

challenge paper

CLIMATE CHANGE, EMISSIONS ABATEMENT

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AN UPDATED ANALYSIS OF CARBON DIOXIDE EMISSION ABATEMENT AS A RESPONSE TO CLIMATE CHANGE

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1. Introduction

In the Copenhagen Consensus for Climate 2010 (Lomborg 2010), reduction of carbon dioxide emissions received a low priority. This follows from the particularities of the *Gedankenexperiment* that is at the core of all Copenhagen Consensus: There is a finite budget, that needs to be spent, on a separate project, informed by disjoint cost-benefit analyses.

Climate policy does not fit in that mould, and carbon dioxide emission reduction fits least.

Climate change is a big problem. In order to halt anthropogenic climate change, the atmospheric concentrations of greenhouse gases need to be stabilized. For that, carbon dioxide emissions need to be reduced to zero. This requires a complete overhaul of the energy sector. That is a big job. It should be done as long as the benefits exceed the costs. If it does not fit in the budget of the Copenhagen Consensus, then more money should be raised. Indeed, it would be profitable to borrow money if the benefit-cost ratio is greater than one.

There is wide agreement in the economic literature that greenhouse gas emission reduction is best done through a carbon tax. A uniform carbon tax implies equimarginal abatement costs. Climate change is a stock problem, so a price instrument is more robust to uncertainty than a quantity instrument. Taxes properly incentivise R&D. That is, climate policy is not about spending money. It is about raising money (and, of course, about finding the best way to spend the revenues raised through a carbon tax.)

Drastic reduction of carbon dioxide emissions would be very expensive with current technologies. R&D is a critical part of CO₂ abatement policy. However, most of that R&D is innovation and diffusion, rather than invention. Grants are suitable for invention. For innovation and diffusion, the regulator should create a credible promise of a future market: In this case, the promise of an emission reduction target or, better, a carbon tax in the future. The best way to give a credible signal is to start now – which has an additional advantage because the regulator does not know how close to market renewable energy technologies really are. That is, R&D and CO₂ abatement are complements, not substitutes.

Cost-benefit analysis, the purported aim of the Copenhagen Consensus, is an analysis of efficiency. Cost-efficacy is a pre-condition for efficiency. Cost-efficacy requires that all alternative solutions to a problem – carbon dioxide emission reduction, reduction of other greenhouse gases, carbon capture and storage, and indeed R&D and geoengineering – are priced equally at the appropriate margin. It is inconceivable that a cost-benefit analysis would conclude that climate change is a problem that should be addressed through one channel – say geoengineering – but not through other channels, provided that those channels are complements and their marginal cost curves go through the origin.

Geoengineering indeed is a complement to carbon dioxide emission reduction. Geoengineering addresses warming, a subset of climate change, whereas carbon dioxide emission reduction addresses the whole of climate change as well as ocean acidification. Geoengineering is a transient, end-of-pipe solution to climate change whereas carbon dioxide emission reduction is a permanent, structural solution. Geoengineering may have a place in an optimal portfolio of climate policy because carbon dioxide emission reduction will take considerable time to sort an effect, but it cannot dominate the portfolio.

The Copenhagen Consensus for Climate 2010 overlooks these issues. Its conclusions are therefore unsupported.

2. Costs and benefits of climate policy: An update

My contribution to the Copenhagen Consensus for Climate 2010 came in 5 parts. I here briefly summarize each of these parts and offer the latest insights.

2.1. Impacts of climate change

In (Tol 2010), I survey the literature on the total economic impact of climate change. No new studies have been published since. The bottom line conclusions are therefore still the same:

- The net impact of climate change is probably positive for moderate climate change but turns negative at some point in the 21st century. The incremental impact becomes negative well within the committed warming. The net benefits are sunk benefits.
- The best estimates of the global average impact of a century of climate change are of the same order of magnitude as annual economic growth rates, and the impacts of centennial climate change are unlikely to exceed decadal growth rates.
- National average impacts may be much larger than global average impacts. Poor countries in the tropics are particularly vulnerable to climate change.
- Impact estimates are very uncertain. Negative surprises are more likely than positive surprises. Primary estimates are available for global warming up to 3°C; beyond that, impact estimates are largely speculative.

