WORKSHOP PROCEEDINGS

Assessing the Benefits of Avoided Climate Change: Cost-Benefit Analysis and Beyond

The Economics of Climate Change Impacts: A Case Study on the Motivation for Government Decisions to Limit Greenhouse Gas Emissions

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Abstract

In the years since the adoption of the Kyoto Protocol, many developed countries and regional and state governments have begun taking more ambitious action on climate change by setting their own emission reduction goals and enacting a variety of greenhouse gas (GHG) emissions reduction policies. While many of these decisions have been based on a precautionary outlook to avoid dangerous climate change, policymakers are also evaluating the costs and benefits of emissions reductions at the global or domestic levels, and in some cases both.

This report reviews three case studies representing different government decisions: the United Kingdom, Australia, and the State of California. These governments used economics as motivation for the development of mitigation policies and have been among the leaders in adopting ambitious goals for GHG emissions reductions. They have also undertaken an extensive analysis of potential impacts and in some cases, have attempted to estimate some of the resulting global and local economic damages from climate change. While it appears that none of the governments undertook a formal benefit-cost analysis using the future benefits of avoided climate change to set its GHG reduction targets, the estimation of the benefits of avoided impacts may have played a role in justifying climate policies.

Introduction

Many governments at the national and sub-national levels have adopted greenhouse gas (GHG) emissions reductions targets. Information on climate change impacts has informed government level discussions on mitigation and has quite likely contributed to the adoption of a range of mitigation measures. For example, European Union (EU) countries such as The Netherlands, and U.S. states such as Washington and Massachusetts, have adopted mitigation measures with the aid of impact assessments. The motivation for adopting such targets has been to avoid the adverse impacts of climate change. For example, the EU has adopted a goal of limiting the increase in global mean temperature to 2°C above pre-industrial levels (EC, 2007). Even the U.S. Supreme Court has acknowledged that future impacts must be taken into account in policy decisions. They ruled in Massachusetts v. the U.S. Environmental Protection Agency (EPA) that EPA's refusal to regulate carbon dioxide (CO_2) has led to "actual" and "imminent" harm, mainly in the form of rising sea levels along the state's coast. The ruling also noted "the harms associated with climate change are serious and well recognized" (Pew, 2007).

As other governments such as the United States address national goals for GHG emissions, an important matter is whether it is necessary to quantify, and more specifically monetize, the impacts (oftentimes referred to as "damages") from climate change to justify emissions reductions. Such analysis can be used to compare monetary benefits of emissions reductions (i.e. value of avoided impacts) with the costs of emissions controls. As a result of the Supreme Court ruling, in June 2008, EPA's "Technical Support Document on Benefits of Reducing GHG Emissions" outlined key concepts and strategies for estimating the social cost of carbon values (Roberts and Spencer, 2008).

This report explores the economic motivating factors behind select governments actions. In particular, it will address whether estimates of total damages from climate change (and benefits from avoiding climate change) were developed and whether those estimates were used to or informed setting of GHG reduction goals or targets. This report reviews three case studies representing different government decisions: the United Kingdom (UK), Australia, and the State of California. It will explore how these governments used economics as motivation for the development of mitigation policies.

Climate agreements and policies have often not utilized economic analysis. The United Nations Framework Convention on Climate Change (UNFCCC) has been the centerpiece of global efforts to combat climate change. In 1997, the UNFCCC Conference of Parties agreed on the Kyoto Protocol. Under this protocol, industrialized countries agreed to reduce their collective GHG emissions by 5.2 percent compared to year 1990 levels by 2008 to 2012 (UNFCCC, 1997). Rather than formally measuring the costs and benefits of the targeted reduction, UNFCCC policymakers decided on what is known as a precautionary approach. The "precautionary principle" states that where there are threats of serious or irreversible damage, the lack of full scientific certainty should not be used as a reason for postponing

such measures, taking into account that policies and measures to deal with climate change should be cost-effective to ensure global benefits at the lowest possible cost (UNFCCC, 1992).

Although it did not recommend a level at which GHGs should be stabilized, the Intergovernmental Panel on Climate Change (IPCC) found that substantial reductions, well below those required under the Kyoto Protocol, would be required to avoid many adverse impacts of climate change. For example, the lowest stabilization level analyzed, a carbon dioxide equivalent (CO_2e) concentration level of 350 to 400 parts per million (ppm), would result in global temperatures 2 to 2.4°C above pre-industrial levels (the EU target), and would necessitate a 50 to 85 percent reduction in GHG emissions below 2000 levels by 2050 (IPCC, 2007a). The IPCC estimated that such reductions could be achieved at an annual cost of around 0.1 percent of gross domestic product (GDP). It did not estimate the value of avoided climate change impacts.

