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How High Should Climate Change Taxes Be?

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Introduction

The polluter pays principle tells us that whoever is responsible for producing pollution is also responsible for paying for the damage caused by the pollution (OECD, 1992). So anyone whose activities lead to the emission of a tonne of carbon dioxide (CO2) should be taxed for the extra damage that is caused by the climate change due to that tonne of emissions.

It can be difficult to determine what the relevant damage includes, particularly in the case of climate change. Some fraction of any greenhouse gas, in particular CO2, that is emitted today will remain in the atmosphere for many years, mixing thoroughly with all other emissions, and causing impacts across the globe (IPCC, 2007a).

Integrated Assessment Models

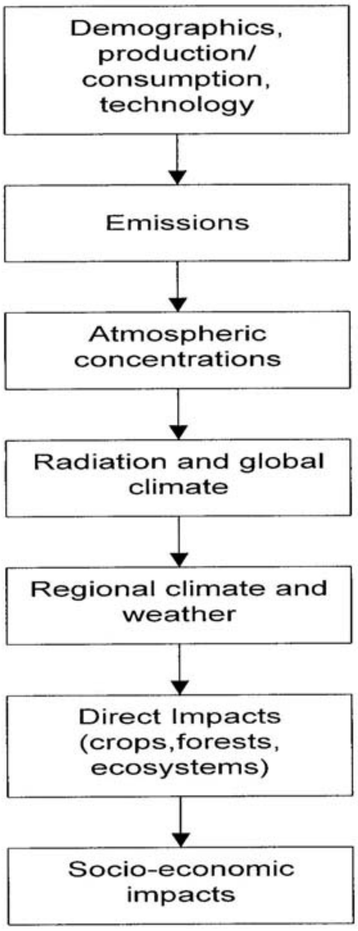
The only way in which the sum of the damage caused by a tonne of CO2 across all regions, all impact sectors and all time periods can be estimated is by the use of an integrated assessment model.

> 'Integrated Assessment Models of climate change are the formal, computerised, representations that have been created to understand and cope with this complex, global problem... Several attempts to define IAMs have been made. They are not totally in agreement, but do provide enough information to come up with a reasonable working definition... The most sensible course seems to be to accept the Weyant et al (1996) definition of IAMs of climate change as models that incorporate knowledge from more than one field of study, with the purpose of informing climate change policy.' (Hope, 2005)

Figure 1 shows the general form of an integrated assessment model (IAM) that can be used to estimate the impacts of climate change.

> ‘Some models (eg PAGE, FUND and DICE) omit [at least part of] the first box, and start with exogenously specified emissions (if they are simulation models), or end with optimal tax levels (if they are optimization models).’ (Hope, 2005)

Figure 1 The form of an integrated assessment model used to calculate climate change impacts



Source: Parson and Fisher-Vanden, 1997, p596.

Of course, the whole issue of climate change is surrounded by uncertainty. The climate sensitivity is uncertain, as are the impacts for a given temperature rise (IPCC, 2007a; Stern, 2007). Finding a way to take this uncertainty into account is one of the main tasks facing the designer of an IAM.