In the same chapter, I survey the literature on the social cost of carbon or the marginal impacts of climate change. I then counted 232 published estimates. Since then, more than

a 100 new estimates have been published (Tol 2011). Despite the large increase in the number of estimates, the results are similar:

- The social cost of carbon is most likely positive. That is, greenhouse gas emissions are a negative externality that should be taxed or otherwise regulated.
- The social cost of carbon strongly depends on the parameters of the welfare function, notably the pure rate of time preference and the rate of risk aversion.
- Estimates of the social cost of carbon are highly uncertain, and the uncertainty is right-skewed, possibly with a fat tail.

Table 1 shows the results of (Tol 2011). The table emphasizes three things. The right tail is heavy, perhaps fat. The discount rate is crucial. Impacts fall disproportionately on the poor, so that equity weighted impacts are much larger than risk neutral impacts.

2.2. Impacts of greenhouse gas emission reduction

New estimates of the costs of greenhouse gas emission reduction are published regularly, but as they add to an already large body of work, overall conclusions change only slowly. The following lessons can be drawn:

- Deep cuts in greenhouse gas emissions are technically feasible.
- The costs of deep emission cuts are relatively small if
 - emission reduction targets are lenient at first but accelerate over time;
 - all emitting sectors are regulated and marginal abatement costs are the same;
 - all gases are regulated and priced uniformly;
 - all countries reduce emissions, and marginal costs are equal; and
 - climate policy is coordinated with other policies.
- The costs of emission reduction rapidly escalate if the above rules are violated.

Since the publication of (Tol 2010), progress has been made in alternative energy technologies, notably in bioenergy and solar power. On the other hand, nuclear power has fallen out of favour. It is also increasingly clear that governments have great difficulty in delivering emission reduction programmes that are least-cost.

3. Scenarios

3.1. Copenhagen Consensus for Climate 2010

In (Tol 2010), \$250 billion per year was spent for a decade, which is equivalent to a budget with a net present value of \$2 trillion at a 5% money discount rate. I considered five scenarios:

1. A carbon tax is levied in the countries of the OECD for 10 years. The carbon tax rises with the rate of discount until 2020, and then falls to zero. The initial level of the carbon tax is such that the net present welfare loss is \$2 trillion.

2. A carbon tax is levied in all countries for 10 years. The carbon tax rises with the rate of discount until 2020, and then falls to zero. The initial level of the carbon tax is such that the net present welfare loss is \$2 trillion.
3. A carbon tax is levied in all countries. The carbon tax rises with the rate of discount. The level of the carbon tax is the same as in Scenario 2, but continues rising after 2020.
4. A carbon tax is levied in all countries. The carbon tax rises with the rate of discount. The initial level of the carbon tax is such that the net present welfare loss is \$2 trillion.
5. A carbon tax is levied in all countries. The carbon tax rises with the rate of discount. The initial level of the carbon tax is set equal to the social cost of carbon.

The first two scenarios are for diagnostic purposes only, illustrating (a) that it is pointless to have a climate policy for 10 years only and (b) that it is largely ineffective and needlessly expensive to limit carbon dioxide emission reduction to OECD countries. The benefit-cost ratio is less than 1%.

The third scenario roughly corresponds to the long-term target of the EU: The atmospheric concentration of carbon dioxide stays well below 450 ppm. But because other greenhouse gases are uncontrolled (because of the silly rules of the Copenhagen Consensus), the global mean temperature continues to rise above 2°C warming. This scenario violates the budget constraint of the Copenhagen Consensus, and its benefit-cost ratio is 2%.

The fourth scenario spends all Copenhagen money on carbon dioxide emission reduction. I argue above that this would be unwise: Other greenhouse gases should be reduced too. Carbon dioxide emissions begin to fall around 2055. The benefit-cost ratio is 26% -- ignoring uncertainty and equity.