In the years since the adoption of the Kyoto Protocol, many developed countries and even regional and state governments have begun taking more ambitious action on climate change by setting their own goals above and beyond the Kyoto Protocol and enacting a variety of GHG emissions reduction policies. Indeed, many nations and sub-national governments have adopted the 2°C target. While many of these decisions have been based on a precautionary outlook to avoid dangerous climate change, policymakers are also evaluating the costs and benefits of emissions reductions at the global or domestic levels, and in some cases both. This report analyzes the motivations for such action by a few governments: the UK, Australia, and California. These governments have been among the leaders in adopting ambitious goals for GHG emissions reductions. They have also undertaken an extensive analysis of potential impacts and in some cases, have attempted to estimate some of the resulting global and local economic damages from climate change. These impacts include among others; increased droughts, a rise in sea levels, and an increase in heat-related illness and disease. The economic damages include changes in energy demand, reduced agriculture output, and increased infrastructure damage and health care costs, among many other economic costs. This report examines the analyses done and attempts to assess whether and to what degree economic analysis of climate change impacts influenced the selection of mitigation targets.

Climate Change Economics: Measuring the Costs and Benefits

This section briefly explains some concepts that some readers may find useful in understanding this report. A key component of estimating future costs of climate change are impact assessments. Impact assessments are detailed estimations of the consequences of future climate change and sea level rise on ecosystems, water resources, agriculture and food security, human health, coastal, and other sectors. Outputs from models of the estimated climate impacts can be entered into socioeconomic models (integrated

assessment models[1]) which link climate, impacts and economic costs into an integrated system to estimate the economic effects of these impacts (Roberts and Spencer, 2008). National studies can also utilize impact studies combined with general circulation models (GCM) to estimate regional or national market impacts. The results of these models can help analysts estimate economic losses. Using some of these concepts and tools, governments such as the UK, Australia, and California have helped establish that climate mitigation is vital to the long-term health of its economies.

Estimations of economic losses from climate change typically include more than financial impacts. Climate change losses include financial (market) impacts such as increases in crop prices, costs of building sea walls, and the value of inundated coastal lands. But, a number assessments of climate change losses (e.g., Nordhaus and Boyer, 2000; Tol, 2002) include estimates of so-called "non-market impacts" such as loss of ecosystems and non-market values of human life. Some of these assessment also include insurance values that describe how much we are willing to pay to avoid a small probability of a highly damaging or possibly catastrophic outcome (Garnaut, 2008). Non-market impacts affect ecosystems or human welfare, but are not easily expressed in monetary terms (IPCC, 2007). These non-market impacts are typically combined with financial or market impacts to estimate total economic impacts. The total values are often compared to GDP, even though a significant portion of the total damages would not be seen in typical GDP accounts.

Besides estimating the value of total damages, another tool for expressing climate change damages that has been widely employed is estimating the damages from emissions of ton of carbon. The "right" price of carbon is often called the "social cost of carbon" (SCC), which can be interpreted as a measure of the marginal damages from emission of an additional ton of carbon. Conversely, it can be thought of as the benefit of avoiding emission of a marginal ton of carbon. In other words, the SCC signals what society should be willing to pay now in order to avoid future damages caused by incremental CO_2e emissions (DEFRA, 2007). One of the many complex issues that face decision-makers is that the costs of mitigation come much earlier than the benefits of avoided climate change. Economists consider a dollar in future years to be less than a dollar today, because a dollar today can be invested and grow over time. Future damages from climate change are reduced (in present value) the further into the future they occur (DEFRA, 2007).[2]

Another important issue is that the impacts of climate change are unlikely to be evenly distributed, either between regions or between income groups. A loss of income among poor people or in poor countries will be more harmful than the same loss of income among wealthier individuals or countries (Garnaut, 2008). To address this, economists use an approach called equity weighting, which gives more weight to impacts on poorer countries and individuals. The application of equity weighting can dramatically affect SCC values.

[1] See the paper by Mastrandrea in this volume for an overview.

[2] Note that there is substantial controversy over what discount rates are appropriate to use for inter- generational consequences of greenhouse gas emissions (Newell & Pizer, 2003).

Applying appropriate discount rates and equity weighting techniques is a complex and highly debated topic. Different choices of these rates can result in widely varying estimates of SCC (Watkiss and Downing, 2008).

The following case studies examine how some prominent governments have attempted to measure the costs and benefits of mitigating climate change. While these governments did not perform a formal environmental benefit-cost analysis, they did try to estimate the costs of climate impacts, and could use these estimates as motivation or justification to pass climate legislation or announce emissions reduction targets.

