similar order of magnitude as a GHG tax. The major difference between the two would concern the direction of the income transfers and this would depend upon how the emissions permits were distributed in the first place. If, for example, permits were auctioned by the government, the direction of the income transfers would be broadly the same as for the tax.

The maintenance of fiscal balance would generally require cuts to other tax rates. Tax cuts would help to offset the slowdown in economic activity that would be caused by the increase in energy prices. Given the revenue outlook, the cuts would have to be very substantial and implemented quickly. If the additional carbon tax revenues are spent by the government on additional public services, this would also generate a benefit for the recipients of those services, but it may not be as large. It would also take much longer to gear-up new public expenditure programs, compared to the lead times that are involved in cutting taxes across the board.

On the face of it, there would be a significant economic benefit from revenue recycling which would help to offset the economic costs of increased energy prices to

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[4] At some minimum level of energy use, consumers are likely to become significantly more resistant to further reductions in their energy use, reflecting both the general absence of alternative energy sources as well as the importance of energy in physical survival.

[5] Other things being equal, a computable general equilibrium model is generally the superior analytical technique for estimating the net impact of such a tax/emissions permit regime in a comprehensive and internally consistent fashion. Unfortunately its extensive data requirements seriously limit its application on a global scale with the very high degree of sectoral detail required to capture the full range of applications of each of the different energy sources in each economyc.

energy users. The Stern Review found that the economic benefit from revenue recycling was the largest single component in modelling studies to estimate the extent of the net impact of GHG stabilisation on GDP. For the studies that Stern examined, the revenue recycling benefit accounted for around 1.9 percentage points of the estimated net loss of GDP, on average.

The problem is that revenue recycling only comes at an economic cost. This cost is due to the interactions that would occur between a carbon tax and the rest of the tax system. Such tax interaction effects were ignored by both of the Stern Review and all but one of the empirical studies it drew upon estimating the GDP forgone from its recommendations. The economic literature, however, provides a strong basis, in principle, for expecting these costs to be significant in relation to the size of the revenue from a carbon tax (Sandmo 1975).

The empirical analysis of taxation systems has shown that the imposition of a tax on GHG emissions would to increase the deadweight losses from other taxes, particularly those on labour, capital and alternative energy sources (Parry 1995 and Bovenberg and Goulder 1996). Auctioning an equivalent quantity of emissions permits would have similar impacts. The empirical economics literature concludes that that the deadweight losses from these tax interaction effects are expected to outweigh the benefits from revenue recycling (Byatt 2006). In the Australian context, this conclusion has been amply confirmed by Industry Commission estimates that *every dollar* of additional taxation imposed on the transport sector in Australia can be expected to generate a *net loss* of GDP of twenty cents (IC 1991).

We have estimated the gross revenue yield that would be expected from either a pure Stern carbon tax or from auctioning an equivalent quantity of emission permits in each of the countries analysed. Our estimates used the same empirical demand relationships that were used to estimate the loss of consumer surplus from higher energy prices. By doing so, our public revenue estimates take into account the significant cuts in energy use that would be expected to occur under the Stern carbon tax/emissions permit regime. As with the loss of consumer surplus, we calculated a high and a low revenue estimate to account for the estimation uncertainty.

On the basis of the previous discussion, we conclude that the losses of consumer surplus from the tax interaction effects will be at least as large as the increase in revenue from the Stern carbon tax/emissions permit regime. The revenue estimates represent the minimum extent of such losses from the imposition of the Stern carbon tax or the sale of the equivalent amount of emission permits.

Administration & compliance costs

Due to the extreme paucity of relevant data and analysis on the subject, we were unable to estimate the public administration and private compliance costs that would be imposed by the Stern carbon tax/emissions permit regime.

Any tax or permit regime for managing environmental emissions requires techniques, devices, and methods to measure, or at least estimate, the relevant emissions to an acceptable degree of accuracy. Moreover, if such a regime is to minimise the cost of abatement it must also extend the relevant financial and regulatory incentives to the use of physical ‘sinks’ or storages for the emissions in questions, and by implication the need to be able to measure or estimate stock changes to an equivalent degree of accuracy. The inherent difficulty in measuring or estimating these physical flows at a reasonable cost is one of the key reasons why tax and permit regimes have been used relatively infrequently to manage environmental emissions (Peterson 2003).

Compared to emissions taxes, permits regimes are even more challenging in this regard. They not only have to measure or estimate the physical flows but also the behaviour of the participants in the permit market. Permits have to be tracked and trades recorded. A regulatory agency has to be able to confirm when permit owners are abiding by the terms of their permits and to enforce compliance when they do not by imposing appropriate penalties and sanctions. For their part, the permit owners need to be confident that they can demonstrate their compliance to the regulator whenever they operate within the terms of their permits.

The most successful emission permit regimes are the Sulphur Dioxide Allowance Trading Program (SO_2) and the Regional Clean Air Incentives Market (RECLAIM) in the US. Their monitoring, accounting and enforcement systems are very similar and rely heavily on self-reporting by the emitters (Peterson 2003).

In the case of the SO_2 program, every large emitter has to install a continuous emissions monitoring system (CEMS). The CEMS provides nearly continuous data (every 15 minutes) on the SO_2 emissions at each emitting facility to the US Environmental Protection Agency (EPA). The data are transmitted to the EPA automatically in electronic format. Smaller emitters are allowed to install cheaper monitoring systems but they are less accurate. Their estimated emissions have to be reported to the EPA via additional equipment and specific software and are subsequently evaluated by the EPA for accuracy and non-compliance. In both cases the EPA carries out site inspections and annual performance audits.

In the light of this experience, we can be confident that the costs of administration and compliance for a carbon tax or emissions permit regime are likely to be very substantial compared to the income transfers that will be generated for governments via carbon tax revenues or sales of emission permits. These costs are likely to be even more substantial for developing countries that have relatively immature or underdeveloped systems of public administration, particularly in the areas of environmental monitoring, accounting and enforcement (Greenspan Bell 2006). .

For these reasons, our estimates of the relevant income transfers are likely to underestimate their associated deadweight losses due to the combination of tax interaction effects, public administration costs and private compliance costs.

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