



THE STERN REVIEW

Ten years on

Peter Lilley

With a foreword by
Nigel Lawson



The Global Warming Policy Foundation

GWPF Briefing 23

GWPF REPORTS

Views expressed in the publications of the Global Warming Policy Foundation are those of the authors, not those of the GWPF, its Academic Advisory Council members or its directors

THE GLOBAL WARMING POLICY FOUNDATION

Director

Benny Peiser

BOARD OF TRUSTEES

Lord Lawson (Chairman)	Peter Lilley MP
Lord Donoghue	Charles Moore
Lord Fellowes	Baroness Nicholson
Rt Revd Dr Peter Forster, Bishop of Chester	Graham Stringer MP
Sir Martin Jacomb	Lord Turnbull

ACADEMIC ADVISORY COUNCIL

Professor Christopher Essex (Chairman)	Professor Ross McKittrick
Sir Samuel Brittan	Professor Robert Mendelsohn
Sir Ian Byatt	Professor Ian Plimer
Dr John Constable	Professor Paul Reiter
Professor Vincent Courtillot	Dr Matt Ridley
Professor Freeman Dyson	Sir Alan Rudge
Christian Gerondeau	Professor Nir Shaviv
Dr Indur Goklany	Professor Philip Stott
Professor William Happer	Professor Henrik Svensmark
Professor David Henderson	Professor Richard Tol
Professor Terence Kealey	Professor Anastasios Tsonis
Professor Deepak Lal	Professor Fritz Vahrenholt
Professor Richard Lindzen	Dr David Whitehouse

CREDITS

Cover image Josh: www.cartoonsbyjosh.co.uk

THE STERN REVIEW

Ten years on

Contents

Foreword by Nigel Lawson	vii
I Peter Lilley: The Stern Review ten years on	1
About the author	2
1 The failings of the Stern Review	3
2 Sacrificing today's poor for tomorrow's rich	7
3 Stern's discount rate	8
4 Was Stern 'right for the wrong reasons'?	10
5 In conclusion	11
Notes	12
II Richard Tol: Research in climate economics since the Stern Review	13
About the author	14
1 Introduction: the Stern Review	15
2 Stern since the Stern Review	16
3 Climate economics since the Stern Review	16
References	19

Foreword

By Nigel Lawson

In my 2008 book, *An Appeal to Reason: A Cool Look at Global Warming*, I observed that 'The Stern Review is essentially a propaganda exercise in support of the UK government's predetermined policy of seeking a world leadership role on climate change. Neither its conclusions nor the arguments on which they are based possess much merit'.

It is clear, in retrospect, that I was too kind. The Stern Review is now ten years old, and this GWPF paper is able to assess it in terms of what has happened to the world's climate since it was published, the state of climate policy, and the development of academic thinking on the subject.

The verdict could not be more damning. Peter Lilley MP, a former senior UK Minister, and one of only five MPs who had the foresight to vote against the UK's 2008 Climate Change Act, whose rationale was based entirely on the Stern Review, and from the consequences of which we are still suffering, has produced in this paper a devastating analysis of its shortcomings and an indisputable demolition of its conclusions. And the leading climate economist, Professor Richard Tol, records how subsequent academic research has moved on, and away, from Stern.

Yet as Peter Lilley points out, government officials still rely on the wholly discredited Stern review to justify UK climate change policy today. He could also have pointed out that, insofar as there may be disadvantages from global warming – and it is far from clear how great those disadvantages are – the only economically rational response is adaptation, which Stern explicitly dismisses.

As founding chairman of the Global Warming Policy Foundation, I hope that the analysis contained in this paper will help to bring much-needed sanity to this important, and at present highly costly, area of policy.

Nigel Lawson
October 2016

Part I

The Stern Review ten years on

Peter Lilley

About the author

Peter Lilley is the MP for Hitchin and Harpenden. He was formerly the Secretary of State for Trade and Industry in the governments of Margaret Thatcher and John Major and also Secretary of State for Social Security. He was one of only five MPs to vote against the passage of the Climate Change Act.

1 The failings of the Stern Review

When the Stern Review was published in 2006 I was chairing the Global Poverty Commission set up by David Cameron. So I was only interested in its implications for developing countries. When I turned to the relevant section, my eye fell upon a reference to a study showing that a 4°C rise could cut yields of one crop variety by 70%. I happened to be familiar with the study, which also shows that an alternative variety of the crop showed *increased* yields at these temperatures. But the Review did not mention this. That example of *suppressio veri* sowed the seed of doubt in my mind about the objectivity of the Review.

A couple of years later came the Climate Change Act. The government, as for any piece of legislation, was required to publish a cost–benefit analysis – called an Impact Assessment – to demonstrate to Parliament that the measure was worthwhile. But this Impact Assessment was unprecedented. It showed that the potential cost of the measure was twice the maximum benefit (in terms of reduction of damage global warming and the damage it would have caused across the world). This – not any scepticism about the science of global warming – prompted me, along with four others, to vote against the Bill. The Impact Assessment flatly contradicted the Stern Review, which claimed that the cost of preventing undue global warming would be a fraction of the benefits. But neither the contradiction, nor the Stern Review itself, nor the cost of this enormously expensive measure were considered at any stage of its passage through Parliament.

Subsequently, whenever I have questioned the economics of the UK's climate change policies, governments have invoked the Stern Review. They still rely on it today. It is claimed to have provided an independent review of the evidence on which government policy is based. It was in this context that I went back to the Stern Review, studied it at length and published an extended critique.¹ In the course of this it became apparent that:

- The Stern Review was not independent. It was commissioned by the Chancellor of the Exchequer and carried out by a team of Treasury officials led by the Treasury Chief Economist, Sir Nicholas Stern.
- It was not a Review. Far from reviewing the evidence, and despite the fact that he did no new research of his own, Stern came out with conclusions way outside the previous consensus of environmental economists. That consensus included the economic assessment of the UN Intergovernmental Panel on Climate Change (IPCC) on whose scientific projections Stern's projections were based. Whereas Stern said the benefits of reducing emissions would be 5–20 times the cost, the IPCC shortly afterwards concluded: 'analyses of the cost and benefits of mitigation indicate that these are broadly comparable in magnitude' so it could not establish 'an emissions pathway or stabilization level where ben-

efits exceed costs'.²

- Above all, it was not an exercise in evidence-based policy making but the most egregious example of policy-based evidence making. The Review selects facts and devises methods to justify a pre-ordained policy.
- Its principal conclusion – that the World should act to prevent the concentration of carbon dioxide in the atmosphere exceeding 550 parts per million – happened to be the target to which the UK government was already signed up (a fact never mentioned in the Report, which simply avoided considering any other target number).
- To justify the costly measures needed to reach that target, Stern had to set aside the discounting rules prescribed by the Government Economic Service (of which Stern himself was the head) and adopt a controversially near-zero rate for discounting over time the benefits of mitigating global warming centuries into the future (though not for discounting the costs of preventing it).

The near unanimous prior commitment of the political parties, the media and environmentalists to take 'whatever action is required to save the planet' guaranteed the Stern Review an uncritical reception in 2006.³ Academic criticism was deferred because the Review was launched some months before physical copies of the full report were made available.

When other environmental economists were able to study its rationale, the Review came in for some heavy criticism, particularly for its use of ultra-low discount rates (discussed below) but also for a range of other questionable devices.

For example, it emerged that Stern was not comparing the cost of preventing emissions with the extra damage those additional emissions would have caused. Instead he compares the cost of stopping *some* future emissions of green house gases (those that would take the level in the atmosphere above his ceiling of 550 ppm) with the damage caused by *all* human greenhouse gas emissions past, present and future (including those up to 550 ppm, which his policy would not prevent). This is inexcusable. However, it would not matter greatly if concentrations of carbon dioxide up to 550 ppm actually cause little damage. But were Stern to argue that, he would promptly raise the question: 'Why set the ceiling so low?' In fact, the Review does let slip that setting the emission ceiling at 650 ppm would only increase damages by the equivalent of some 0.6% of GDP 'now and forever'.