Case Study 1: United Kingdom

Overview

The UK has for the last decade been a global leader in developing an understanding of the costs and risks of climate change by sponsoring leading research into both mitigation and adaptation. Examples include the implementation of an official Social Cost of Carbon in 2002 (GES, 2002), the recent government-commissioned Stern Review on the Economics of Climate Change (Stern, 2006), and the research of the UK Climate Impacts Programme (which started in 1997), which brings together the scientific evidence for climate change impacts and adaptation in the UK. The UK has taken several steps to measure benefits and costs that could justify its stated climate targets.

The Department for Environment, Food and Rural Affairs (DEFRA) published its first national assessment of the possible impacts of climate change on the UK, the Climate Change Impacts Review Group (CCIRG) report in 1991, followed by a second CCIRG report in 1996 (CCRIG, 1996). The UK signed the Kyoto Protocol in the spring of 1998, with formal ratification in 2002. The UK's target of GHG emissions reductions under the agreement was a 12.5 percent reduction by 2008-2012 compared to 1990 levels (DEFRA, 2007). This commitment led to the development of the UK's first national Climate Change Programme in November 2000. The program identified both the risks associated with climate change, and also a range of policy measures and initiatives. These included innovative new policy measures, a climate change levy (a tax on electricity), c**limate change agreements with industry,** and a UK emissions trading scheme. Climate change also played a major role in shaping the influential 2003 Energy White Paper, which proposed a 60 percent reduction of CO_2 emissions relative to 1990 levels by 2050 (UK, 2003).

In November 2008, the UK passed the Climate Change Act 2008, which created the world's first long-term, legally binding framework to reduce GHG emissions to at least 80 percent by 2050 (DEFRA, 2008) and at least a 26 percent reduction in CO_2 by 2020 – with the 2020 target to be updated following advice from the Climate Change Committee (CCC), an independent body set up as part of the Act. The CCC has recommended two sets of carbon budgets: the **Intended budget,** which will apply following a new global deal on climate change; and the **Interim budget**, which will apply before a global deal is reached. As

proposed by the CCC, the Intended budget would require an emissions reduction of 42 percent in 2020 relative to 1990, and the **Interim budget** would require an emissions reduction of 34 percent in 2020 relative to 1990 (CCC, 2008a). These targets link to the recently adopted European Commission 2020 target of at least a 20 percent reduction in GHG emissions by 2020 on 1990 levels – rising to 30 percent if there is an international agreement, and the UK's potential split of this target under the burden sharing agreement. The UK Government is currently reviewing the CCC advice, and announce proposals for the level of the first three carbon budgets (2008-12, 2013-17 and 2018-22) in the Spring of 2009.

Studies of Climate Change Impacts and Economic Costs

A number of studies of climate change impacts have been undertaken to help understand how the UK will be affected by climate change. A qualitative impact study has also been completed for each region in the UK, and a number of quantitative and economic sector-specific studies have been undertaken as well. There has been one cross-sectoral analysis of the economic impacts in the UK (Metroeconomica, 2006). The UK Climate Impacts Programme produced guidelines that describe a methodology for calculating the costs of climate impacts and explains how to compare these to the costs of adaptation measures (UKCIP, 2004).

The Stern review is the one of the more comprehensive reviews on the economic costs of climate change. Although the review took a global outlook, it has been very influential in UK policy since its publication in 2006. The review made use of many impact studies and estimates that the cost of inaction on climate change significantly outweighs the projected cost of coordinated global action, contingent on the specific assumptions it made. The review predicts that the value of the damages from unmitigated climate change could be significantly more (up to 5 to 20 percent of GDP) than the global cost of action to stabilize atmospheric concentrations of GHGs at 550 ppm CO_2e (Stern, 2006).

The review considered the economic costs of the impacts of climate change for business-as-usual growth and the costs and benefits of action to reduce the emissions of GHGs, but it does not look at the benefits (in economic) terms of mitigation. It is important to note that there are still residual costs as a result of mitigation, (Stern, 2006):

- It considered physical impacts of climate change on the economy, human life, and the environment, and examines the resource costs of different technologies and strategies to reduce GHG emissions
- It included integrated assessment models that estimate the economic impacts of climate change, and macro-economic models that represent the costs and effects of the transition to low-carbon energy systems for the economy as a whole
- The review used comparisons of the current level and future trajectories of SCC with estimated marginal abatement cost.

One controversial aspect of the Stern Report was its use of a low discount rate. Many experts argue that the review adopted a global rather than a national perspective, with substantial aversion to risk, and consideration of intertemporal and geographical equity (Watkiss and Downing, 2008). Therefore, a lower discount rate and equity weighting was used than most UK estimates, resulting in a relatively high estimate of damages. The use of such a low discount rate has been criticized by a number of economists (e.g., Yohe, 2006; Nordhaus, 2007).