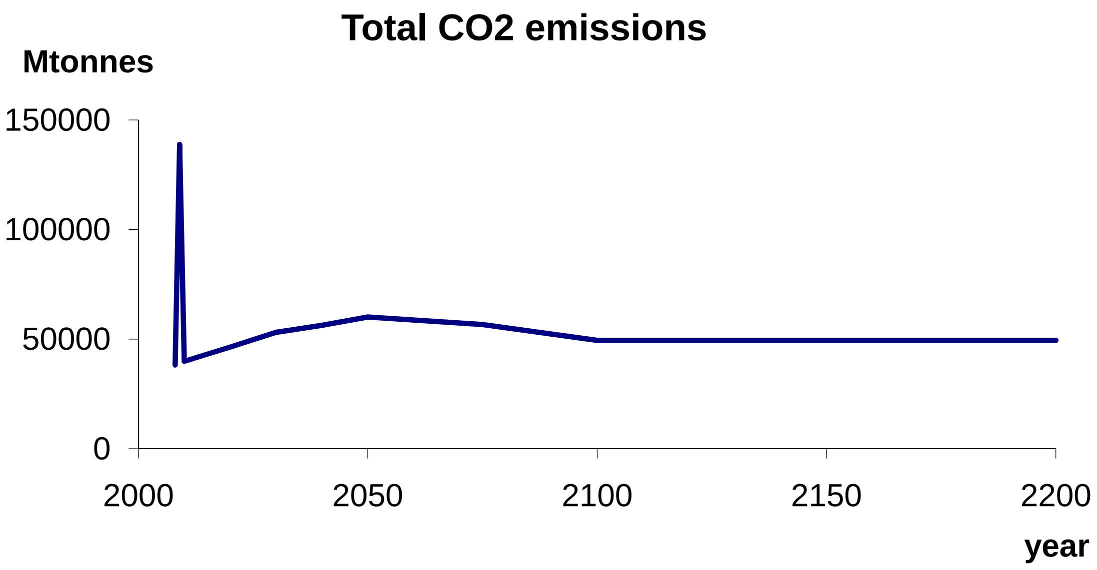
> ‘Uncertainty is a common problem for policy making, particularly in the environmental area. But it is almost the main defining characteristic here. Parson and Fisher-Vanden, 1997, state that ‘Uncertainty is central to climate change’ (p609).’ (Hope, 2005)

The normal use of an IAM is to calculate the total climate change impacts if the demographics, GDP and emissions follow a specified scenario, such as one of the business as usual scenarios defined by the IPCC’s Special Report on Emission Scenarios (Nakicenovic and Swart, 2000). But it can also be used to find the marginal impact if one extra tonne of CO2 is emitted, which is what is required by the polluter pays principle.

Calculating the social cost of carbon dioxide

The calculation is done in the following way. The model is used as normal to find the Net Present Value (NPV) of the total climate change impacts under a particular scenario, such as the A1B business as usual scenario. It is then run again with an extra spike of emissions superimposed upon the emissions from the scenario, as shown in figure 2, where the spike is 100 Gigatonnes of CO2, and the NPV of the climate change impacts is again found. Subtracting the NPV of impacts from the original scenario gives the extra impacts caused by the spike of emissions. Dividing this by the number of tonnes in the spike, in this case 100 billion, gives the extra impacts from one extra tonne of CO2 emissions, commonly called the social cost of CO2 (SCCO2).

Figure 2 Emissions over time used to find the social cost of CO2 under the A1B scenario