It also emerged that his use of the phrase 'now and forever' about the impact of climate change is highly misleading. The Review's headline conclusion⁴ that 'If we don't act the overall costs of climate change will be equivalent to losing at least 5% of global GDP *each year now and forever*' (emphasis added) gives the impression that we are about to experience a loss of 'at least 5% of GDP' *now* due to global warming.⁵ The key words 'equivalent to' are invariably overlooked.⁶ They refer to the Review's novel and misleading practice of projecting by how much unrestricted climate

change would reduce GDP each year from now (when the reduction is negligible) to infinity (when it will be large). This is then discounted back to the present. They then calculate what constant percentage reduction in GDP, also discounted back to the present at Stern's very low rate of discount, has the same present value.⁷ To say this averaged value – which reflects high impacts centuries hence – describes the impact of climate change on GDP 'now' is simply untrue. In fact, far from experiencing a 5% loss of GDP now, the impact of warming could be beneficial now and for several decades, because moderately higher temperatures boost crop yields, as do increased concentrations of carbon dioxide.

The Review also compared the cost of climate change averaged from now to eternity with the actual cost of limiting emissions in the decades ahead. This gave the impression that over our lifetimes there would be a net benefit to humanity from the crash programme that Stern advocates. In fact, closer analysis of the Review showed that even in the most extreme case considered,⁸ the cumulative costs of reducing emissions would exceed the benefits of reduced climate change experienced over the rest of this century.

After receiving a critical mauling from some fellow economists at a symposium at Yale, Stern has largely eschewed public debate with critics.⁹ Instead, he employs a full time 'attack dog' – one Bob Ward – who is tasked with launching ad hominem attacks and debating ripostes against anyone who has the temerity to question his master's views.

Stern has nonetheless taken some of the criticisms to heart, and as a result has changed his position on a range of quite fundamental issues. He has blithely adopted a new methodology, with a new (higher) discount rate and a new (tougher) target, resulting in a new (higher) cost of mitigation, a new (more scary) scenario if we do nothing, and new (alleged) health risks that are in fact unrelated to climate change.

New methodology Stern's original methodology applied conventional cost-benefit analysis to projections based on science that he claimed was 'certain'.¹⁰ Since the harmful effects of global warming were predicted to be far into the future, he had to discount over time at a near-zero rate. This led Professor Martin Weitzman to dismiss Stern's 'economic modelling of climate change impacts, which deservedly has drawn strong criticism from economists'. However, Weitzman concluded that Stern might nevertheless be 'right for the wrong reasons', a position he justified by suggesting that an alternative methodology could still justify a crash programme to reduce emissions. He argued that if there is a finite possibility, however small, of an infinitely bad outcome (human extinction) then virtually any cost is worth incurring to prevent it. The Stern Review's projections based on the notion that 'the science is certain' do not generate infinitely bad outcomes. To generate potentially infinitely bad outcomes, Stern and his team have implicitly jettisoned the claim that 'the science is certain' and adopted the notion that the science is so uncertain that we cannot rule

out the possibility that greenhouse gases may produce a climate response beyond anything known to the IPCC. Whether Weitzman's theorem can rescue the Review's conclusions is examined further below.

New discount rate In a lecture to the American Economic Association in 2008, Stern said 'with the benefit of hindsight, my inclination would be [to discount for higher incomes at twice the rate used in the Stern Review]'.¹¹ That would mean using a basic rate of discount of 2.7% pa instead of 1.4% pa used in the Review. This would dramatically reduce his headline estimates of the cost of global warming. Instead of being equivalent to a loss of 5% of GDP 'now and forever', his base case loss would be about 1.5% and his 'high climate' case loss would be reduced from 14.4% of GDP to about 5% 'now and forever'. However, his replacement of 'certain science' by 'uncertain science' generates extreme outcomes, implying consumption falling below current levels. And in these circumstances his new approach to discount rates increases the significance of expected losses.¹²

New target at double the cost The Review adopted, without attribution, the UK government's target of preventing atmospheric carbon dioxide exceeding 550 ppm. Some environmentalists found this insufficiently stringent. Stern has subsequently advocated a target ceiling of 500 ppm (the current level is already over 400 ppm). He acknowledges that this will double the (minimum) cost to 'about 2 per cent of global GDP each year'.¹³

New scary scenario Although substantially higher than the losses projected by most environmental economists, the threat of losing 5% of future GDP, as predicted by the Review, did not provoke great public alarm. So in subsequent lectures Stern drops references to lost GDP and emphasises the threat of mass migration and conflict. He cites a village in North India with which he is familiar and postulates that its inhabitants and much of the population of North India will migrate en masse towards Europe – a vision worthy of a UKIP poster. Given that his own forecasts imply that the population of India will have raised their living standards several fold, albeit by harnessing fossil fuels, before the temperature has risen very much, it is not obvious why Indians who do not migrate now would do so in future.

New health risks unrelated to climate change Most recently Stern has begun to highlight the health risk of particulates from coal and diesel as a reason for restricting fossil fuel use, as much as their impact on the climate. This may be because the impact of rising temperatures is distant, whereas the health risks of particulates are immediate. The most alarming implication of a rising temperature is melting of the ice caps. But the IPCC says this will take 'millennia'. By contrast, particulates from coal – which are hideously visible in countries like China – kill people here and now. But it may well be that China will deem it more sensible to scrub emissions from coal-fired power stations rather than close them down. In the UK, the major health threat from fossil

fuels is particulates from diesel cars in particular. Yet the switch to diesel was encouraged precisely because diesel emits less carbon dioxide per mile than petrol. From the Stern Review onwards, the potential threat from carbon dioxide was assumed to be far graver than the dangers (well known even then) of particulates from diesel. The flexibility with which Lord Stern has adapted his evidence, changed his theoretical rationale, developed more vivid threats and harnessed health consequences unrelated to carbon dioxide is impressive. But all these changes have been directed to buttressing his pre-ordained commitment to a programme of largely decarbonizing the economy by 2050. Not all these changes made it explicitly into his most recent opus restating his view.¹⁴ Nonetheless, that so much buttressing has been required might have raised doubts about the solidity of his original Review. Unfortunately, successive British governments continue to base their policy on the Review with unwavering faith.

2 Sacrificing today's poor for tomorrow's rich

My original interest in Stern's work was its implications for developing countries. Given the extraordinary lengths he goes to justify his policy recommendations, I find his reluctance to respond to criticisms of their impact on poor people particularly depressing. Poor countries are more vulnerable to climate change – whether natural or man-made – because they are poor. The cure for poverty is growth, which requires energy. The cheapest form of energy at present is usually fossil fuels. Preventing or discouraging poor countries from using fossil fuels will slow their growth and prolong their poverty. On Stern's 'Business as usual' scenario (that is, with no fresh steps to reduce carbon dioxide emissions) developing countries will account for the bulk of growth in emissions as the poorest two-thirds of the world's population catch up with the most developed nations. So Stern's crash programme to limit emissions would involve major restraint by them even if developed countries decarbonise almost totally. Requiring poor countries to use renewables, which cost two or three times as much as fossil fuels, means they would be able to afford only a half or a third as much energy. That means remaining poor for longer and consequently more vulnerable to climate change (and all other natural hazards) for longer. And they would remain hungry longer. The Stern Review calculated that the biofuel target will require 10% of the world's arable land. But this would drive up food prices by more than the yield loss he expects if temperatures rise 4°C. Conceivably, poor countries would make these sacrifices if they were necessary to prevent their children and grandchildren being poorer still. But even in the worst case shown in the Stern Review, people in developing countries are still expected to be far better off a century or two ahead than now.¹⁵ In his worst case, the negative impacts – both economic and non-economic – of global warming are equivalent to a 37% loss¹⁶ of income per head relative to what

incomes would have been without any global warming. Nonetheless, people in developing countries are still expected to have average levels of wellbeing more than 6 times their current incomes by 2100 and 20 times by 2200, when their incomes will be two-thirds higher than incomes of people in the industrialised world today. So, even in Stern's worst case the higher incomes generated by harnessing energy from fossil fuels far outweigh the costs imposed on them by the resultant global warming. In short, he wants to sacrifice the wellbeing of poor people today to benefit their far better off descendants a century or two hence. This perverse result is the direct consequence of Stern's supposedly 'ethical' discount rate.

