Benefits & Costs of Kyoto*

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Technical abstract: The 1998 Kyoto protocol signaled a new earnestness of international intent toward addressing the perceived risk of climate change. Kyoto demands that developed nations turn their economies so as to hit differentiated, sub-1990 level carbon emission targets within the next decade or so. But when thinking of the Kyoto protocol imagine trying to turn a battleship on a dime with a third of the crew on-board. Improbable, but doable…but for what benefit…and at what cost? The magnitude depends on *what you choose to believe* about the answer to these questions: Are we on the cusp of a catastrophe? Will developing countries ever participate? What will we do with any revenues that are raised in a trading system? Should nations be forced to reduce some fixed percentage of emissions at home? Can carbon sinks reduce costs? Will people adopt new energy-efficient technologies without a price hike in energy? The answers to these questions from economic analysis says that the catastrophes have to be exceedingly likely for Kyoto to make sense.

Non technical abstract: The 1998 Kyoto protocol signaled a new earnestness of international intent toward addressing the perceived risk of climate change. Kyoto demands that developed nations turn their economies so as to hit differentiated, sub-1990 level carbon emission targets within the next decade or so. Meanwhile, developing nations sit on the sideline uncommitted, serious in their refusal to stifle economic growth by controlling their swelling carbon emissions. The protocol asks for immediate action to address an uncertain, long-term, global threat in which the nations soon to be the world's largest emitters may never participate. As such, few experts in the rules of civilized engagement see the Kyoto accord as the answer, and few see Buenos Aries as the means to appease their disappointment. The protocol's short-term comeback to a long-term question of climate change has left most experts demanding either deeper emission reductions or broader emission coverage or an entirely new process.

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When thinking of the Kyoto protocol imagine trying to turn a battleship on a dime with a third of the crew on-board. Improbable, but doable…but for what benefit…and at what cost? Estimates of the expected benefits and costs are all over the board. Some studies suggest the US could meet its target at negligible or modest cost; others call Kyoto an economic disarmament driven by rank political opportunism. And to assume the costs are somewhere in-between puts the theorist at risk of being compared to a cigarette manufacturer stealing the life out of children or to a fool who has bestowed long lasting economic advantages to his international competitors.

But still we must understand what drives the magnitude of these benefits and costs if we are to make any progress in this debate. The magnitude depends on *what you choose to believe* about the answer to these questions: Are we on the cusp of a catastrophe? Will developing countries ever participate? What will we do with any revenues that are raised in a trading system? Should nations be forced to reduce some fixed percentage of emissions at home? Can carbon sinks reduce costs? Will people adopt new energy-efficient technologies without a price hike in energy?

The answers to these questions from economic analysis says that the catastrophes have to be exceedingly likely for Kyoto to make sense. The benefits generated by this moderate benchmark are nearly identical to those produced by the Kyoto protocol, even accounting for secondary and catastrophic impacts. The temperature difference between the Kyoto protocol and the moderate baseline are less than 0.1 degrees Celsius at any time over the next century. This small difference reflects the long lags in emission flows and concentration stocks over the century, and that the most serious emissions will come later in the century from the expanding economies of the developing nations. The net result is that Kyoto did not gain any benefits over the next best alternative.

Delay is not denial. A "broad, then deep" approach to climate change represents the view that we can allow emissions to grow at least for the next few decades before serious reductions are necessary. Shifting emissions reductions into the future allows time for a gradual adaptation of the energy capital stock, developing low cost and low carbon technology substitutes, removing carbon from the atmosphere via the carbon cycle, and, since the economy yields a positive return on capital, future reductions can be made with a smaller commitment of today’s resources.

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The Tempest
Act 2, Scene 1

SEBASTIAN
What a strange drowsiness possesses them!
ANTONIO
It is the quality o' the climate.

I. Introduction

By now you have probably read or heard the reviews about the climate change protocol emerging from Kyoto last December—some experts in the rules of civilized engagement see the accord as a crucial first step, others see it as a serious misstep, few see it as the answer. The protocol's short-term comeback to a long-term question has left most reviewers demanding either deeper emission reductions or broader emission coverage or both. The complexities and frustrations are manifest in the comment from Bert Bolin, former chair of the Intergovernmental Panel on Climate Change: "The Kyoto conference did not achieve much with regard to limiting the buildup of greenhouse gases in the atmosphere….Only if the new cooperation among countries succeeds will the Kyoto conference represent a step toward the ultimate objective of the convention."[1]

But regardless of your view, the 1997 Kyoto accord did signal a new earnestness of intent toward addressing the perceived risk of climate change. Kyoto demands that developed nations turn their economies so as to hit differentiated, sub-1990 level carbon emission targets within the next decade or so. Meanwhile, developing nations sit on the sideline uncommitted, serious in their refusal to stifle economic growth by controlling their swelling emissions. The Kyoto protocol asks for immediate action to address an uncertain, long-term, global threat in which the nations soon to be the world's largest emitters may never participate. Think of trying to turn a battleship on a dime with a third of the crew on-board. Improbable, but doable…but for what benefit…and at what cost?