Using an integrated assessment model, Stern estimated the cost of business-as-usual climate change to equate to an average reduction in global per-capita consumption of 5 percent at a minimum. Stern estimated economic and non-economic (non-market) costs, and also discontinuities into its analysis. It estimated that the potential scale of the climate response could increase the cost of climate change from 5 to 7 percent, and non-market costs could increases the total cost of unmitigated climate change from 5 to 11 percent (Stern, 2006). The review also describes how many important effects are omitted from the analysis because of uncertainty. Cost estimates would increase if the analysis incorporated effects such as distributional impacts, dynamic feedbacks, and social contingent impacts.

The Stern review also influenced the Social Cost of Carbon used in UK government. In 2002, the UK Government (GES, 2002) recommended an illustrative marginal global SCC estimate, based on the economic literature at that time, for use in policy appraisal across Government (an illustrative marginal global SCC estimate of £70[3]/tonne of carbon (tC), within a range of £35 to £140/tC, rising at £1/tC per year from the year 2000). These SCC values have been used widely in regulatory impact appraisal and in the consideration of environmental taxes and charges, though it was not used to set medium or long-term greenhouse gas emission targets. The results of the Stern review were used to update this value. . The Stern review arrived at a value for the SCC (at £60/tCO_2 or £218/tC) that was several times the existing UK SCC and the wider literature, even though the Stern analysis uses many of the same models and damage functions.

However, a further modification was made to the Stern SCC value before implementation. The UK Government (DEFRA) modified the Stern estimate into an official shadow price of carbon (SPC) by using a Stern SCC estimate that assumes the recommended Stern emissions stabilization trajectory, based on a 550 ppm CO_2e future (DEFRA, 2007). This reduces the SCC value to £30/tCO_2 for a current emission[4]. This differs from a traditional shadow price, which usually is determined by the intersection of marginal damages and marginal abatement costs (FOE, 2008). While the SCC is purely a measure of the damage caused by carbon and the manner in which this is valued, the SPC is regarded by DEFRA as a more versatile concept which can be adjusted over time to take into account policy development and technological advancement (DEFRA, 2007). Government ministers must

[3] £70 = $100.23. 1 GBP = 1.43 (2-26-09) http://finance.yahoo.com/q?s=GBPUSD=X.

[4] The Stern SCC value for a 550ppm CO2e target (£30/tCO_2) was updated for a 2007 emission, expressed in 2007 prices, to £25/tCO_2e.

factor a carbon price when making all policy and investment decisions covering transport, construction, housing, planning, and energy (Wintour, 2007). The UK Treasury's "Green Book" guidance adopts the SPC as the basis for incorporating carbon emissions in project level benefit-cost analysis and regulatory impact assessments (PWA, 2008).

Analysis of Mitigation Policies

"The Impact Assessment of the Climate Change Bill," published in 2007, contains a high-level discussion of the costs and benefits of UK action to mitigate climate change to a degree consistent with the government's established medium and long-term objectives, along with an analysis of the key drivers and uncertainties surrounding these assessments (UK, 2007). The assessment draws on a range of different modeling results applicable to both the UK economy and draws on analogous mitigation cost studies in other developed countries. The impact assessment includes research undertaken as part of the Stern review, together with analysis conducted for the 2007 Energy White Paper (UK, 2007).

The recently passed Climate Change Act requires that emissions be reduced by at least 80 percent by 2050, compared to 1990 levels (DEFRA, 2008). In meeting these requirements, the government focused on GDP impacts of the carbon budgets, which was estimated using three alternative models (resource cost, macroeconometric, and general equilibrium). The government used the MARKAL-Macro model, which focuses on long-run mitigation costs of meeting the 2050 target, as well as a study conducted by Oxford Economics to explore the potential short-run adjustment costs of meeting a 2020 target (DEFRA, 2007).

After reviewing the economic impacts of climate change, the Stern review analyzed the costs of mitigation options. The review's analysis found that the costs for stabilization at 500-550 ppm CO_2e were centered on 1 percent of GDP by 2050, with a range of plus or minus 3 percent around the central estimate. To put into context, global GDP is projected to be around $100 trillion by 2050, thus annual costs would approach $1 trillion (Stern, 2006). The range reflects a number of factors, including the pace of technological innovation and the efficiency with which policy is applied across the globe (Stern, 2006). The estimates do not take co-benefits into account, for example, in terms of reduced ill health and environmental damage from reduced air pollution levels and increased energy security. The review estimated that meeting the stabilization targets would reduce the percentage loss of climate change impacts to 0.6 percent of global GDP. The Stern report uses its estimates of avoided damages resulting from climate change mitigation and weighs them against the costs, and concludes that the costs of inaction would likely be much more significant in terms of damage to the world economy (Stern, 2006).