3 Stern's discount rate

Usually we discount the future using the market rate of return. There is a simple practical rationale for this. If £100 today could be invested safely to yield 5% it will be worth £105 in a year's time. So £105 in a year's time is worth £100 today. There is room for dispute about what the true rate of return actually is, not least given market interest rates at present.

Stern dismisses discounting at the market rate of return on three rather unconvincing grounds: that there are no long-term capital markets spanning centuries ahead; that capital markets are imperfect; and that the market rate reflects irrational and unethical views.

Instead he derives a rational and ethical rate of discount based on a paper by Ramsay published in 1928. But Stern ignores Ramsay's assumption that rational discounting will drive the market rate of return to converge with the theoretical rate of discount. As long as the two do diverge it is perfectly rational and ethical to take into account the market rate of return.

Ramsay argues that to discount future 'enjoyments' in comparison with current ones, just because they are the future (pure time preference) is irrational. On the other hand, he accepts that it is rational to put a lower value on a marginal change in our consumption the richer we are. Gaining or losing £100 matters less to us the higher our incomes. He also assumes that ethically we should put the same value on a change in consumption of other people, including future generations, as we would if it accrued to ourselves in identical circumstances. So if incomes are expected to rise (or fall) we should discount for that change.

Unfortunately, neither reason nor ethics can quantify by how much we should discount to reflect the decline in utility of a change in income as incomes rise. Stern adopts a value for this which implies that we should be prepared to sacrifice up to 10% of our current income to prevent a 10% decline in the level of income in future – however high future incomes may be. This convenient arithmetic drives his recommendation that this generation – billions of whom are poor – should make sacrifices

to ensure that future generations who will be far richer even after the impact of climate change should be protected from that impact.

Stern's conclusions follow logically from his rational, ethical, arithmetical and economic assumptions. But other equally ethical assumptions are available! Unfortunately, Stern seems to think he has a monopoly of ethics and denounces anyone who advocates using a higher/market rate. He asserts that they 'simply do not care much for what happens in the future beyond the next few decades'. In fact, if you attach an ethically high – that is, infinite – value on the continued existence of the human race it does not matter whether your discount rate is ethically low or not: this is the central and valid kernel of Weitzman's critique.

Most people who would be willing to make sacrifices to 'save humanity' would not want to sacrifice a bean to make future generations even richer. Unfortunately, the basic equation used by the Stern Review assumes that we should treat those richer and poorer than ourselves symmetrically. This makes the algebra simple. However, arguably, an asymmetric approach makes more ethical sense; in other words, we have a positive obligation to compensate those poorer than ourselves for the impact of global warming but no obligation to compensate those richer than ourselves. This is difficult to capture in a convenient mathematical formula. But our ethics should not be driven by algebraic convenience. There are other ethical systems that do not involve maximising utility across time and generations. A well-established alternative puts an obligation on each generation to pass on to its successors at least as much 'societal capital' as it inherited – above all, the accumulated learning coupled with the institutions of democracy and the market that will give our successors the opportunity to advance as we have done, at least materially. Moreover, using a discount rate that differs from the market rate of return has serious implications which he ignores. Given his claims to superior rationality, Stern should follow through the logical implications of his analysis. He fails to do so. Most serious, it means that he does not discount the true cost of investing in preventing global warming – which is the opportunity cost of capital – at the same rate as he discounts the benefits of these investments.¹⁷ If we invest £100 in reducing emissions, we hope to create a stream of future benefits from reduced climate change – but we do so at the expense of foregoing the stream of future dividends that £100 could have earned. Both the future benefits and the cost of dividends foregone should be discounted at the same rate. The US government puts the return on capital foregone at 7%; the UK assumes it is 3.5%. To someone who discounts the future at 1.4% pa a stream of dividends of £7 pa is worth £500 – not £100. Likewise, a stream of dividends of £3.5 pa is worth £250. By ignoring this, Stern potentially understates the cost of his programme by a factor of between 2½ and 5. He cannot have his cake and eat it. He cannot rationally use his 'ethical' low rate to discount future benefits of cutting emissions but implicitly use a market rate of interest to discount the cost of his programme. But that is what he

does.

4 Was Stern 'right for the wrong reasons'?

As mentioned above, Stern's conclusions were criticized by some economists as too high. Yet a loss of 5% or even 20% of GDP did not provide the apocalyptic scenario that would mobilise public opinion. So Stern and his supporters have increasingly fallen back on versions of the 'precautionary principle' – in particular Weitzman's 'Dismal Theorem'. This argues that if there is a finite risk, however small, of an infinite loss (like human extinction) then heroic efforts to prevent it are justified.

For greenhouse gases to unleash a catastrophe capable of destroying humankind the 'climate sensitivity' would have to be very high. Climate sensitivity is the amount by which the temperature would rise if atmospheric carbon dioxide doubled. In the past the IPCC said its best estimate was 3°C and somewhere in the range 1.5–4.5°C and recent estimates have been at or below the bottom of that range. Weitzman says that figures like 10°C or more would need to be possible to invoke his theorem.

The climate models on which Stern and others base their predictions incorporate values for climate sensitivity invariably in the conventional range and supposedly based on the certain laws of physics. Stern says 'The key conclusion, that the build-up of greenhouse gases in the atmosphere will lead to several degrees of warming, rests on the laws of physics and chemistry'.

To apply Weitzman's theorem, these assertions and faith in climate models must be discarded. Instead Weitzman relies on measurement based on empirical studies. Such estimates vary and have a range of uncertainty. The variance of estimates of climate sensitivity arises from natural variance in the climate system, poor model fit and measurement errors.

The larger these sources of uncertainty, the higher the probabilities that will be attributed to extreme values of climate sensitivity. Paradoxically, this means that the less well climate models fit the facts and the less well the facts validate 'the science' the models incorporate, the greater the probability that will be attributed to extreme climate sensitivity. Common sense suggests this is not a solid basis for spending trillions of pounds on mitigation policies. It would be better invested in efforts to bring models and theory into line with the facts.

It should be remembered that climate sensitivity is not a random variable; it is effectively a constant. It does not take one value today and another a few years hence. If climate sensitivity has a high value then it must have had a high value in the past and will have a high value in future.

Greenhouse gas concentrations are over half way to doubling since the industrial revolution. If the true value of climate sensitivity is, as Weitzman postulates, over 10°C for a doubling of carbon dioxide, we might have expected at least a 5°C rise in the

world's temperature by now. In fact, it has risen by barely 0.8°C over the last couple of centuries. That is only compatible with a climate sensitivity over 10°C if man-made warming has been obscured or offset by random or cyclical natural variations producing a cooling effect. But those factors should abate in due course. In which case, if the true value of the climate sensitivity is very high, that will manifest itself in rapid temperature increases relatively soon. This would give the world an early warning that strong measures are indeed needed in time to prevent further dramatic warming. But Weitzman's theorem is only applicable if we cannot learn the true value of climate sensitivity until it is too late. The most compelling evidence that climate sensitivity cannot be at catastrophic levels is, as Professor Lindzen points out, the fact that we are here. If the climate sensitivity is very high, the Earth's climate would have been so unstable over the last few billion years that life would at some point have been extinguished.

So Weitzman's theorem cannot be used to show Stern was right – even for the wrong reasons.

5 In conclusion

The Stern Review was a brilliant work of advocacy. It selected the methodology, facts and even ethical principles that supported a preconceived conclusion. It pleased those who were already convinced of the need for heroic measures to tackle global warming. But it evoked criticism from some economists that it exaggerated the costs of global warming and from some environmentalists that it presented no apocalyptic vision.