This essay examines the benefits and costs of Kyoto. My task is to take the Kyoto protocol at face value, consider what the accord asks for and allows, and evaluate the potential benefits and costs that might accrue if it enters into force in 1999. My attempt to remain dispassionate occasionally wavers; a remnant from lively White House discussions past while serving as the senior economist for environmental policy at the Council of Economic Advisers during the run-up to Kyoto. The negotiating pressure during that time made me appreciate the force of Dales' remark that "[t]he politicians must decide what the public wants and stake their political lives on their decision; they are in a much better position to assess the benefits and costs of their action (or inaction) than any body of experts."[2]

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[1] B. Bolin, The Kyoto Negotiations on Climate Change: A Science Perspective, *Science*, vol. 279, January 16, 1998, pp. 330-331.
[2] J. Dales, *Pollution, Property, and Prices*, University of Toronto Press, 1968.

Still economists are not shy about saying that behavior matters more to climate policy than many people think; and that wealth spent here is not spent somewhere else; and that with more reasonable policy, it is possible to provide more human and environmental health with less wealth. So understanding the benefit and costs can help frame the climate change debate by identifying the elements of Kyoto that inflate costs with no additional benefits.[3] We consider what the literature says about estimating the benefits and costs for the US and the world; consider the key modeling assumptions that drive these estimates—e.g., the stringency of the abatement policy, the flexibility of policy instruments such as international emission trading systems or sinks; and the development and diffusion of technology. Not surprisingly, the benefits and costs of Kyoto depend on what one *chooses to believe* about the nature of climate protection. Most economists believe that the threat of catastrophe will have to be imminent for the Kyoto protocol to make sense given the likely impact on the U.S. economy.

II. The Kyoto Protocol

Achieving more financial and commercial well-being while preventing untold global catastrophe—what madman would be against that goal? Essentially this was what the representatives of some 150 countries supposedly set out to do when they met in Kyoto, Japan on December 1997 at the third Conference of the Parities (COP-3) to the United Nations Framework Convention on Climate Change (UNFCC). Their task was to create a legally binding international agreement for climate protection—the so-called Kyoto Protocol. The protocol will enter into force 90 days after the date on which "not less than 55 Parties to the convention, incorporating Parties included in Annex I which accounted in total for at least 55 per cent of the total carbon dioxide emissions for 1990 of the Parties included in Annex on have deposited their instruments of ratification, acceptance, approval or accession" (Article 24). The protocol is open for signatures by Parties between 16 March 1998 and 15 March 1999. In November 1998, the U.S. was the 60th nation to sign.

The Kyoto conference culminated years of negotiations to strengthen the first international climate change treaty signed by over 160 countries at the 1992 Earth Summit in Rio de Janeiro. The original treaty, UNFCC, called on industrial nations to voluntarily reduce their greenhouse gas emissions to 1990 levels by 2000 (see Table 1). Emissions from most nations, however, have actually risen since Rio. Since voluntary

[3] Several technical reviews of the costs and benefits of climate change policy exist. See the Intergovernment Panel on Climate Change (IPCC) Working Group III, *Climate Change 1995: Economics and Social Dimensions of Climate Change. The Contribution of Working Group III to the Second Assessment Report of the Intergovernment Panel on Climate Change* (J. Bruce, H. Lee, and E. Haites, eds.). Cambridge, Cambridge University Press, 1996; and its critique, *Economics and Policy Issues in Climate Change* (W. Nordhaus, ed.), Washington, D.C., Resources for the Future, 1998. Others question whether benefit-cost analysis is useful at all considering the uncertainties involved—see for example the papers by Bolin and Tietenberg in the climate change policy forum in *Environmental and Development Economics* 3, 1998, pp. 347-409.

actions did not do the job, many advocates of climate protection saw the Kyoto protocol as the way to correct this perceived misdirection.