The UK's Decision Process

A review of UK policies over the past decade have found several occasions where the government used a SCC in regulatory impact appraisal and in the consideration of environmental taxes and charges. The UK's most recent white paper analysis of the Climate

Change Act goals considered the SCC in the analysis of the necessary short-term steps toward an 80 percent reduction, but the value was not used explicitly in the benefit-cost analysis of the long-term goal (PWA, 2008). Stern's economic analysis is often credited as a key motivation behind such an ambitious mitigation target, but in fact, an earlier 60 percent long-term target (consistent with a 2 degrees target) preceded the Stern review by some years, and there were already moves to consider updating the target, due changes in the science (i.e. that a 60 percent reduction would not achieve the previous 2 degrees ambition level; IPCC, 2007c). While it compares the costs of inaction against the cost of taking action and does not include specific estimates of avoided damages, the real justification for action is focused on a multi-attribute analysis that shows stabilization levels and probability ranges for temperature increases. Yet, as stated by Ed Miliband, Secretary of State at the Department of Energy and Climate Change, "The reductions required can be achieved at a very low cost to our economy: the cost of not achieving the reductions, at national and global level, will be far greater" (CCC, 2008b).

Case Study 2: Australia

Overview

The IPCC report, "Climate Change 2007: Impacts, Adaptation, and Vulnerability" (IPCC, 2007b), finds that Australia is one of the most vulnerable of all industrialized countries to the impacts of climate change. This reflects Australia's already variable and semi-arid climate, poor soils, vulnerable ecosystems, and a high proportion of the population living in coastal areas. A comprehensive economic analysis of the impacts of climate change was commissioned by the government, known as the Garnaut Climate Change Review (Garnaut, 2008). The review focused on economic impacts on Australia, but also included global impacts, compared to the Stern review, which took a solely global outlook. The review was highly influential in the Australian government's most recent climate reduction target.

While the Australian government has not been as active on climate issues as the UK, it has recognized the importance of impacts and adaptation with the establishment in 2004 of a National Climate Change Adaptation Program. This program prepares all areas of government, vulnerable industries, communities, and ecosystems to manage the consequences of climate change. The Adaptation Program is closely linked with the Department of Climate Change, established in 2007, which improves the scientific understanding of the causes, nature, timing, and consequences of climate change to better inform industry and government decision-makers. Based on the Garnaut review, Treasury modeling, and previous climate impacts research, the Australian government has endorsed a carbon emissions reduction target of 15 percent by 2020, following the introduction of a carbon trading scheme in 2010. A more ambitious 25 percent reduction target would be kept open as a possibility if the international community agrees to ambitious targets at a United Nations Summit in Copenhagen at the end of 2009 (Reuters, 2008).

Studies of Climate Change Impacts and Economic Costs

In an attempt to measure the costs of climate change, Australia produced "*Climate Change: An Australian Guide to the Science and Potential Impacts"* in 2003 (Australia Office of Climate Change, 2003). The analysis found that climate change is projected to increase the severity and frequency of many natural disasters, such as bushfires, cyclones, hailstorms, and floods. Insured losses from these events are estimated to total billions of dollars (Australia Office of Climate Change, 2003). An update to the analysis also identified the following potential effects and costs of climate change to Australia's economy (Australia Office of Climate Change, 2008):

- The drought that began in 2002 was estimated to cut growth in the country's GDP by 0.7 percent in 2007. Restrictions on water use in Australian cities resulting from the current drought have cost around $900 million a year and affected over 80 percent of Australia's households.
- The frequency of drought may increase by up to 20 percent over most of Australia by 2030, and up to 40 percent in southeast Australia and 80 percent in southwest Australia by 2070.
- Water flows into the Murray-Darling Basin, already stressed, are estimated to decline by 15 percent if the temperature warms by 1°C. Reductions in flows of around 50 percent are possible by the end of the century. Irrigated agriculture in the Murray-Darling Basin could decline by up to 92 percent.
- If the temperature rises by 2°C, national livestock carrying capacity is projected to decrease by 40 percent.
- Changes in temperatures and rainfall are projected to increase road maintenance costs by 31 percent by 2100.

In 2004, Australia released "Economic Issues Relevant to Costing Climate Change Impacts" (Australian Greenhouse Office, 2004), which identifies sectors of the Australian economy that are particularly vulnerable to climate change, and estimates the costs of climate change for some of these sectors. The sectors reviewed include agriculture, biodiversity (which includes national reserves, species diversity, and ecosystems), coasts (which includes fisheries, marine life, the Great Barrier Reef, and coastal infrastructure), forests (which includes natural and plantation forests), settlements (which includes infrastructure, local government, planning, human health, transport, energy, and emergency services), and water (which includes drought, water quality, and water supplies) (Australian Greenhouse Office, 2004).