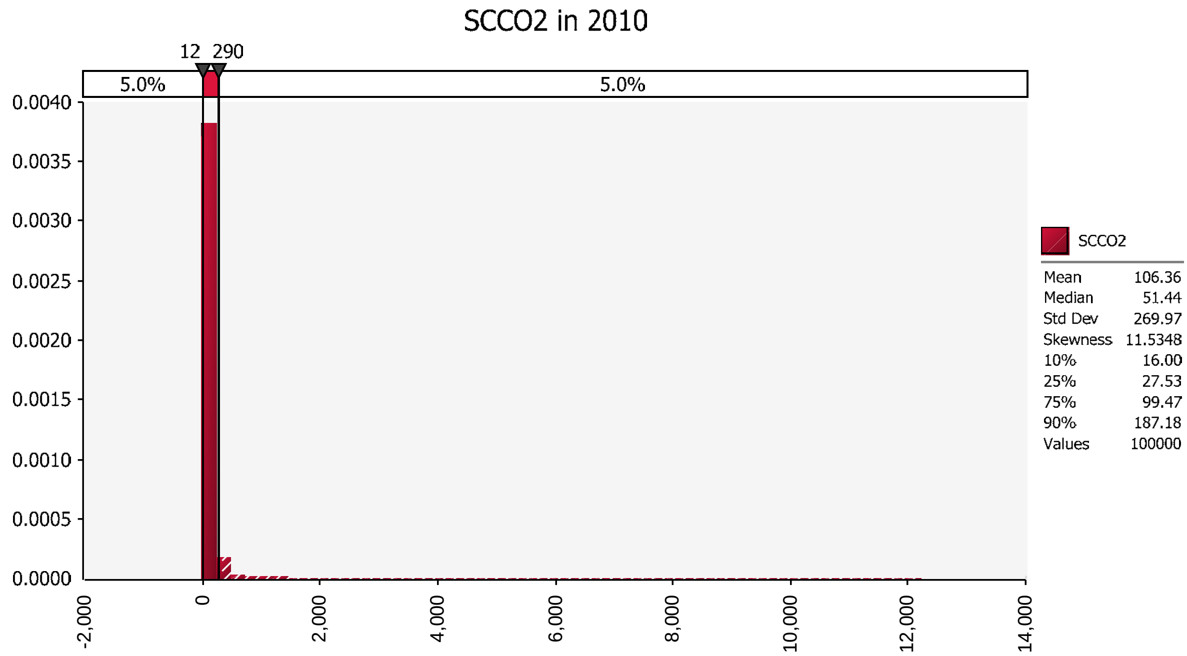
Results for the SCCO2

Figure 3 shows the full probability distribution of the SCCO2 from the current default version of one leading IAM, PAGE09 version 1.7 (Hope, 2011c). PAGE09 uses simple equations to simulate the results from more complex specialised scientific and economic models. It does this while expressing the most important inputs as probability distributions, to reflect the full range of scientific and economic opinion (Hope, 2011b), and calculating probability distributions for all outputs, usually by running the model 100 000 times, and so correctly accounting for the profound uncertainty that exists around climate change. New features in PAGE09 include the representation of sea level rise and the explicit dependence of impacts on GDP per capita (Hope, 2011a).

Calculations are made for eight world regions, ten time periods out to the year 2200, for three impact sectors and catastrophes such as the melting of the Greenland or West Antarctic ice sheets, to which the model gives the more neutral name of discontinuities.

Because the theoretical basis of the PAGE09 model is the calculation of expected utility, the appropriate summary statistic to use in policy making is the expected, or mean, value (Schoemaker, 1982). As can be seen from figure 3, the mean value is $106 per tonne of CO2, with a 5 – 95% range of $12 – 290. This assumes GDP, population and emissions follow the A1B business as usual scenario.