The Kyoto protocol takes a "deep, then broad" stand. "Deep" in that the emission targets require what many observers consider a rapid reduction in carbon emissions for industrial nations; "then broad" in that developing nations have no obligations at this time, but are hoped to join the agreement eventually once someone convinces them that it is in their best interest to join. It is this "deep, then broad" angle that has left many experts unimpressed by the protocol, which seems to some as a quick political fix rather than a serious response driven by the natural sciences and economics.[4]

So what does the Kyoto protocol say?

- *Targets and Timetables* (Article 3). The protocol set a legally-binding target for 39 of the world's most developed countries to reduce greenhouse gas emissions in aggregate by 5.2% from a 1990 baseline for the period 2008-2012. The targets are differentiated by nation, ranging from an 8 percent reduction (the European Union) to a 10 percent increase (Iceland) from 1990 levels. The United States agreed to a target of 7% reduction; Japan a 6% reduction (see Table 2). Each party must show demonstrable progress towards meeting its target by 2005.

- *Nations can act jointly to hit their target* (Article 4). The protocol lets a group of nations form a multi-country “bubble” in which the group has an overall target to reach. Each nation inside the bubble has its own commitment to the rest of the group. The bubble met the demand of the European Union (EU) that it should be able to comply as a group. The bubble does require the EU to adjust its commitment if its membership enlarges.

- *Greenhouse gases* (Article 3-Annex A). The protocol covers six greenhouse gases, carbon dioxide, methane, nitrous oxide, hypdrofluorocarbons (HFCs), perflurocarbons (PFCs), and sulfur hexaflouride (SF6) as a "basket." The latter three use a 1995 baseline instead of 1990. The inclusion of the six gases allows for some flexibility in reaching the target. Reductions in one gas can be used to substitute for reductions in other gases.

- *Emission trading* (Article 17). The protocol allows for emission trading among the nations to fulfill their commitments. An emission-trading program provides greater flexibility to a nation to achieve its target. The domestic government can issue “greenhouse gas emission permits” to the private sector that equal the target set by the protocol. While the permits could then be freely bought and sold domestically between firms (Article

[4] See, for example, H. Jacoby, R. Prinn, and R. Schmalensee, Kyoto's Unfinished Business, *Foreign Affairs*, July/August 1998, pp. 54-66.

2), it is left unclear as to whether firms can trade uninhibited across borders. The trading price forces sources to reduce its greenhouse gas emissions so long as the tax exceeded the incremental cost of emissions reduction. This would stimulate fossil fuel users to improve energy efficiency, use less carbon-intensive fuels, and consume less of the goods and services produced in the carbon-intensive ways. Apparently, disagreements about international trading were almost enough to deflate the conference. In return for emission trading, the US gave up its opposition to the EU bubble.

- *Joint Implementation/Clean Development Mechanism* (Articles 6 & 12). Joint Implementation (JI) is when one nation gets credit for implementing a project to reduce carbon emissions in another country. JI is limited to the Parties. A new device, the Clean Development Mechanism (CDM), was developed for joint projects with developing nations through the payment of a special administrative fee by developed nations. According to the protocol, "[t]he purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3." A small portion of proceeds from the special fee is to be used to help the poorest of the poor nations, such as the island states, adapt to climate change.

- *Carbon Sinks* (Article 3). The protocol allows for carbon sinks—land and forestry practices that remove carbon emissions from the atmosphere. Sinks could play an important role for some nations because they represent a low-cost option. Sinks are ambiguously defined in the protocol, and will be a challenge to measure.[5] Sinks might even turn out to be an escape value for the US since little is known with certainty the net uptake of the terrestrial sinks in North America. According to the State Department, once one adjusts the US's accounting method, sinks will account for about 3 percent of the 7 percent reduction below 1990 levels as asked for by Kyoto.[6]

- *No Harmonization of actions.* The protocol allows each nation to figure out its own best strategy to meet its commitment. No everyone sees this as a good thing—some critics have argued that the world would have been better served by a common action rather than a common target.[7]

[5] See R. Sedjo, B. Sohngen, and P. Jagger, *Carbon Sinks in a Post Kyoto World*, Climate Issues Brief No. 12, Resources for the Future, Washington, D.C., October 1998.
[6] US Department of State, *The Kyoto Protocol on Climate Change: State Department Fact Sheet*, 15 January 1998.

What didn't the Kyoto protocol achieve?