The fifth scenario spends a fraction (5%) of the Copenhagen budget on carbon dioxide emission reduction. Carbon dioxide emissions begin to fall around 2090. The benefit-cost ratio is 151% -- again ignoring uncertainty and equity.

Scenarios 3-5 illustrate that an economic case can be made for carbon dioxide emission reduction, even under conservative assumptions. The analysis ignores that large and right-skewed uncertainty about climate change and its impacts, and the analysis also ignores that the impacts of climate change would fall disproportionately on the global poor. At the same time, Scenarios 3-5 illustrate that while some carbon dioxide emission reduction is justified, there are limits to the desired stringency of climate policy.

3.2. *Copenhagen Consensus for Climate 2012*

The main difference between the current and the previous edition of the Copenhagen Consensus for Climate is that the budget is much smaller: \$75 billion for a period of 4 years, with a net present value of \$70 billion. This is less than the budget of the cheapest Scenario 5 above, so that all those scenarios are impermissible for the current edition of the Copenhagen Consensus for Climate.

Figure 1 shows the net present welfare loss, the benefit-cost ratio, the peak year of emissions, and the carbon dioxide concentration in 2100, each as a function of the initial carbon tax for Scenarios 3-5. See also Table 2. I added, by interpolation, Scenario 6: A carbon tax of \$3/tC is levied on all emissions of carbon dioxide from fossil fuel combustion and industrial processes from all sectors in all countries in 2010; the carbon tax increases with the rate of discount to \$242/tC in 2100.

For such a tax, the net present welfare loss is \$280 billion, which exceeds the Copenhagen budget. Emissions peaks around 2080, and the atmospheric carbon dioxide concentration in 2100 is 815 ppm. The benefit-cost ratio is 1.02. This project is worthwhile, albeit only just so.

I add a seventh scenario by interpolation. The initial tax is \$1.8/tC. Emissions peak around 2090 (as in Scenario 5) but the carbon dioxide concentration rises to 875 ppm. The net present value of the emission reduction costs is \$70 billion, equal to the Copenhagen Consensus for Climate budget. The benefit-cost ratio is 1.56.

3.3. *Biased benefit cost ratios?*

Table 2 shows the benefit-cost ratio for the five scenarios. There are several biases in the results. First, the benefits are taken from the FUND model, which estimates a social cost of carbon of \$2/tC for the 5% discount rate. A comparison to Table 1 (Tol 2011) reveals that the average in the literature for that discount rate is \$10/tC – I therefore multiply the benefits by five. Second, the benefits are not equity-weighted – that is, the analysis assumes that a dollar to a poor woman is worth the same as a dollar to a rich woman. Table 1 reveals that the social cost of carbon increases by a factor 1.5 if equity-weighted. Third, the analysis ignores uncertainty. Table 1 suggests that the social cost of carbon decreases by a factor 0.4 if the expected benefits are considered rather than the best guesses.¹ Fourth, that factor 2.4 only considers within-model uncertainty. Table 1 suggests that, for a discount rate of about 5%, the social cost of carbon increases by a factor 1.9 if between-model uncertainty is included too. Put together, Table 1 underestimates the benefits by a factor 33.6.²

Table 3 shows the corrected benefit-cost ratios. The low carbon taxes (\$2/tC and \$3/tC) could already be justified with conservative assumptions, and look very attractive if equity, uncertainty, and model bias are corrected. The \$12/tC tax can also be justified but the assumptions of Table 2 need to be stretched further. The \$250/tC is unjustifiable.

Table 3 does not correct all biases. One could argue that the cost estimates suffer from similar biases. However, the uncertainty about the costs of emission abatement is more symmetric, the costs are more equitably spread over countries, and FUND tends to be closer to the middle of the model distribution albeit a bit on the expensive side. The biascorrection factor would thus be smaller. As the (incomplete) results in Table 3 are so

¹ This is counterintuitive. The explanation is that only the more sophisticated analyses include uncertainty, and more sophisticated analyses tend to be less pessimistic about climate change and its impacts.

² There are, of course, different ways of navigating through Table 1. If, for instance, we evaluate the equity bias and the within model bias at the mean rather than the mode, then the total bias would be 3.0. Time did not permit us going back to the data underlying Table 1 and further refining the analysis.

robust, it is not likely that further bias corrections would qualitatively change the conclusion.