Figure 3 The SCCO2 from the PAGE09 default model

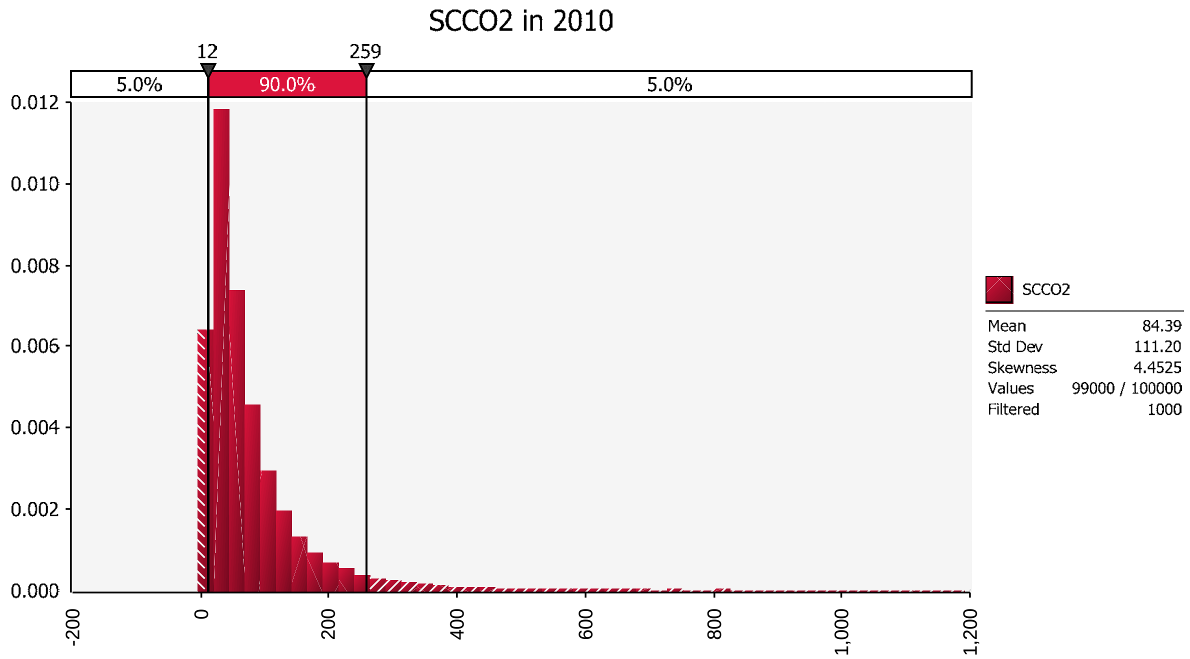


Source: Hope, 2011c

The most obvious feature of the distribution is its large positive skewness, with a few values as high as about $10000 per tonne of CO2. This is because the PAGE09 model keeps track of whether a discontinuity, such as the melting of the Greenland or West Antarctic ice sheets, has been triggered. These high values result when the small increase in emissions brings forward the date at which a discontinuity occurs.

The skewness is so extreme that it is difficult to see the shape of the distribution when all the values are included. So figure 4 shows the same result but with the top 1% of values omitted.

Figure 4 The SCCO2 from the PAGE09 default model, top 1% of values omitted



Source: Hope, 2011c

Comparing the mean value of $84 per tonne for this truncated distribution with the mean value of $106 per tonne when all runs are included shows that the top 1% of runs contribute $22, or about 20%, to the mean SCCO2 value in the default PAGE09 model. This confirms the importance of properly representing uncertainty when making estimates of the SCCO2.

The standard deviation of the result in figure 3 is $270, so the standard error of the mean is $270/sqrt(100000), which is about $0.75. So another 100000 runs would be 95% sure to produce a mean value for the SCCO2 within about $1.5 per tonne of the mean value shown in figure 3. Given this level of precision, it is probably best to describe the result in round numbers as showing that the mean SCCO2, and therefore the recommended level for a climate change tax, is about $100 per tonne of CO2.

Existing CO2 prices

Actual prices for CO2 are lower than this. Sweden has had a tax on CO2 since 1991; in 2010 its level is $40 per tonne of CO2. British Columbia in Canada began to tax CO2 in 2008, the tax is now $30 per tonne of CO2 (CTC, 2011). Australia has passed a law to institute a tax in 2012, at $25 per tonne of CO2 (Paton, 2011).

Allowances in the European Union Emission Trading Scheme, although not technically a climate change tax, are trading at about $20 per tonne of CO2 in 2010. Their price has been as high as about $40 per tonne of CO2 in 2005 and 2008, and as low as $12 per tonne in 2009 (Ares, 2011).

What does a tax of $100 per tonne of CO2 imply?

What changes to the prices of energy and transport does a tax of $100 per tonne of CO2 imply? Using the UK as an example, with an assumed exchange rate of $1.6 to the pound (Defra, 2007, annex 1), it would add 12 pence to the price of a litre of petrol, which has a typical retail price in 2010 of about 120 pence per litre (AA, 2010). The price rise of about 10% is relatively modest as about 65% of the price of petrol in the UK is already made up of duties and tax, rather than the cost of raw materials (HMRC, 2011).

The tax would add about 1 p/kwh to the price of gas for domestic customers, which has a typical retail price of about 3 p/kwh (DECC, 2011a). It would add about 4 p/kwh to the price of electricity from coal, and just under 2 p/kwh to the price of electricity from gas, both of which have a typical retail price of 11 p/kwh (DECC, 2011a) in 2010. Energy efficiency, renewable energy sources and nuclear power would not attract a climate change tax and so would not rise in price, and may well become cheaper with economies of scale and the reductions of other taxes. The price rises of 20 to 40% for gas and electricity generated from fossil fuels would make these other options much more economically attractive.