As a result, Stern has subsequently modified or abandoned his initial methodology; doubled his interest rate thus enormously reducing his original headline estimates of the cost of inaction; tightened his emissions target thereby doubling the cost of achieving it; adopted scarier visions of mass migration and conflict, which scarcely featured in the original report; and invoked health risks unrelated to carbon dioxide emissions. However, he continues to ignore the possibility of alternative pathways, higher emission targets, and greater reliance on adaptation. Changes on this scale should give pause for thought – especially as they all serve to buttress his original thesis or dramatise its message.

Moreover, Stern's conclusions still require undue sacrifices from today's poor to make wealthier future generations richer still and sacrifices from the UK which may prove futile if others do not emulate us.

It is time the government ceased to use the Stern Review to justify its climate change policy. They should commission a new and genuinely independent review.

Notes

1. What is wrong with Stern? The failings of the Stern Review of the Economics of Climate Change. Peter Lilley, GWPF Report 9, 2012.
2. IPCC, Climate Change 2007: Mitigation of Climate Change (Working Group III Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change). Cambridge, UK: Cambridge University Press, 2007, p. 18.
3. Apart from a powerful pre-emptive critique on the basis of Stern's draft documents, which also challenged Stern's use of the scientific evidence: *The Stern Review: A Dual Critique: The Science* Robert M. Carter, C. R. de Freitas, Indur M. Goklany, David Holland and Richard S. Lindzen; *Economic Aspects* Ian Byatt, Ian Castles, Indur M. Goklany, David Henderson, Nigel Lawson, Ross McKittrick, Julian Morris, Alan Peacock, Colin Robinson and Robert Skidelsky. *World Economics* Oct-Dec 2006.
4. Stern Review, p. xv.
5. The words 'at least' are also contentious. The body of the report shows that a 5% loss of GDP averaged over time is the mean for his base line case, not a minimum. The 95% probability range for this case is between an averaged loss of just 0.6% and 12.3% of GDP. Stern Review Table 6.1, p. 186.
6. Even the government does so. For example, the DECC Impact Assessment of the Climate Change Act quotes Stern as concluding that the cost of climate change if we do nothing 'is estimated at 5% to 20% of global GDP now and forever', omitting the words 'equivalent to'.
7. Stern Review Box 6.3, pp. 183–5.
8. Stern Review Figure 6.5c, p. 178
9. Stern has refused to debate face to face with prominent critics like Professor Tol, Professor Mendelsohn and Lord Lawson, and has never responded to *What is Wrong With Stern?*, except via Bob Ward.
10. In the report (p.10) he said 'The key conclusion, that the build-up of greenhouse gases in the atmosphere will lead to several degrees of warming, rests on the laws of physics and chemistry.'
11. '...with the benefit of hindsight, my inclination would be...a higher eta...there is a case for raising eta, although it remains true that many would see the implications of eta = 2 for intragenerational distribution as very egalitarian.' Stern, The economics of climate change, Ely Lecture, *American Economic Review: Papers & Proceedings*, 2008.
12. What is wrong with Stern? Op cit, p. 58.
13. Stern N. 'Time for a green revolution', *New Scientist*, 21 Jan 2009.
14. *Why are we Waiting?*, Nicholas Stern, MIT Press, 2015
15. What is Wrong with Stern? Op cit, Table 1, p. 23
16. Stern's estimate of the loss of well-being caused by climate change includes non-economic factors like environmental degradation and loss of bio-diversity which are not included in GDP.
17. Robert Mendelsohn 'A critique of the Stern Report', *Regulation*, Winter 2006/7.

Part II

Research in climate economics since the Stern Review

Richard Tol

About the author

Richard Tol is Professor of Economics at the University of Sussex and at the Vrije Universiteit, Amsterdam. He is one of the world's foremost experts on the economics of climate change. He is a member of the GWPF's Academic Advisory Council.

1 Introduction: the Stern Review

The Stern Review of the Economics of Climate Change¹ was written by a team of civil servants at HM Treasury, led by Sir Nicholas H. Stern. Few if any of the team members had a prior publication record in climate economics. The Stern Review was launched to worldwide publicity by Prime Minister Tony Blair and Chancellor of the Exchequer Gordon Brown in November 2006. Headlines focussed on Stern's estimates of the welfare impacts of anthropogenic climate change, which were high compared to previous studies and subsequent ones.^{2,3} The difference is by and large explained by Stern's choice of discount rate, which was not only unconventionally low but also at odds with HM Treasury guidelines⁴ for which he was responsible as head of the Government Economic Service. The discount rate used by Stern, a former Chief Economist at the World Bank, also sharply deviates from the then practice at that institution.⁵ The Stern Review was formally published some six months later,⁶ amended to include a sensitivity analysis for the discount rate.⁷ The Stern Review not only put the impacts of anthropogenic climate change higher than prior work, it also presented costs of climate policy that are lower than earlier estimates.⁸ Perhaps incongruently, the Stern Review concluded that the previously established long-term targets of the UK government and the European Commission needed no adjustment.

In June 2007, Sir Nicholas was appointed the I.G. Patel Professor of Economics and Government at the London School of Economics and Political Science, where in May 2008 he founded the Grantham Research Institute on Climate Change and the Environment, primarily funded by a charitable donation by the Grantham Foundation for the Protection of the Environment, and in September 2008 the Centre for Climate Change Economics and Policy (CCCEP), a joint centre with the University of Leeds, primarily funded by the Economic and Social Research Council.

In February 2016, Professor Stern, now Baron Stern of Brentford, published a paper in *Nature*,⁹ calling integrated assessment models 'grossly misleading', in that they 'underestimate seriously both the potential impacts of dangerous climate change and the wider benefits of a transition to low-carbon growth' while 'estimate[s of] the costs of climate-change mitigation [...] also suffer [...] from major shortcomings'.

Stern is certainly not the only economist who has serious misgivings about the state of climate economics. Professor Robert Pindyck of the Massachusetts Institute of Technology is another vocal critic.^{10,11} But whereas Pindyck's research had mostly focussed on methods of dynamic optimization under uncertainty, including applications to issues in energy and environment, in 2016 Stern had led one of the world's most well-endowed research programmes in climate economics for seven years – total funding for Stern's research centre exceeds £31 million. Where Pindyck is an outsider from a cognate subdiscipline looking in, Stern is an insider. Indeed, the 2016 Stern critique of the economics of anthropogenic climate change applies very much to the 2006 Stern Review.

2 Stern since the Stern Review

This begs the question what did Stern do between 2007 and 2016 with the many millions in research funding he acquired? Why does he complain about the state of research rather than brag about how he reshaped the field? I cannot answer the second question, although I note that the CCCEP appears to have inflated its research output.¹² I can have a look at the first question.

Note that the Grantham Institute aims 'to create a world-leading centre for policy-relevant research and training on climate change and the environment, bringing together international expertise on economics, finance, geography, the environment, international development and political economy.' In other words, its remit is much broader than research in economics. Nonetheless, as an economist working at a top research university, one would reasonably expect Stern to lead in economics research. Has he?