Building upon previous impacts studies, the Garnaut Climate Change Review was an independent study commissioned by Australia's Commonwealth, and state and territory governments. The review examined the impacts of climate change on the Australian economy, and recommended medium- to long-term policies and policy frameworks to

improve the prospects for economic growth. To test the case for action, the review compared a scenario of no mitigation (or business-as-usual) and a scenario of a 550 ppm future, and compared the costs of mitigation of climate change with the benefits of avoiding climate change (Garnaut, 2008). The report estimated that the global gross national product (GNP) would fall by around 8 percent by 2100, with losses in developing countries likely to be higher than the global average. Among the impacts for Australia that the review estimated were that unmitigated climate change causes real wages to be around 12 percent lower than they would otherwise have been. The largest impacts were found in agriculture and mining. Garnaut found that the effects of climate change on infrastructure that have not been estimated could subtract an additional 0.8 percentage points from the GNP by the end of the century. These negative impacts on infrastructure have a significant effect on Australia's output and consumption of goods and services, and are responsible for about 40 percent of total climate change costs. The infrastructure impacts affect a wide range of assets, including commercial and residential buildings, water supply and electricity infrastructure, and ports (Garnaut, 2008). Garnaut did not measure the non-market impacts and insurance values, but states that these effects will be very significant in a no mitigation future.

The review recommended that Australia push internationally for CO_2e concentrations of 450 ppm, which would commit Australia to reductions of 25 percent on 2000 levels by 2020, and 90 percent by 2050. It also recommended that Australia have a fallback position of 550 CO_2e concentrations, which would entail a 10 percent reduction in emissions by 2020, and an 80 percent reduction by 2050 (Garnaut, 2008). Garnaut further recommended that, should all negotiations collapse at the Copenhagen Summit, Australia should still reduce its emissions by 5 percent by 2020 on 2000 levels.

Analysis of Mitigation Policies

The Australian Treasury Department published "*Australia's Low Pollution Future: The Economics of Climate Change Mitigation" in 2008, which* presents the results of economic modeling of the potential economic impacts of reducing emissions over the medium- and long-term (Treasury of Australia, 2008). The report found that early global action is less expensive than later action. The modeling indicates that economies that act early face lower long-term costs; around 15 percent lower than if the country delays action until there is international agreement. The report also concluded that average annual GNP growth will only be one-tenth of 1 percent per year less than it would be in a world without action to tackle climate change (Treasury of Australia, 2008).

National emissions targets are based on the per capita allocation approach developed by the Garnaut Climate Change Review. Australia's emissions reduction targets in these scenarios are 10 percent below 2000 levels by 2020 and 80 percent below by 2050 for stabilization at 550 ppm. The targets are 25 percent below 2000 levels by 2020 and 90 percent below by 2050 for stabilization at 450 ppm (Treasury of Australia, 2008). The

modeling does not include the economic impacts of climate change itself, so does not assess the benefits of reducing climate change risks through mitigation. Yet the report concludes that average annual GNP growth will only be 0.1 percent per year less than it would be in a world without action to mitigate climate change. The report shows that from 2010 to 2050, real GNP per capita grows at an average annual rate of 1.1 percent in the policy (GHG reduction) scenarios, compared to 1.2 percent in the reference scenario. It states that taking early action will allow an orderly and gradual adjustment to a low-carbon economy, while choosing to delaying action, and then playing catch up, will deliver a sharper shock to the economy in the future (Treasury of Australia, 2008).

The Garnaut review analyzes the three scenarios: the no mitigation scenario, in which the world does not attempt to reduce GHG emissions; and the 550 and 450 ppm scenarios, which represent global efforts to reduce emissions sufficiently to reach those CO_2 concentration levels. The review's economic modeling focused on five areas of impact: primary production, human health, infrastructure, cyclones, and international trade. Climate change shocks were imposed on each area to estimate the likely market costs of climate change (Garnaut, 2008). Expected climate change damages are less in the 450 scenario than in the 550 scenario, but only by half a percent of GNP. The small expected market gain from the 450 scenario to 2100 is not in itself adequate to justify the additional mitigation costs associated with it. Rather, the report states that stronger mitigation is justified by insurance value and non-market value benefits in the 21st century, and much larger benefits beyond, and that the costs of action are less than the costs of inaction (Garnaut, 2008).

The review concludes that there likely will be more technological progress than currently anticipated assuming a significant and rising carbon price, support for the emergence of low emissions technologies, and new policies, such as an emissions trading scheme, are permanent. Such developments would favor a 450 ppm outcome over a 550 ppm outcome. Given the benefits after the year 2200 of stronger mitigation and the greater risks of catastrophic consequences to the natural environment under the 550 ppm scenario, the review judges that it is worth paying less than an additional 1 percent of GNP as a premium in order to achieve a 450 ppm result (Garnaut, 2008).