Taking into account the extra damage from emissions high up in the sky, which multiply their effect by about a factor of 3 (RCEP, 2002, para 3.35), the climate change tax would add about £60 to the price of a return air ticket from London to Barcelona. Since the advent of low-cost airlines, it is not really possible to give a typical retail price for flights such as this; but £60 is a noticeable increase in the fare.

Climate change tax revenue and other tax reductions

The UK's domestic emissions of CO2 in 2010 are about 500 million tonnes (DECC, 2011b). So a uniform and comprehensive tax of $100 per tonne of CO2 would raise about £32 billion of revenue in the first year. The UK's share of international air travel emissions of about 35 million tonnes of CO2 should also be included (DfT, 2010). Doing so, again with a multiple of 3 to take into account its higher impacts, would raise about another £7 billion, giving a total revenue of about £40 billion.

For comparison, other taxes in the UK raise approximately the following amounts: Council tax £25 billion, corporation tax £40 billion, Value Added Tax £75 billion, National Insurance contributions £100 billion, Income tax £145 billion. The UK's total tax take is about £500 billion. (Chote et al, 2010). So a climate change tax of $100 per tonne of CO2 would raise about 8% of the UK's tax revenues.

There are good reasons for making any tax on CO2 fiscally neutral, mainly because the resulting reductions in other taxes would bring down the costs of employment, reduce structural unemployment and increase GDP (Green Fiscal Commission, 2009, chapter 7).

> ‘ If the revenues from the taxes are spent on reducing burdensome taxes, then the costs of tackling climate change are reduced by about 2% of GDP, and may even be converted to benefits.’ (Barker, 2005).

With £40 billion per year of revenue from a climate change tax, the UK government would have many options for reducing other taxes. For instance, it could choose to reduce the standard rate of income tax by about 5 pence in the pound (from 20 pence to 15 pence), losing about £20 billion per year in revenue, and reduce the standard rate of VAT by 4% (from 20% to 16%), losing about £16 billion per year in revenue (Chote et al, 2010). The remaining £4 billion could be divided between welfare payments to the poorest, such as the present £2 billion winter fuel payments to pensioners (Kirkup, 2010), and support for basic research into new, more climate-friendly technologies.

So a tax on CO2 of $100 per tonne would have significant effects on relative prices and the balance of tax revenues. But there are six reasons for thinking that the appropriate tax on CO2 could be higher than the $100 per tonne mean result from the PAGE09 model.

Why the tax should be higher than $100 per tonne of CO2

Time horizon

The PAGE09 model has a time horizon of 2200, but some of the CO2 emitted in 2010 will still be in the atmosphere for many years beyond this. Around 25% of emissions are expected to stay in the atmosphere for several centuries (IPCC, 2001, p187). The effect of discounting means that any impacts caused after 2200 will be greatly reduced, but not eliminated. Crudely extending the time horizon of the PAGE09 model to 2300 increases the mean SCCO2 from the A1B scenario by about 20%.

Omitted impacts

Some impacts are omitted entirely from PAGE09, and all other integrated assessment models. The two most obvious omissions are the effects of ocean acidification (ESF, 2009), and the possible increases in war and large-scale migration from climatic causes, known as socially-contingent impacts (Watkiss et al, 2005). By definition the scale of these omitted impacts is unknown, as the relevant economic studies have yet to be attempted, but they cannot safely be assumed to be negligible, particularly if the climate sensitivity turns out to be towards the high end of what presently appears possible, 5 deg C or above (IPCC, 2007).

Richer regions

The mean SCCO2 of $100 per tonne is the marginal impact in the year 2010, as measured by someone with the mean GDP per capita in the EU. Some regions are much richer, particularly the US, with average annual GDP per capita of $42K in year 2005 dollars (World Bank, 2011), compared to about $29K in the EU, in purchasing power parity terms in year 2005 dollars (Indexmundi, 2011). Once these marginal impacts are corrected, using a mean marginal utility of consumption of just over 1, the appropriate values for the US will be about 50% higher than for the EU.