- *Developing country participation*. No agreement was reached in Kyoto on what commitment developing countries should assume to reduce their greenhouse gas emissions. And Kyoto does not include a separate article for nations to voluntarily assume binding targets. But it is clear to everyone that climate protection requires the participation on the developing countries because by the middle of the next century, they are predicted to generate the largest share of carbon emissions. But they remain unmoved by the protocol. Developing nations have no incentive to reduce their economic growth. China, for example, is the second largest emitter after the US, but its per capita emissions are about a seventh of those in the United States. A Chinese delegate captured the sentiment underlying the opposition: "[w]hat they [developed nations] are doing is luxury emissions, what we are doing is survival emissions."[8] Substantial compensation might be required to induce their necessary participation.

- *Specifics on emission trading and the Clean Development Mechanism*. The protocol also left the specific rules and regulations about international emissions trading to be defined at a future date. Although both trading and the mechanism have the potential to generate low-cost emissions reductions for developed countries and tangible benefits to the host country, two factors limit their scope—transaction costs and additionality. Transaction costs are the time, effort, and other resources needed to search out, negotiate, consummate, and get governmental approvals for heterogeneous deals. How the rules are eventually defined will determine the friction in all these flexibility tools. Additionality reflects the fear that people will try to use the Clean Development Mechanism to get credit for emissions changes that would have happened anyway in spite of some reduction project. Options to address additionality range from detailed scrutiny of every project before approval to the development of simple formulae applied across all projects. An obvious tradeoff exists between reliability and cost among these options. The developers of the Mechanism need to define and pre-test the institutional, administrative, and financial arrangements, the guidelines on the criteria for eligibility and certification, and verification and monitoring of emission reductions.

- *Specifics on compliance and enforcement.* Both emissions trading and the Clean Development Mechanism require measures to assess compliance and to hold participants responsible for noncompliance. Under the Framework Convention and the Kyoto Protocol, the Annex I capped countries are ultimately responsible for achieving their emissions targets, whether they are net buyers or sellers of permits or credits. Presumably

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[7] R. Cooper, Toward a Real Global Warming Treaty, *Foreign Affairs* 1998, March/April 66-79.

[8] Quoted in S. Huber and C. Douglass, *Two Perspectives on Global Climate Change. A Briefing Book*, Center for the Study of American Business, Washington University of St. Louis, July 1998.

the Protocol Parties will then reassign this responsibility to the domestic private sector through strategies to monitor emissions and spot check specific investment projects. The protocol says enforcement procedures to deal with non-compliance will be established at the first meeting of the Parties to the Protocol. But until the details are fleshed out and this uncertainty is resolved, those firms falling under a trading system will remain skeptical about the workability of the scheme. For instance, whether the buyer or seller should be liable for the penalty of trading a permit that should not have been traded remains a major question mark.

III. Benefits from Kyoto

The potential benefits from Kyoto are captured by the avoided damages from climate change.[9] Potential climate risks avoided include more severe weather patterns, hobbled ecosystems, less biodiversity, less potable water, loss of coastal areas from rising sea levels, rises in mean temperature, more infectious diseases such as malaria, yellow fever, and cholera. On the plus side, climate change might benefit agriculture and forestry by increasing productivity with longer growing seasons and more fertilization. These gains (or losses) can be categorized into four broad sets, increasingly difficult to quantify—the avoided losses to market goods and services, non-market goods, secondary impacts, and catastrophes.

Traditionally, people have judged the benefits of climate protection as the reduction in human and environmental risks from the *business-as-usual* (BAU) baseline. Under BAU, modelers have estimated that carbon concentrations might be expected to double pre-industrial levels within the next half century, with mean temperatures predicted to rise by about 1 degrees Celsius by 2050, and 2.5 degrees by 2100. With Kyoto, the expected rate of slowing temperature rise is minor—between 4 and 14 percent of BAU baseline, with global-mean warming reductions between 0.04-0.10 degrees Celsius by 2050 and 0.08-0.28 degrees C by 2100.[10]

Researchers have estimated the total impact on Gross World Product from climate change around 1 or 2 percent. The impact on Gross Domestic Product (GDP) in the United States has been estimated to be around plus or minus 1 percent. Most industries in the developed nations are separate from climate—less than 3 percent of US livelihoods, for instance, are earned in agriculture and other climate-sensitive outdoor activities.[11] And even if we include the potential non-market damages, Nordhaus has argued that the market and non-market benefits to the US are probably at most about 2

[9] Benefits can be more than just avoided damages if one includes indirect or secondary benefits such as reduced congestion or air pollution. We address the validity of this point shortly.