The Stern Review has certainly been visible. According to Scopus, it has been cited 6780 times (as at September 21, 2016). Of these, 1434 citations are in the economics literature, including prominent critiques¹³ and papers that reach opposite conclusions.^{14,15} Nick Stern has not rested on his laurels. He has published 30 papers since 2006, including eleven that are cited more than 10 times^{16–24} and one cited 322 times.²⁵

However, querying Scopus for 'London School of Economics', 'climate' and 'economics' returns only 89 papers published since 2006, and only 68 excluding Stern himself. Among the five most-cited,^{26–30} two^{27,30} are unrelated to Stern's research centre. One paper from Stern's centre was published in a top journal,³¹ as was another LSE paper unrelated to Stern.³² Seven papers were published in top field journals.^{28, 33–38} For such a large, well-endowed centre, that is a meagre harvest for ten years of research – and arguably none of these papers presents a breakthrough in how we view the economics of anthropogenic climate change; Stern's most-cited paper²⁵ is a summary of the Stern Review.⁶

3 Climate economics since the Stern Review

That said, things have changed in the subdiscipline of climate economics since the publication of the Stern Review. An immediate impact was that the debate on climate policy was reinvigorated. Professor Martin L. Weitzman of Harvard University declared that Stern was 'right for the wrong reasons'.³⁹ Weitzman argued that Stern's argument for a low discount rate was flawed, but that Stern's justification of stringent climate policy can be revived via considerations related to deep uncertainty.^{13, 40–44} Weitzman's striking result comes apart if his analysis is generalized to include mitigation policy³⁶ or the feedbacks of anthropogenic climate change on economic growth,⁴⁵

or if his constant relative risk aversion is replaced by more realistic hyperbolic absolute risk aversion.³⁶ Furthermore, project evaluation methods that are robust to large uncertainties do not recommend policies that are very different from cost–benefit analysis.⁴⁶

Shortly after the Stern Review, another prominent economist, Professor Hans-Werner Sinn of the Ludwig Maximilian University of Munich, published his *Green Paradox*,¹⁵ now cited 188 times. Sinn argues that attempts to reduce greenhouse gas emissions will increase emissions, as producers of fossil fuels are incentivized to exhaust their resources faster. Sinn’s intervention led to a renewed interest by resource economists in anthropogenic climate change, and a series of papers that push the mathematical sophistication of climate policy analyses.^{47–76} It also led to a new policy proposal: those concerned about anthropogenic climate change should buy up fossil fuel reserves.⁷⁷

Bard Harstad recently published another potentially seminal paper.⁷⁸ Economists were quick to point out that greenhouse gas emission reduction is a public good.^{79–84} The attractions of free-riding thus make international cooperation hard to achieve. Battagline and Harstad, however, point out that in a game of permanent and transient emission reductions, global cooperation is stable if the duration of treaties is negotiable but the domestic instrument mix is not.

While the Harstad paper is too fresh to assess its impact, another recent paper⁸⁵ has already left its mark, having been cited 39 times in its first two years. Golosov et al. build a relatively complex and complete model that can nonetheless be solved to yield an analytical solution to the social cost of carbon. While unrealistic, Golosov’s work does provide new insights into the key drivers of our concerns for anthropogenic climate change, and inspired a new line of research in climate economics,^{88–97} bringing renewed analytical rigour to the estimates of the social cost of carbon, the sufficient statistic for expressing concerns about anthropogenic climate change.⁹⁸ These new studies largely bypassed Stern and his team.

There was further change afoot. Unable to get a climate bill through Congress, the Obama administration stretched the Clean Air Act to amend energy efficiency and other technical standards. According to Executive Order 12866, this requires a regulatory cost–benefit analysis and hence an official price of carbon. This has led to an explosion of learned papers on what that price should be.⁹⁹ Although the US government did take advice from non-US academics – a rarity – Stern’s team was not represented.^{100–103}

Professor Michael Greenstone of the University of Chicago spearheaded an empirical revolution in environmental economics.^{104–107} Economics generally has seen a shift from theory to empirics, with new data sources becoming available and new econometric techniques being developed. Somewhat belatedly, environmental economics followed, with Greenstone not only introducing a new approach but also

opening up the top journals to research on the impacts of the environment and environmental policy on economic indicators. A number of other – often younger – economists were inspired by this, and published a series of empirical papers on the impacts of anthropogenic climate change^{108–130} and climate policy^{31,131–145}. Again, the involvement of Stern’s research team was minimal, particularly for the impact of anthropogenic climate change.

In summary, the economic study of climate change and climate policy has been transformed since 2006. Integrated assessment models have reached new levels of analytical sophistication, and a solid body of empirical research has emerged. However, the major changes in this field cannot be traced back to the publication of the Stern Review and the subsequent, substantial research grants to Stern. Although some new developments can be seen as a response to the Stern Review, the majority is independent of Stern’s work. Stern’s team have been followers in some of the changes in the profession, and leaders in none. In research terms, therefore, the Stern Review has a disappointing legacy.

Acknowledgements

David Henderson, Nigel Lawson, Nic Lewis, Peter Lilley and Gary Yohe had excellent comments on a previous version of this paper.

References

1. Stern, N.H., et al., *Stern Review: The Economics of Climate Change*. 2006, London: HM Treasury.
2. Arent, D., et al., 'Key economic sectors and services', in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, C.B. Field, et al., (eds). 2014, Cambridge: Cambridge University Press. p. 659–708.
3. Tol, R.S.J., 'The impacts of climate change according to the IPCC.' *Climate Change Economics*, 2016. **07**(01): 1640004.
4. Treasury, *The Green Book: Appraisal and Evaluation in Central Government*. 2003, HM Treasury: London.
5. Belli, P., et al., *Handbook on Economic Analysis of Investment Operations*. 1998, Washington, DC: World Bank.
6. Stern, N.H., et al., *Stern Review: The Economics of Climate Change*. 2007, Cambridge: Cambridge University Press.
7. Saltelli, A. and B. D'Hombres, 'Sensitivity analysis didn't help. A practitioner's critique of the Stern review.' *Global Environmental Change*, 2010. **20**(2): 298–302.
8. Barker, T., et al., 'Mitigation from a cross-sectoral perspective', in *Climate Change 2007: Mitigation – Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, B. Metz, et al., (eds). 2007, Cambridge: Cambridge University Press. p. 619–690.
9. Stern, N., 'Economics: Current climate models are grossly misleading.' *Nature*, 2016. **530**(7591): 407–409.
10. Pindyck, R.S., 'Climate change policy: What do the models tell us?' *Journal of Economic Literature*, 2013. **51**(3): 860–872.
11. Pindyck, R.S., 'The use and misuse of models for climate policy', Working Paper, 2015.
12. Rose, D., 'Exposed: How top university helped secure £9million of YOUR money by passing off rivals' research as its own...to bankroll climate change agenda', in *Mail on Sunday*, 23 October 2016.
13. Weitzman, M.L., 'On modelling and interpreting the economics of catastrophic climate change.' *Review of Economics and Statistics*, 2009. **91**(1): 1–19.
14. Tol, R.S.J., 'The economic effects of climate change.' *Journal of Economic Perspectives*, 2009. **23**(2): 29–51.

15. Sinn, H.W., 'Public policies against global warming: A supply side approach.' *International Tax and Public Finance*, 2008. **15**(4): 360–394.
16. Stern, N. and C. Taylor, 'Climate change: Risk, ethics, and the stern review.' *Science*, 2007. **317**(5835): 203–204.
17. Dietz, S. and N. Stern, 'Why economic analysis supports strong action on climate change: A response to the stern review's critics.' *Review of Environmental Economics and Policy*, 2008. **2**(1): 94–113.
18. Fankhauser, S., F. Sehleier, and N. Stern, 'Climate change, innovation and jobs.' *Climate Policy*, 2008. **8**(4): 421–429.
19. Hepburn, C. and N. Stern, 'A new global deal on climate change.' *Oxford Review of Economic Policy*, 2008. **24**(2): 259–279.
20. Bowen, A. and N. Stern, 'Environmental policy and the economic downturn.' *Oxford Review of Economic Policy*, 2010. **26**(2): 137–163.
21. Smith, L.A. and N. Stern, 'Uncertainty in science and its role in climate policy.' *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 2011. **369**(1956): 4818–4841.
22. Stern, N., 'The structure of economic modeling of the potential impacts of climate change: Grafting gross underestimation of risk onto already narrow science models.' *Journal of Economic Literature*, 2013. **51**(3): 838–859.
23. Stern, N., 'Ethics, equity and the economics of climate change paper 2: Economics and politics.' *Economics and Philosophy*, 2014. **760**.
24. Dietz, S. and N. Stern, 'Endogenous growth, convexity of damage and climate risk: How Nordhaus' framework supports deep cuts in carbon emissions.' *Economic Journal*, 2015. **125**(583): 574–620.
25. Stern, N.H., 'The economics of climate change.' *American Economic Review*, 2008. **98**(2): 1–37.
26. Falkner, R., H. Stephan, and J. Vogler, 'International climate policy after copenhagen: towards a 'building blocks' approach.' *Global Policy*, 2010. **1**(3): 252–262.
27. Pretty, J., et al., 'The top 100 questions of importance to the future of global agriculture.' *International Journal of Agricultural Sustainability*, 2010. **8**(4): 219–236.
28. Dechezleprêtre, A., et al., 'Invention and transfer of climate change-mitigation technologies: A global analysis.' *Review of Environmental Economics and Policy*, 2011. **5**(1): 109–130.
29. Di Falco, S., M. Veronesi, and M. Yesuf, 'Does adaptation to climate change provide food security? A micro-perspective from Ethiopia.' *American Journal of Agricultural Economics*, 2011. **93**(3): 825–842.