Other taxes are distortionary

The climate change tax will replace other taxes which are distortionary. For instance income taxes reduce the incentive to work by reducing the net reward for labour below its marginal product as assumed by models of perfect competition. There are very few reasons in a rational world why we would want to discourage work. Layard, 2005, gives perhaps the only minor reason – that we expect extra income to make us happier than it actually does. So, at the margin, when we are trying to decide between a marginally higher CO2 tax and a marginally higher income tax rate, it would initially be more economically efficient to raise the CO2 tax rate slightly above $100 per tonne, since this brings us best estimate damage reduction benefits of $100, rather than raise income taxes marginally above 20%, which brings us no compensating benefits.

It is unclear how high the climate change tax needs to be before the balance tilts in the other direction. Would a climate change tax of $150 be too high? With such a tax, we may have chosen to bring standard rates of income tax down to 15%. So the question that would need to be asked is whether increasing the difference between the climate change tax and the best estimate of impacts to slightly more than $50, would cause more or less distortion than taxing income at a fraction more than 15%, when we would ideally like it to be taxed at zero.

> ‘All else being equal, we should consider the marginal impact of the final dollar of taxation for each of the taxes in our economy. What's the damage done to the economy from collecting an extra dollar of sales revenue? Of corporate income tax? Of sales tax?’ (Moffatt, 2011) And, of course, an extra dollar of revenue from a climate change tax.

To answer this question requires the use of comprehensive modes of the macro economy, such as E3MG (Barker et al, 2005) and has not yet been attempted.

Present day dollars

In PAGE09, the social cost of CO2 is calculated in year 2005 US dollars, for a tonne of carbon dioxide emitted in 2010. Converting to year 2010 dollars would increase the values by just over 10% (US Dept of Commerce, 2011). If inflation continues at about 2% per year, taxes valued in future years’ dollars would need to be increased proportionately.

Increasing over time

The mean social cost of CO_2 is increasing over time in real terms, as we get closer to the time when the most serious impacts from climate change might occur. The rate of increase is about 2% per year (IPCC, 2007b, chapter 20).

A climate change tax of $250 in the United States

Pulling together all the adjustments that can be quantified would suggest that the best estimate of an appropriate CO_2 tax in the US in 2012 would be about $106 x 1.2 x 1.5 x 1.14 x 1.04 = $225 per tonne of CO_2, in year 2012 dollars. This does not include adjustments for the omission of some impacts from the SCCO2 calculation, nor for the taxes being replaced being themselves distortionary. Increasing by a very conservative 10% to adjust for this, gives a tax of about $250 per tonne of CO_2.

What effect would such a climate change tax have on the balance of taxes in the US? The US emits about 10 times as much CO_2 as the UK, 5500 million tonnes per year (EPA, 2011). So a uniform and comprehensive tax of $250 per tonne of CO_2 would raise about $1400 billion of revenue in the first year. The US's share of international air travel emissions is harder to estimate but appears to be about 50 million tonnes of CO_2 (OECD, 2010). Including these, again with a multiple of 3 to take into account its higher impacts, would raise about another $35 billion.

For comparison, other taxes in the US raise approximately the following amounts: Business taxes $600 billion, social insurance taxes $900 billion, ad valorem taxes $1100 billion, Income tax $1500 billion. The US's total tax take, federal state and local, is about $4500 billion per year. (Chantrill, 2011). So a climate change tax of $250 per tonne of CO_2 would raise about one third of the US's tax revenues. The reductions in other taxes that would be needed to achieve fiscal neutrality would exceed even the wildest dreams of the deficit hawks in the Republican party (CBO, 2005).

When the tax should be lower than $100 per tonne of CO2

There are also three reasons for thinking that the appropriate tax on CO_2 could in some circumstances be less than the $100 per tonne mean result from the PAGE09 model.