[10] T. Wigley, "The Kyoto Protocol: CO_2, CH_4 and Climate Implications," *Geophysical Research Letters* 25, 1998, 2285-2288.

[11] These aggregate estimates also mask significant variability in impacts across regions, economic sectors, and industries.

percent of GDP.[12] At the margin, the damages avoid have been estimated to be about $25 TC, the extra benefit obtained from reducing carbon emissions by one tonne.[13] These impacts are not trivial, but the impact on economic output is not likely to cause the next global depression either.

Thomas Schelling views climate protection as a political problem, whose costs will be relatively low: "a few trillion dollars over the next 30 or 40 years, out of an OECD GDP rising from $15 trillion to $30-40 trillion annually."[14] Although doable, he wonders whether this is really the right question. He points out that climate policy really amounts to a wealth transfer from today's industrial nations to the future generations in the developing nations. The benefits from Kyoto are most likely to accrue to the future generations in developing nations because their economies depend more on favorable climate for agriculture, forestry, and fishing. He wonders whether it would be better to invest in development today than pay for climate relief tomorrow.

Two topics in non-market valuation are likely to trigger major debates about the likely magnitude of potential benefits—human health and ecosystem/endangered species services. First, consider health. There are numerous lists on the potential threats to human health including old scourges like cholera, plague, yellow and dengue fever, tuberculosis, malaria, and thirty diseases new to medicine, like E. coli, hatavirus and HIV.[15] But there is less talk about the odds the events will come to pass. What are the odds, what is the variability around these odds, how credible are these odds? [16]

Despite the warnings, the cause and effects are still uncertain. It is not clear that malaria rates will increase if those mosquito fail to adapt to changes in temperature, humidity or precipitation.[17] And attached to these threats must be advances in technology and nutrition and medical care. Adaptation may be the key to prevention. Once we acknowledge that adaptation plays a key role, we must account for the fact that risk depends on private and collective choices. The economic variables that drive adaptation, such as relative price and wealth, must be considered in the estimation of health risk. Given the relative marginal effectiveness of different self-protection actions, how people confront risk differs across individuals and situations, even though the natural phenomena that trigger these actions apply equally to everyone.

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[12] R. Nordhaus, To Slow or not to Slow: The Economics of the Greenhouse Effects, *Economic Journal*, 1991, 101, 920-937.

[13] D. Pearce, Economic Development and Climate Change, *Environment and Development Economics* 3, 1998, 389-392.

[14] T. Schelling, The Costs of Combating Global Warming, *Foreign Affairs*, 1997, November/December, 8-14; T. Schelling, "Some Economics of Global Warming," *American Economic Review* 82, 1992, 1-14.

[15] See for instance P. Epstein, "Climate, Ecology, and Human Health, *Consequences*, 3, 1997, 3-19.

[16] Moore (1998) makes the case that moderately warmer weather is more conducive to human health, such that climate change might reduce mortality rates in the US by about 40,000 per year. See T. Moore, "Health and Amenity Effects of Global Warming," *Economic Inquiry* 36, 1998, 471-488.

[17] A. Krupnick, *Climate Change, Health Risks, and Economics*, Weathervane, www.weathervane.rff.org. May 1998.

More information is needed to determine the bias in assessing health risks solely in terms of natural science information given that the sources of systematic variation are relative prices, incomes, and other economic and social parameters. If economists are going to be effective in the debate over setting health-based standards, they must insert themselves into the econometrics of epidemiology.[18] Biases associated with measurement and specification errors are prevalent. When account is taken of self-protection behaviors, ambient concentrations are not synonymous with exposure. Economic variables affect behavior which affect the risks faced by people, and exclusion of these variables from risk assessment biases predictions. Studies have shown that people persistently below the poverty line are far more likely to become sick than wealthy people for a variety of reasons including habits, lifestyle, less medical screening, and the ability to self-protect. The evidence suggests that behavioral choices frequently associated with poverty (e.g., high discount rates) are the most significant threat to health. Wealth equals health, even in warmer or colder climates.