30. Dolan, P., et al., 'Influencing behaviour: The mindspace way.' *Journal of Economic Psychology*, 2012. **33**(1): 264–277.
31. Aghion, P., et al., 'Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry.' *Journal of Political Economy*, 2016. **124**(1): 1–51.
32. Martin, I.W.R. and R.S. Pindyck, 'Averting catastrophes: The strange economics of scylla and charybdis.' *American Economic Review*, 2015. **105**(10): 2947–2985.
33. Dietz, S. and G.B. Asheim, 'Climate policy under sustainable discounted utilitarianism.' *Journal of Environmental Economics and Management*, 2012. **63**(3): 321–335.
34. Martin, R., et al., 'Anatomy of a paradox: Management practices, organizational structure and energy efficiency.' *Journal of Environmental Economics and Management*, 2012. **63**(2): 208–223.
35. Dietz, S. and C. Hepburn, 'Benefit-cost analysis of non-marginal climate and energy projects.' *Energy Economics*, 2013. **40**: 61–71.
36. Millner, A., 'On welfare frameworks and catastrophic climate risks.' *Journal of Environmental Economics and Management*, 2013. **65**(2): 310–325.
37. Heal, G. and A. Millner, 'Uncertainty and decision making in climate change economics.' *Review of Environmental Economics and Policy*, 2014. **8**(1): 120–137.
38. Martin, R., L.B. de Preux, and U.J. Wagner, 'The impact of a carbon tax on manufacturing: Evidence from microdata.' *Journal of Public Economics*, 2014. **117**: 1–14.
39. Weitzman, M.L., 'A Review of the Stern Review on the Economics of Climate Change.' *Journal of Economic Literature*, 2007. **45**(3): 703–724.
40. Weitzman, M.L., 'Additive damages, fat-tailed climate dynamics, and uncertain discounting.' *Economics – the Open-Access, Open-Assessment E-Journal*, 2009. **3**(2009–39): 1–23.
41. Weitzman, M.L., 'GHG targets as insurance against catastrophic climate damages.' *Journal of Public Economic Theory*, 2012. **14**(2): 221–244.
42. Weitzman, M.L., 'A precautionary tale of uncertain tail fattening.' *Environmental and Resource Economics*, 2013. **55**(2): 159–173.
43. Weitzman, M.L., 'Tail-hedge discounting and the social cost of carbon.' *Journal of Economic Literature*, 2013. **51**(3): 873–882.
44. Weitzman, M.L., 'Fat tails and the social cost of carbon.' *American Economic Review*, 2014. **104**(5): 544–546.
45. Horowitz, J. and A. Lange, 'Cost-benefit analysis under uncertainty - A note on Weitzman's dismal theorem.' *Energy Economics*, 2014. **42**: 201–203.

46. Anthoff, D. and R.S.J. Tol, 'Climate policy under fat-tailed risk: An application of FUND.' *Annals of Operations Research*, 2014: 1–15.
47. Chakravorty, U., A. Leach, and M. Moreaux, 'Would hotelling kill the electric car?' *Journal of Environmental Economics and Management*, 2011. **61**(3): 281–296.
48. Eichner, T. and R. Pethig, 'Carbon leakage, the green paradox, and perfect future markets.' *International Economic Review*, 2011. **52**(3): 767–805.
49. Hoel, M., 'The supply side of CO2 with country heterogeneity.' *Scandinavian Journal of Economics*, 2011. **113**(4): 846–865.
50. Hoel, M., 'The green paradox and greenhouse gas reducing investments.' *International Review of Environmental and Resource Economics*, 2011. **5**(4): 353–379.
51. Benchekroun, H. and C. Withagen, 'On price taking behavior in a nonrenewable resource cartel-fringe game.' *Games and Economic Behavior*, 2012. **76**(2): 355–374.
52. Hassler, J. and P. Krusell, 'Economics and climate change: Integrated assessment in a multi-region world.' *Journal of the European Economic Association*, 2012. **10**(5): 974–1000.
53. Quentin Grafton, R., T. Kompas, and N. Van Long, 'Substitution between biofuels and fossil fuels: Is there a green paradox?' *Journal of Environmental Economics and Management*, 2012. **64**(3): 328–341.
54. Smulders, S., Y. Tsur, and A. Zemel, 'Announcing climate policy: Can a green paradox arise without scarcity?' *Journal of Environmental Economics and Management*, 2012. **64**(3): 364–376.
55. van der Ploeg, F. and C. Withagen, 'Is there really a green paradox?' *Journal of Environmental Economics and Management*, 2012. **64**(3): 342–363.
56. van der Ploeg, F. and C. Withagen, 'Too much coal, too little oil.' *Journal of Public Economics*, 2012. **96**(1–2): 62–77.
57. Van Der Werf, E. and C. Di Maria, 'Imperfect environmental policy and polluting emissions: The green paradox and beyond.' *International Review of Environmental and Resource Economics*, 2012. **6**(2): 153–194.
58. Eichner, T. and R. Pethig, 'Flattening the carbon extraction path in unilateral cost-effective action.' *Journal of Environmental Economics and Management*, 2013. **66**(2): 185–201.
59. Ploeg, F.V.D., 'Cumulative carbon emissions and the green paradox.' *Annual Review of Resource Economics*, 2013. **5**: 281–300.
60. Strand, J., 'Strategic climate policy with offsets and incomplete abatement: Carbon taxes versus cap-and-trade.' *Journal of Environmental Economics and Management*, 2013. **66**(2): 202–218.

61. Ulph, A. and D. Ulph, 'Optimal climate change policies when governments cannot commit.' *Environmental and Resource Economics*, 2013. **56**(2): 161–176.
62. Buchholz, W., R. Cornes, and D. Rübbelke, 'Potentially harmful international cooperation on global public good provision.' *Economica*, 2014. **81**(322): 205–223.
63. Di Maria, C., I. Lange, and E. van der Werf, 'Should we be worried about the green paradox? Announcement effects of the Acid Rain Program.' *European Economic Review*, 2014. **69**: 143–162.
64. Michielsen, T.O., 'Brown backstops versus the green paradox.' *Journal of Environmental Economics and Management*, 2014. **68**(1): 87–110.
65. Ritter, H. and M. Schopf, 'Unilateral climate policy: harmful or even disastrous?' *Environmental and Resource Economics*, 2014. **58**(1): 155–178.
66. Van Der Ploeg, F. and C. Withagen, 'Growth, renewables, and the optimal carbon tax.' *International Economic Review*, 2014. **55**(1): 283–311.
67. Jensen, S., et al., 'An introduction to the green paradox: The unintended consequences of climate policies.' *Review of Environmental Economics and Policy*, 2015. **9**(2): 246–265.
68. Sinn, H.W., 'The green paradox: A supply-side view of the climate problem.' *Review of Environmental Economics and Policy*, 2015. **9**(2): 239–245.
69. van der Meijden, G., F. van der Ploeg, and C. Withagen, 'International capital markets, oil producers and the Green Paradox.' *European Economic Review*, 2015. **76**: 275–297.
70. van der Ploeg, F. and C. Withageny, 'Global warming and the green paradox: A review of adverse effects of climate policies.' *Review of Environmental Economics and Policy*, 2015. **9**(2): 285–303.
71. van Long, N., 'The green paradox in open economies: Lessons from static and dynamic models.' *Review of Environmental Economics and Policy*, 2015. **9**(2): 266–284.
72. Harstad, B., 'The market for conservation and other hostages.' *Journal of Economic Theory*, 2016. **166**: 124–151.
73. Hart, R., 'Non-renewable resources in the long run.' *Journal of Economic Dynamics and Control*, 2016. **71**: 1–20.
74. Hassler, J. and H.W. Sinn, 'The fossil episode.' *Journal of Monetary Economics*, 2016. **83**: 14–26.
75. Nachtigall, D. and D. Rübbelke, 'The green paradox and learning-by-doing in the renewable energy sector.' *Resource and Energy Economics*, 2016. **43**: 74–92.