Lower emissions

The mean value of $100 applies to one more tonne of CO_2 emitted on top of the business as usual emissions from IPCC scenario A1B. But if climate change is recognised as a serious problem, it would be perverse to continue to allow emissions to rise like this, even though that is what seems to be happening at present (Le Quere et al, 2009). Suppose instead that global CO_2 emissions decline by about 50% by 2050, and 80% by 2100, giving peak CO_2 concentrations of slightly under 500 ppm, and a 50% chance of limiting the global mean temperature rise since pre-industrial times to 3 degC.

An extra tonne of CO_2 emitted in 2010 on top of this lower emissions scenario would have a mean SCCO2 of about $75. The reduced chance of a discontinuity in this scenario, and all that that implies, means that the extra impact from one more tonne of emissions is lower than if emissions are allowed to grow unchecked.

So the choice between a climate change tax of $100 per tonne and one of $75 per tonne depends on one's view of the likelihood of emissions in the rest of the world continuing to rise in a business as usual fashion, or being brought under control. Economic theory would suggest that the appropriate climate change tax should assume that CO_2 emissions will follow an optimal path in the future – one that minimises the mean sum of impacts, abatement costs and adaptation costs (Tietenberg and Lewis, 2009). Exactly what this path looks like is still to be determined, but it could well resemble the lower emissions scenario sketched out here.

Higher discount rates

The mean SCCO2 of $100 comes from runs of the PAGE09 model using a range of pure time preference rates and equity weights, whose mean values imply consumption discount rates ranging from the order of 2.3% per year in the US to 5.5% per year in China. There is great controversy about whether such discount rates are consistent with the rates of return seen on actual investments in the economy.

Nordhaus (2007) argued that real rates of return are closer to 5.5 or 6% per year in the US, and that consumption discount rates in integrated assessment models should reflect this. As others have pointed out,

> 'the historic average return… includes the last 40 years or so, a period during which total credit market debt in the U.S. has doubled five times, and now stands at over 350% of GDP… The reason these returns existed in the past was because we were experiencing debt fuelled, unsustainable rates of rapid economic growth' (CIVFI, 2011).

Real rates of return on the Standard and Poor 500 with dividends re-invested have been about -3.4% per year from 2000 to 2010 (SSI, 2011).

Again it is not possible to settle these controversies here. But we can see the effect of using higher values for the pure time preference rate and the equity weights, giving mean consumption discount rates of about 4% per year in the US, by running the PAGE09 model with those input value distributions. They reduce the mean SCCO2 by about $50, to around $55 per tonne of SCCO2.

Poorer regions

The mean SCCO2 of $100 per tonne is the marginal impact in the year 2010, as measured by someone with the mean GDP per capita in the EU. Some regions are much poorer, particularly the developing world, with average global annual GDP per capita of about $10K, compared to about $29K in the EU, in purchasing power parity terms (Indexmundi, 2011). Once these marginal impacts are weighted, using a mean marginal utility of consumption of just over 1, the appropriate climate change tax values for regions with the global average income per capita will be about 70% lower than for the EU, at about $30 per tonne of CO2. In the poorest regions of the world, such as India, with per capita income of about $4K per year (Indexmundi, 2011), the appropriate initial climate change tax would be about $10 per tonne of CO2.

Conclusion

If the best current scientific and economic evidence is to be believed, and climate change could be a real and serious problem, the appropriate response is to institute today a climate change tax equal to the mean estimate of the damage caused by a tonne of CO2 emissions. The raw calculations from the default PAGE09 model suggest the tax should be about $100 per tonne of CO2 in the EU. But correcting for the limited time horizon of the model, and bringing the calculations forward to 2102, in year 2012 dollars, brings the suggested tax up to about $150 per tonne of CO2.

There are good arguments for setting the initial tax at about $250 per tonne of CO2 in the US, while starting off at a much lower level, maybe $15 per tonne of CO2, in the poorest regions of the world, all in the year 2012, in year 2012 dollars.

That such policy advice would not pass the laugh test, particularly in the US, shows that the rhetoric about getting to grips with climate change has not been seriously thought through to its logical conclusion. As a result, rather than falling, greenhouse gas emissions are continuing to rise (Le Quere et al, 2009). A fiscally neutral significant climate change tax is the best chance we have of bringing the climate change problem under control.

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