4. Conclusion

In this paper, I revisit the scenarios of the Copenhagen Consensus for Climate 2010. I argue that the format of the Copenhagen Consensus is ill-suited for a problem like climate change, and that it is inappropriate for evaluating the different aspect of climate policy. Climate policy is a long programme, not a short project, and revenue should be raised through a carbon tax, rather than spent by a blue-ribbon panel. Climate policy is a portfolio of adaptation, abatement of various gases, R&D, and perhaps geoengineering. Ignoring the complementarity of these options is silly.

I reassess the estimates of the costs and benefits of carbon dioxide emission reduction, and find that no reason has arisen in the last two years to radically change the numbers published in 2010.

I re-evaluate the scenarios of the 2010 project, and add two new scenarios, one that fits the revised budget, and one that is the most stringent justifiable policy. Based on conservative assumptions, modest carbon dioxide emission reduction can be justified. If this does not fit within the budget of the Copenhagen Consensus, then money should be borrowed. The analysis above reveals that the Copenhagen Consensus budget is indeed inadequate for a problem like climate change.

Properly accounting for uncertainty and equity, modest emission reduction appears to be a very lucrative proposition and more stringent emission reduction can readily be justified.

Very stringent emission reduction targets, in line with the long term goals of the European Union, do not pass the benefit-cost test, however.

References

Lomborg, B. (ed.) (2010), *Smart Solutions to Climate Change -- Comparing Costs and Benefits* Cambridge University Press, Cambridge.

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Table 1. The social cost of carbon (\$/tC); sample statistics and characteristics of the Fisher-Tippett distribution fitted to 311 published estimates, and to three alternative ways to split the sample.*

	All	PRTP			Equity		Uncertainty	
		0%	1%	3%	Yes	No	Best	Mean
Mean	177	276	84	19	168	177	206	68
SD	293	258	93	18	200	316	332	93
Mode	49	126	48	10	65	44	55	23
P(SCC)<0	25%	10%	17%	11%	16%	27%	25%	22%
33%	35	125	35	8	59	26	40	19
50%	116	212	71	15	117	112	135	49
67%	213	339	112	23	189	213	250	86
90%	487	646	204	44	478	489	573	177
95%	669	749	252	52	614	690	777	233
99%	1602	966	359	68	789	1684	1676	422
N	311	53	76	84	102	209	242	69

* PRTP = pure rate of time preference; equity = equity-weighted; uncertainty = best guess or mean value

Table 2. Selected characteristics of the scenarios: Initial carbon tax, peak year of carbon dioxide emissions, atmospheric concentration of carbon dioxide in 2100, net present value of the costs of emission reduction, benefit-cost ratio.

Scenario	Tax	Peak year	Concentration	NPV costs	Benefit-cost ratio
7	\$1.8/tC	2090	875	\$70 10 ⁹	1.56
5	\$2/tC	2090	850	\$100 10 ⁹	1.51
6	\$3/tC	2080	815	\$280 10 ⁹	1.02
4	\$12/tC	2055	675	\$2,000 10 ⁹	0.26
3	\$250/tC	2010	425	\$47,600 10 ⁹	0.02

Table 3. Corrected benefit-cost ratios

Scenario	7	5	6	4	3	Factor
Tax	\$1.8/tC	\$2/tC	\$3/tC	\$12/tC	\$250/tC	
Table 2	1.56	1.51	1.02	0.26	0.02	-
Equity weighting	2.30	2.23	1.50	0.38	0.03	1.5
Between-model uncertainty	2.96	2.87	1.93	0.49	0.04	1.9
Within-model uncertainty	0.65	0.63	0.43	0.11	0.01	0.4
Multi-model	7.78	7.55	5.09	1.30	0.10	5.0
All of the above	9.14	8.86	5.98	1.53	0.12	5.9

Figure 1. Selected characteristics of the scenarios as a function of the initial carbon tax; blue dots are taken from (Tol 2010) , red triangles are interpolated.