76. Strand, J., 'Mitigation incentives with climate finance and treaty options.' *Energy Economics*, 2016. **57**: 166–174.
77. Harstad, B., 'Buy coal! A case for supply-side environmental policy.' *Journal of Political Economy*, 2012. **120**(1): 77–115.
78. Battaglini, M. and B. Harstad, 'Participation and duration of environmental agreements.' *Journal of Political Economy*, 2015. **124**(1): 160–204.
79. Hoel, M., 'Global environmental problems: the effects of unilateral actions taken by one country.' *Journal of Environmental Economics and Management*, 1991. **20**: 55–70.
80. Carraro, C. and D. Siniscalco, 'The international dimension of environmental policy.' *European Economic Review*, 1992. **36**: 379–387.
81. Carraro, C. and D. Siniscalco, 'Strategies for the international protection of the environment.' *Journal of Public Economics*, 1993. **52**: 309–328.
82. Barrett, S., 'Self-enforcing international environmental agreements.' *Oxford Economic Papers*, 1994. **46**: 878–894.
83. Nordhaus, W.D. and Z. Yang, 'RICE: A regional dynamic general equilibrium model of optimal climate-change policy.' *American Economic Review*, 1996. **86**(4): 741–765.
84. Schelling, T.C., 'Some economics of global warming.' *American Economic Review*, 1992. **82**: 1–14.
85. Golosov, M., et al., 'Optimal taxes on fossil fuel in general equilibrium.' *Econometrica*, 2014. **82**(1): 41–88.
86. Van der Ploeg, F., 'Abrupt positive feedback and the social cost of carbon.' *European Economic Review*, 2014. **67**: 28–41.
87. Kagan, M., F. van der Ploeg, and C. Withagen, 'Battle for climate and scarcity rents: Beyond the linear-quadratic case.' *Dynamic Games and Applications*, 2015. **5**(4): 493–522.
88. Dennig, F., et al., 'Inequality, climate impacts on the future poor, and carbon prices.' *Proceedings of the National Academy of Sciences of the United States of America*, 2015. **112**(52): 15827–15832.
89. Bommier, A., B. Lanz, and S. Zuber, 'Models-as-usual for unusual risks? On the value of catastrophic climate change.' *Journal of Environmental Economics and Management*, 2015. **74**: 1–22.
90. Desmet, K. and E. Rossi-Hansberg, 'On the spatial economic impact of global warming.' *Journal of Urban Economics*, 2015. **88**: 16–37.
91. Engström, G. and J. Gars, 'Optimal taxation in the macroeconomics of climate change.' *Annual Review of Resource Economics*, 2015. **7**(1): 127–150.

92. Rezai, A. and F. van der Ploeg, 'Robustness of a simple rule for the social cost of carbon.' *Economics Letters*, 2015. **132**: 48–55.
93. van der Ploeg, F., 'Second-best carbon taxation in the global economy: The Green Paradox and carbon leakage revisited.' *Journal of Environmental Economics and Management*, 2016. **78**: 85–105.
94. van den Bijgaart, I., R. Gerlagh, and M. Liski, 'A simple formula for the social cost of carbon.' *Journal of Environmental Economics and Management*, 2016. **77**: 75–94.
95. Engström, G., 'Structural and climatic change.' *Structural Change and Economic Dynamics*, 2016. **37**: 62–74.
96. Acemoglu, D., et al., 'Transition to clean technology.' *Journal of Political Economy*, 2016. **124**(1): 52–104.
97. van der Ploeg, F., 'Untapped fossil fuel and the green paradox: a classroom calibration of the optimal carbon tax.' *Environmental Economics and Policy Studies*, 2015. **17**(2): 185–210.
98. Boehringer, C., A. Loeschel, and T.F. Rutherford, 'Decomposing the integrated assessment of climate change.' *Journal of Economic Dynamics Control*, 2007. **31**: 683–702.
99. Tol, R.S.J., 'Economic impacts of climate change', Working Paper, 2015, University of Sussex: Falmer.
100. Pizer, W., et al., 'Using and improving the social cost of carbon.' *Science*, 2014. **346**(6214): 1189–1190.
101. Greenstone, M., E. Kopits, and A. Wolverton, 'Developing a social cost of carbon for us regulatory analysis: A methodology and interpretation.' *Review of Environmental Economics and Policy*, 2013. **7**(1): 23–46.
102. Marron, D.B. and E.J. Toder, 'Tax policy issues in designing a carbon tax.' *American Economic Review*, 2014. **104**(5): 563–568.
103. Sunstein, C.R., 'On not revisiting official discount rates: Institutional inertia and the social cost of carbon.' *American Economic Review*, 2014. **104**(5): 547–551.
104. Chay, K.Y. and M. Greenstone, 'Does air quality matter? Evidence from the housing market.' *Journal of Political Economy*, 2005. **113**(2): 376–424.
105. Greenstone, M., 'Estimating regulation-induced substitution: The effect of the clean air act on water and ground pollution.' *American Economic Review*, 2003. **93**(2): 442–448.
106. Chay, K.Y. and M. Greenstone, 'The impact of air pollution on infant mortality: Evidence from geographic variation in pollution shocks induced by a recession.' *Quarterly Journal of Economics*, 2003. **118**(3): 1121–1167.

107. Greenstone, M., 'The impacts of environmental regulations on industrial activity: Evidence from the 1970 and 1977 Clean Air Act Amendments and the Census of Manufactures.' *Journal of Political Economy*, 2002. **110**(6): 1175–1219.
108. Deschênes, O., M. Greenstone, and J. Guryan, 'Climate change and birth weight.' *American Economic Review*, 2009. **99**(2): 211–217.
109. Deschênes, O. and M. Greenstone, 'Climate change, mortality, and adaptation: Evidence from annual fluctuations in weather in the US.' *American Economic Journal: Applied Economics*, 2011. **3**(4): 152–185.
110. Deschênes, O. and M. Greenstone, 'The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather.' *American Economic Review*, 2007. **97**(1): 354–385.
111. Dell, M., B.F. Jones, and B.A. Olken, 'What do we learn from the weather? The new climate-economy literature.' *Journal of Economic Literature*, 2014. **52**(3): 740–798.
112. Dell, M., B.F. Jones, and B.A. Olken, 'Temperature shocks and economic growth: Evidence from the last half century.' *American Economic Journal: Macroeconomics*, 2012. **4**(3): 66–95.
113. Dell, M., B.F. Jones, and B.A. Olken, 'Temperature and income: Reconciling new cross-sectional and panel estimates.' *American Economic Review*, 2009. **99**(2): 198–204.
114. Hsiang, S.M. and K.C. Meng, 'Tropical economics.' *American Economic Review*, 2015. **105**(5): 257–261.
115. Burke, M., S.M. Hsiang, and E. Miguel, 'Climate and conflict.' *Annual Review of Economics*, 2015. **7**(1): 577–617.
116. Hsiang, S.M. and A.S. Jina, 'Geography, depreciation, and growth.' *American Economic Review*, 2015. **105**(5): 252–256.
117. Burke, M., S.M. Hsiang, and E. Miguel, 'Global non-linear effect of temperature on economic production.' *Nature*, 2015. **527**(7577): 235–239.
118. Hsiang, S.M. and M. Burke, 'Climate, conflict, and social stability: What does the evidence say?' *Climatic Change*, 2014. **123**(1): 39–55.
119. Cane, M.A., et al., 'Temperature and violence.' *Nature Climate Change*, 2014. **4**(4): 234–235.
120. Hsiang, S.M., M. Burke, and E. Miguel, 'Quantifying the influence of climate on human conflict.' *Science*, 2013. **341**(6151).
121. Hsiang, S.M., 'Climate change and civil conflict: New clues from El Nino.' *Earth*, 2011. **56**(11): 70–71.