Estimating the social value of endangered species and ecosystem services is also a challenge. When considering endangered species values, people disagree about the usefulness of the primary tool to reveal the monetary value of these preferences—contingent evaluation surveys. These public opinion surveys use a sequence of questions to put a monetary value on personal preferences. But since people are responding to a survey rather than facing their own budget constraint and actually spending their own money, no market discipline exists to challenge their statements. For instance, if one summed the stated preferences from various endangered species surveys as a crude measure of benefits, the average person was willing to pay about $1000 to protect 18 different species. Multiplying $1000 by the number of U.S. households, suggest that we would be willing to pay over 1 percent of GDP to preserve less than 2 percent of the endangered species.[19] Many will find these values to be suspiciously high. Despite the challenge in measuring the value of preservation, determining a plausible range for these values is needed for helpful judgments about the potential for climate change benefits.

One might claim that climate protection might avoid damages to the global ecosystem services in the range of $33 trillion.[20] This estimate is meaningless, however, since willingness to pay is constrained by the world's ability to pay—a world GDP of about $18 trillion.[21] And if one accounts for the fact that people make some contribution

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[18] See T. Crocker, and J. Shogren, "Endogenous Risk and Environmental Program Evaluation," *Environmental Program Evaluation. A Primer* (G. Knaap and T.J. Kim, eds.) Urbana, IL: University of Illinois Press, 1997, pp. 255-269; G. Duncan, "Does Poverty Affect the Life Chances of Children?" *American Sociological Review* (forthcoming); M. Kremer, "Integrating Behavioral Choice into Epidemiological Models of AIDS," *Quarterly Journal of Economics* 111, 1996, 549-574; S. Korenman and J. Miller, "Effects of Long-term Poverty on Physical Health of Children in the National Longitudinal Survey of Youth," photocopy, 1997.

[19] G. Brown and J. Shogren, "Economics of the Endangered Species Act," *Journal of Economic Perspectives*, 1998, 3-20.

[20] R. Costanza, et al., "The Value of the World's Ecosystem Services and Natural Capital," *Nature* 387, 1997, 253-260.

[21] See for example V.K. Smith, "Mispriced Planet," *Regulation*, Summer 1997, 16-17. On reflection, most economists would agree with M. Toman's point that the $33 trillion figure is "a serious underestimate of infinite," see *Nature*, 395, 1 October 1998, 430.

to total world income, the potential maximum ecosystem benefits are easily cut in half.[22] But it is questionable whether these number really mean anything at all given the false baseline of an all-or-nothing outcome with climate change. The most likely changes will not be a binomial Armageddon vs. Eden revelation.

Another way to amplify the benefits of the Kyoto protocol is to consider the potential secondary impacts that come from discouraging coal and other fossil fuel consumption. The Kyoto protocol would reduce emissions of such air pollutants as carbon monoxide, sulfur and nitrogen oxides, and toxic trace pollutants in exhaust gases. By reducing BTUs generated by fossil fuel consumption, emissions of these pollutants would inevitably fall, reducing damages to health, visibility, materials, and crops. Studies in Europe and the U.S. have estimated that the non-climate benefits might be as large or larger than the benefits from avoiding climate change. The estimated secondary benefits range from $3 to $78 per ton carbon reduction ($1992) based on a pre-1997 ozone/particulate matter National Ambient Air Quality Standards (NAAQS) baseline.[23] The benefits from reducing air pollution damages could offset 30 to 100 percent of carbon abatement costs given the pre-NAAQS baseline.

But should these secondary impacts count when considering the level of climate protection? One argument against there inclusion is the fear of double counting—the already existing NAAQS rules that were tighten in 1997 might produce the majority of the potential health benefits, not climate change policy. The Administration has estimated that extra benefits from climate change given a post-NAAQS baseline are about a billion dollars in 2010.[24] If our current air quality policies are effective, they should be capturing all the positive net social benefits. Claiming these net benefits for climate change just says that our other environmental policies are flawed, and that we should be focusing on attention on improving them. Climate change policy should not serve as a catch-all bailout for all our perceived social ills.

Finally, researchers, policymakers, politicians have raised the specter of catastrophe and surprise. Modelers often presume climate change will be gradual—a slow and steady rise in temperature or precipitation. But many people warn that this steady flow ignores the real risk of a sudden rupture or a straw-camel-back scenario, e.g., a catastrophe such as a structural change in ocean currents like the Gulf Stream, the melting of the Western Antarctic ice sheet, waves of environmental refugees. These threats are enough to scare most people into action.

While careful to not making any causal link, some point to El Niño as an illustrative example of the damages one might expect with climate change. Stuart Eizenstat, Under Secretary of State for Economic, Business, and Agricultural Affairs,

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[22] See A. Alexander, et al., "A Method for Valuing Global Ecosystem Services," *Ecological Economics* (forthcoming).