Australia's Decision Process

While Australia has not utilized a diverse range of economic tools as compared to the UK, the Garnaut review is one of the first of its kind to detail the economics of climate change at a country-specific level. Australia's Minister of Climate Change and Water, Senator Penny Wong, stated that the review, "… shows that while there will be some unavoidable costs from climate change, the costs of taking action to reduce carbon pollution are less than the costs that would be incurred if we fail to act" (Australia, 2008b). The Australian government weighed both the Garnaut review and the Treasury's report on mitigation costs before deciding on a 15 percent reduction by 2020. Senator Wong has also stated

that, "the Treasury's modeling demonstrates that early global action is less expensive than later action; that a market-based approach allows robust economic growth into the future even as emissions fall; and that many of Australia's industries will maintain or improve their competitiveness as the world moves to reduce carbon pollution" (Australia, 2008a). While the review found that a target of 25 percent reduction was economically feasible, the risks of international competition have kept the government from initially endorsing such a goal. Both the government and Dr. Garnaut have stated that the reduction targets should be increased to 25 percent with a new global agreement in 2009 (Taylor, 2008). If the world cannot agree on Australia's goals, Dr. Garnaut stated that the country should still aim to cut emissions by 10 percent by 2020, or 5 percent at an absolute minimum (Sydney Morning Herald, 2008).

Case Study 3: California

Overview

California has been at the forefront of climate change research and policy in the United States. In 2007, the California Air Resources Board (ARB) adopted GHG emissions limits as a result of the Global Warming Solutions Act of 2006 (AB32). AB32 establishes the first comprehensive program of regulatory and market mechanisms to achieve quantifiable reductions in GHG emissions in the United States. The law sets an economy-wide cap on California GHG emissions at 1990 levels by no later than 2020. This goal represents approximately an 11 percent reduction from current emissions levels and nearly a 30 percent reduction from projected business-as-usual levels in 2020 (California, 2008a).

Studies of Climate Change Impacts and Economic Costs

The Energy Commission's Public Interest Energy Research (PIER) Program published "Global Climate Change and California: Potential Implications for Ecosystems, Health, and the Economy," in 2003 (PIER, 2003a). The report contains a detailed study on the potential effect of climate change on the California economy. The study examines potentially affected sectors and the interactions between climate change and increased population, and economic and technological growth. It considers a wide range of climate change scenarios, varying among temperature and precipitation. Some economic impacts were projected, though many believe these impacts were underestimated. A review of the 2003 study was conducted and discussed the strengths and weaknesses of the PIER 2003 study. The review recommended that the findings be viewed not as specific predictions, but rather as a sensitivity analysis that considers a range of potential outcomes (PIER, 2003b).

In addition, a paper in the Proceedings of the National Academy Sciences (PNAS) released after the 2003 PIER study was considered to be very influential in California's decision making process. "Emissions Pathways, Climate Change, and Impacts on California", showed that the level of impacts gets worse with increased global GHG emissions. The study shows the implications and associated impacts in California of the highest and lowest IPCC

emissions pathways for climate change (Hayhoe et al., 2004). Under the high emissions scenario, heatwaves in Los Angeles are six to eight times more frequent, with heat-related excess mortality increasing five to seven times. Alpine and subalpine forests are reduced by 75–90 percent. Finally, snowpack declines 73–90 percent, with cascading impacts on runoff and streamflow that, combined with projected modest declines in winter precipitation, could fundamentally disrupt California's water rights system times. While the study did not estimate economic impacts, it has been used as motivation for climate policies that avoid the largest impacts of the high emission scenario (Hayhoe et al., 2004).

Building upon the work of the PNAS study, the 2006 impacts assessment report, "**Our Changing Climate: Assessing the Risks to California" (California, 2006) was stated to be a primary motivating factor in the development of California AB32 (California, 2007).** For this report, PIER developed 20 technical papers analyzing issues such as potential impacts of climate change on agriculture and energy and water resources. These papers include impacts on forest resources, agriculture, water supply management, health impacts, sea level rise, and changes in energy demand. The research served as the basis for evaluations of California climate change impacts at the state government's top levels. While the assessment did not calculate economic impacts, a soon to be published 2008 **impact report (California, forthcoming) will analyze the economic impacts of climate change air quality, public health, forestry, agriculture, and coastal protection. In 2008**, Governor Arnold Schwarzenegger issued a directive mandating the preparation of biennial science reports on the potential impacts of climate change on California (California, 2008a).