122. Hsiang, S.M., K.C. Meng, and M.A. Cane, 'Civil conflicts are associated with the global climate.' *Nature*, 2011. **476**(7361): 438–441.
123. Hsiang, S.M., 'Human at high temperatures: Reconsidering the economic implication of climate change.' *Earth*, 2011. **56**(2).
124. Hsiang, S.M., 'Temperatures and cyclones strongly associated with economic production in the Caribbean and Central America.' *Proceedings of the National Academy of Sciences of the United States of America*, 2010. **107**(35): 15367–15372.
125. Strobl, E., 'The economic growth impact of hurricanes: Evidence from U.S. coastal counties.' *Review of Economics and Statistics*, 2011. **93**(2): 575–589.
126. Barrios, S., L. Bertinelli, and E. Strobl, 'Trends in rainfall and economic growth in Africa: A neglected cause of the African growth tragedy.' *Review of Economics and Statistics*, 2010. **92**(2): 350–366.
127. Barrios, S., L. Bertinelli, and E. Strobl, 'Climatic change and rural-urban migration: The case of sub-Saharan Africa.' *Journal of Urban Economics*, 2006. **60**(3): 357–371.
128. Cragg, M.I. and M.E. Kahn, 'Climate consumption and climate pricing from 1940 to 1990.' *Regional Science and Urban Economics*, 1999. **29**(4): 519–539.
129. Kahn, M.E., 'The death toll from natural disasters: The role of income, geography, and institutions.' *Review of Economics and Statistics*, 2005. **87**(2): 271–284.
130. Boustan, L.P., M.E. Kahn, and P.W. Rhode, 'Moving to higher ground: Migration response to natural disasters in the early twentieth century.' *American Economic Review*, 2012. **102**(3): 238–244.
131. Martin, R., et al., 'Industry compensation under relocation risk: A firm-level analysis of the EU emissions trading scheme.' *American Economic Review*, 2014. **104**(8): 2482–2508.
132. Meng, K.C., 'Using a free permit rule to forecast the marginal abatement cost of proposed climate policy.' Working Paper, 2016, NBER.
133. Bel, G. and S. Joseph, 'Emission abatement: Untangling the impacts of the EU ETS and the economic crisis.' *Energy Economics*, 2015. **49**: 531–539.
134. Aichele, R. and G. Felbermayr, 'The effect of the kyoto protocol on carbon emissions.' *Journal of Policy Analysis and Management*, 2013. **32**(4): 731–757.
135. Leahy, E. and R.S.J. Tol, 'Greener homes: an ex-post estimate of the cost of carbon dioxide emission reduction using administrative micro-data from the Republic of Ireland.' *Environmental Economics and Policy Studies*, 2012. **14**(3): 219–239.
136. Commins, N., et al., 'Climate policy and corporate behaviour.' *Energy Journal*, 2011. **32**(4): 51–68.

137. Allcott, H. and D. Taubinsky, 'Evaluating behaviorally motivated policy: Experimental evidence from the lightbulb market.' *American Economic Review*, 2015. **105**(8): 2501–2538.
138. Allcott, H., C. Knittel, and D. Taubinsky, 'Tagging and targeting of energy efficiency subsidies.' *American Economic Review*, 2015. **105**(5): 187–191.
139. Allcott, H. and S. Mullainathan, 'Behavior and energy policy.' *Science*, 2010. **327**(5970): 1204–1205.
140. Allcott, H. and T. Rogers, 'The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation.' *American Economic Review*, 2014. **104**(10): 3003–3037.
141. Allcott, H., 'Social norms and energy conservation.' *Journal of Public Economics*, 2011. **95**(9–10): 1082–1095.
142. Kahn, M.E., N. Kok, and J.M. Quigley, 'Carbon emissions from the commercial building sector: The role of climate, quality, and incentives.' *Journal of Public Economics*, 2014. **113**: 1–12.
143. Rivers, N. and B. Schaufele, 'Salience of carbon taxes in the gasoline market.' *Journal of Environmental Economics and Management*, 2015. **74**: 23–36.
144. Costa, D.L. and M.E. Kahn, 'Energy conservation "nudges" and environmentalist ideology: Evidence from a randomized residential electricity field experiment.' *Journal of the European Economic Association*, 2013. **11**(3): 680–702.
145. Davis, L.W. and M.E. Kahn, 'International trade in used vehicles: the environmental consequences of NAFTA.' *American Economic Journal: Economic Policy*, 2010. **2**(4): 58–82.

GWPF BRIEFINGS

1	Andrew Turnbull	The Really Inconvenient Truth or 'It Ain't Necessarily So'
2	Philipp Mueller	The Greening of the Sahel
3	William Happer	The Truth about Greenhouse Gases
4	Gordon Hughes	The Impact of Wind Power on Household Energy Bills
5	Matt Ridley	The Perils of Confirmation Bias
6	Philipp Mueller	The Abundance of Fossil Fuels
7	Indur Goklany	Is Global Warming the Number One Threat to Humanity?
8	Andrew Montford	The Climate Model and the Public Purse
9	Philipp Mueller	UK Energy Security: Myth and Reality
10	Andrew Montford	Precipitation, Deluge and Flood
11	Susan Crockford	On the Beach
12	Madhav Khandekar	Floods and Droughts in the Indian Monsoon
13	Indur Goklany	Unhealthy Exaggeration
14	Susan Crockford	Twenty Reasons not to Worry about Polar Bears
15	Various	The Small Print
16	Susan Crockford	The Arctic Fallacy
17	Indur Goklany	The Many Benefits of Carbon Dioxide
18	Judith Curry	The Climate Debate in the USA
19	Indur Goklany	The Papal Academies' Broken Moral Compass
20	Donoughue and Forster	The Papal Encyclical: a Critical Christian Response
21	Andrew Montford	Parched Earth Policy: Drought, Heatwave and Conflict
22	David Campbell	The Paris Agreement and the Fifth Carbon Budget
23	Various	The Stern Review: Ten Years of Harm

The Global Warming Policy Foundation is an all-party and non-party think tank and a registered educational charity which, while openminded on the contested science of global warming, is deeply concerned about the costs and other implications of many of the policies currently being advocated.

Our main focus is to analyse global warming policies and their economic and other implications. Our aim is to provide the most robust and reliable economic analysis and advice. Above all we seek to inform the media, politicians and the public, in a newsworthy way, on the subject in general and on the misinformation to which they are all too frequently being subjected at the present time.

The key to the success of the GWPF is the trust and credibility that we have earned in the eyes of a growing number of policy makers, journalists and the interested public. The GWPF is funded overwhelmingly by voluntary donations from a number of private individuals and charitable trusts. In order to make clear its complete independence, it does not accept gifts from either energy companies or anyone with a significant interest in an energy company.

Views expressed in the publications of the Global Warming Policy Foundation are those of the authors, not those of the GWPF, its trustees, its Academic Advisory Council members or its directors.

Published by the Global Warming Policy Foundation

For further information about GWPF or a print copy of this report, please contact:

The Global Warming Policy Foundation
55 Tufton Street, London, SW1P 3QL
T 0207 3406038 M 07553 361717
www.thegwpf.org

Registered in England, No 6962749
Registered with the Charity Commission, No 1131448