[23] D. Burtraw and M. Toman, *The Benefits of Reduced Air Pollutants in the US From Greenhouse Gas Mitigation Policies*, Climate Issues Brief No. 7, Resources for the Future, October 1997.

[24] See the PM NAAQS and Ozone NAAQS Regulatory Impact Analyses, Office of Air Quality Protection and Standards, US Environmental Protection Agency, http://www.epa.gov/ttncaaa1/t1ria.html.

said "[f]or a preview of the type of severe weather…look at the devastation wrought by this winter's El Niño."[25] But according to FEMA, the El Niño winter was no costlier than the previous two winters in the US—$289 million in 1997-98 compared to $294 million in 1996-97 and $280 million in 1995-96.[26]

The problem is that researchers do not have any reasonable estimates of the odds that these events will come to pass. The best these researchers are willing to say is that these severe events are "uncertain."[27] But all "all severity-no probability" scenarios can lead people to knee-jerk reactions. The challenge it to get researchers to quantity these odds for more informed policy judgments. It matters whether the odds are 10 percent or one-tenth of 0.1 percent.

In addition, the BAU baseline is not the only benchmark in town to judge the benefits of Kyoto. In fact, the BAU path is less credible after Kyoto since the developed world has already agreed to do something to address climate change.[28] According to Article 2 of the Framework Convention on Climate Change, the objective is to stabilize "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." Numerous different emissions reduction scenarios can work to stabilize concentrations at some level, including the "broad, then deep" pathway recommended by many researchers and policymakers: broad participation by both developed and developing countries, and a gradual emission reduction path to achieve a desired long-term concentration target.[29]

Delay is not denial, some say.[30] The "broad, then deep" represents the view that we can allow emissions to grow at least for the next few decades before serious reductions are necessary.[31] And while advocates of this policy run the risk of being dubbed irrelevant to the process, the moderate reduction baseline calls for an emission path that peaks around 2020 and would result in essentially the same concentration level in 2100 as Kyoto, at a fraction of the costs. Implementation of this benchmark would require an initial, modest increase in the price of carbon emissions, and a credible commitment to increase the price over time. Shifting emissions reductions into the future

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[25] S. Eizenstat, Stick With Kyoto, *Foreign Affairs* 77, 1998, 119-121.

[26] J. Allen, El Niño's Price Tag Sets No Disaster Record, *Washington Post*, 5 April 1998.

[27] E. Barron, Written Testimony, Committee on Environment and Public Works, US Senate, 11 July 1997; E. Barron, climate models: how reliable are their predictions, *consequences* 1, 1995, 16-27.

[28] In fact, some companies are being quite aggressive. British Petroleum, world's 3rd largest Petroleum Company, has taken on emission trading themselves, and has opened a new solar manufacturing facility. See S. Percy, "Making Progress beyond Kyoto," *How Workable is the Kyoto Protocol*, Weathervane, www.weathervane.rff.org. March 1998.

[29] The "broad, then deep" seems to be consistent with one side of the domestic US political strategy reflected in the non-binding Byrd-Hagel resolution, passed in the Senate 95-0, that stated that the US should accept no climate agreement that did not demand comparable sacrifices of all participants.

[30] R. Schmalensee, "Greenhouse Policy Architectures and Institutions," MIT Joint Program on the Science and Policy of Global Climate Change, Report No. 13, November 1996; S. Schneider and L. Goulder, "Achieving Carbon Dioxide Targets Cost-Effectively: What Needs to be Done Now?," *Nature* 1997.

[31] T. Wigley, R. Richels, and J. Edmonds, "Economic and environmental choices in the stabilization of atmospheric CO2 concentrations, *Nature*, 379, 1996, 240-243. A. Manne and R. Richels, "On Stabilizing CO2 Concentrations: Cost-effective Emission Reduction Strategies," EMF 14, April 1997.

allows time for a gradual adaptation of the energy capital stock, developing low cost and low carbon technology substitutes, removing carbon from the atmosphere via the carbon cycle, and, since the economy yields a positive return on capital, future reductions can be made with a smaller commitment of today's resources.

The benefits generated by this moderate benchmark are nearly identical to those produced by the Kyoto protocol, even accounting for secondary and catastrophic impacts. The temperature difference between the Kyoto protocol and the moderate baseline are less than 0.1 degrees Celsius at any time over the next century. This small difference reflects the long lags in emission flows and concentration stocks over the century, and that the most serious emissions will come later in the century from the expanding economies of the developing nations. The net result is that Kyoto did not gain any benefits over the next best alternative.