Analysis of Mitigation Policies

California recently released the AB32 Scoping Plan, which contains the main strategies California will use to mitigate GHG emissions (California, 2008a). The Scoping Plan contains a range of GHG reduction policies and measures, which include direct regulations, alternative compliance mechanisms, monetary and non-monetary incentives, voluntary actions, and a economy wide cap-and-trade system. Included as an appendix to the Scoping Plan was an economic analysis, which contains an assessment of the economic impacts of the recommended measures in AB32 (but not an analysis of the value of avoided damages from climate change). **California modeled the economic costs of AB32 and found benefits to the economy from mitigation, in addition to the avoided costs of climate impacts (California, 2008b). This provided further motivation for a portfolio of mitigation policies.** The Scoping Plan also contains a section that describes the costs and benefits of the market-based compliance mechanisms.

California's Decision Process

As a direct result of PIER's 2006 impact assessment, Eileen Wenger Tutt of the California Environmental Protection Agency stated, "The quality of research contained in the scenario analysis performed by PIER far exceeded our expectations. The findings of the report

contributed greatly to our understanding of the effects of climate change emissions in California. These findings were the basis of the scientific evidence reflected in the March 2006 Climate Action Team report and in AB32, the California Global Warming Solutions Act of 2006" (California, 2007). By collecting information on the potential impacts of climate change, the State apparently developed motivation to set emissions reduction goals that surpass any other state in the country, and even surpass many developed countries' goals, despite a lack of a federal policy on climate change.

Policymakers in California also found benefits in the state taking pre-emptive action, even though climate change mitigation will require global action. California policymakers also acted because state industries could gain significant advantage from the state's "first mover" status (California, 2008b). These benefits include job creation, investment opportunities from outside sources (California is the leading recipient of venture capital for low-carbon technology in the world), and a chance to be rewarded for taking early action when more comprehensive federal or global climate agreements are developed.

Conclusions

This report briefly examines the role that the analysis of potential economic losses from climate change played for three governments: the United Kingdom, Australia, and the State of California, in providing support for GHG emissions reduction policies. While it appears that none of the governments undertook a formal benefit-cost analysis using the future benefits of avoided climate change to set its GHG reduction targets, it appears that the estimation of the benefits of avoided impacts may have played a role in justifying climate policies. However, it is also possible that the levels of emissions reductions selected by each government would have been selected even if formal economic analysis of the benefits of such reductions had not been done.

Impacts studies have provided useful information enabling all three governments to help support long-term GHG emissions reduction targets. Using integrated assessment models, the UK government concluded that the dangers of global unabated climate change will be equivalent to at least 5 percent of GDP each year, and could possibly rise to 20 percent of GDP or more if a wider range of risks and impacts are taken into account. In contrast, the costs of action to avoid the worst impacts could be limited to around 1 percent of global GDP if the world pursues optimal policies (Stern, 2006). The analysis by Stern, which does not explicitly look at avoided damages but compares the costs of inaction against the cost of taking action, was used as motivation for Britain's recent adoption of Climate Change Act targets. The government also found that the cost of meeting the Act's proposed budgets is less than 1 percent of GDP in 2020 (CCC, 2008a).

Impacts of changes in climate[5] have already been felt throughout the Australian economy and this appears to have played a key role in the Australian government adopting GHG

[5] It is not clear whether such changes can be attributed to anthropogenic climate change.

emissions reduction targets. The government commissioned the Garnaut review to examine how much mitigation is justified. The review compared the costs of mitigation with the benefits of climate change avoided by mitigation using integrated assessment models. The review found that the overall cost to the Australian economy of tackling climate change would be in the order of 0.1-0.2 percent of annual economic growth to 2020. The review estimated that global GNP would decline around 8 percent by 2100 from climate impacts, with losses in developing countries likely to be higher than the global average (Garnaut, 2008).

In California's case, policymakers acknowledged that previous impacts assessments were a key motivation into passing legislation on an ambitious emissions reduction target. Yet, these impacts assessments focused on physical and biological impacts such as loss of snowpack and increase in deaths from excess heat. The next impacts assessment will provide greater economic details on economic damages from business-as-usual emissions on a sector by sector basis.

The three governments studied in this report are all leaders in pledging to substantially reduce future GHG emissions. Each of them have also been leaders in assessing the impacts of climate change. Two, the UK and Australia, have estimated the total value of economic losses from climate change. The third, California, has conducted extensive analysis of climate change impacts. The UK and Australia concluded that substantial reductions in GHG emissions would cost less than the impacts of climate change, while California did not make such a calculus. In spite of this, it does not appear that emissions reduction targets were based on a formal application of benefit-cost analysis. For example, none of the governments calculated economically optimal emissions reductions, e.g., where the marginal benefit of emissions reductions is equal to the marginal cost. Instead, it appears that the calculation of economic losses from climate change (or in the case of California description of projected impacts) was useful to and informed the policy process. The setting of targets was apparently based on a number of considerations, such as cost-effectiveness and competitiveness, not just avoided economic impacts.

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