IV. Costs of Kyoto

As expected, the costs of Kyoto are all over the board. Some studies suggest the US could meet its target at negligible or modest cost; others call Kyoto an "economic disarmament" driven by rank political opportunism. And to assume the costs are somewhere in-between puts the theorist at risk of being compared to a cigarette manufacturer stealing the life out of children or to a fool who has bestowed long lasting economic advantages to his international competitors. It's wild out there.

On the modest side sits the Clinton Administration's report on the Kyoto protocol that emerged from the Council of Economic Advisers (CEA). Again relative to the BAU baseline, the Administration report states the costs to the US to meet its Kyoto target are "likely to be modest if those reductions are undertaken in an efficient manner employing the flexibility measures of emissions trading (both domestic and international), joint implementation, and the Clean Development Mechanism." By modest, the Administration means an annual GDP drop of less than 0.5 percent—roughly some $10 billion dollars; no expected negative effect on the trade deficit; increase gasoline prices by about 5 cents a gallon; lower electricity rates; and no "significant aggregate employment effect."[32] The marginal costs in this case fall around $10-$20 tC. Essentially, a "broad and deep" baseline is built right into the Administrations estimates of costs. And these estimates might be plausible if all goes exactly right with the world; a big "if."

In contrast, forecasts from the economic consulting firms, WEFA Inc. and DRI/McGraw Hill Inc., estimate the US GDP could take an annual hit of nearly 3 percent of GDP, or about $250 billion a year—with intra-nation emission trading. Plus the trade deficit would increase by tens of billions of dollars; gasoline prices would increase by nearly 50 cents a gallon; electricity prices would nearly double; and two million U.S. jobs

[32] The pre-Kyoto results from the President's Interagency Analysis Team (IAT) are within this range as well. An exception is that the IAT estimates that reducing emissions to 1990 levels by 2010 would cost 900,000 jobs in 2005, and 400,000 jobs by 2010. Also see J. Yellen, *The Economics of the Kyoto Protocol*, Statement before the Committee on Agriculture, Nutrition, and Forestry, US Senate, 5 March 1998.

would disappear.[33] The impact on energy use is analogous to that felt during the decade of OPEC price shocks. The marginal costs here are upwards of around $200 to $300 tC. These estimates obviously do not see all going right with Kyoto. Rather they see trouble in premature assumptions of rapid technological improvement, and in the likely friction imposed on any emission trading or technology transfer system by the institutions that eventually might see the light of day.

Other observers are more in the middle of the pain distribution.[34] Kyoto will not destroy national economies, but it will not be painless either, they say. Researchers at Resources for the Future, for instance, estimate that Kyoto could cost about 1 percent of GDP annually, at a worst 2 percent.[35] Plus energy costs would increase for an average U.S. household (about $2,500/yr) by about 25 percent, this includes a gasoline price rise of 30 cents a gallon. These estimates fall within the range of those cost estimates produced by Charles Rivers Associates—about 1.4 - 2.0 percent losses in 2020.[36] The Australian government estimated global losses at about 1 percent annually globally at 2020.[37] Prior to Kyoto, the Energy Modeling Forum (EMF) estimated the short-term costs of a 1990 by 2010 strategy at 0.5 - 1.5 percent annual drop in US GDP; and the medium term costs between 0.6 - 2.6 percent drop in GDP by the year 2020.[38] The post-Kyoto EMF estimates have yet to be released.

Another interesting story emerges when we compare the costs of Kyoto relative to the more moderate "broad, then deep" emission path baseline. Nordhaus and Boyer have used the RICE-98 model to address the relative benefits and costs of the Kyoto protocol to a moderate or “optimal” baseline.[39] While preliminary, their results suggest that while both paths yield nearly identical emission reductions, the Kyoto accord without global trading could be 8 to 14 times more expensive than the moderate path.

In general and for all models, cost estimates are likely to be on the low side for several reasons—models presume the most efficient possible climate control program, even though today only one such program is on-going; models assume the control

[33] Also see the report by the U.S. Energy Information Administration, *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity*, October 1998. The report finds that full U.S. compliance with the Kyoto Protocol could raise gasoline prices 53 percent and electric rates 86 percent by the year 2010. The report predicts a drop in U.S. GNP of about 4 percent by 2010 under a worst-case scenario.

[34] See for example Nordhaus (1991), M. Grubb et al., "The Costs of Limiting Fossil-Fuel CO2 Emissions: A Survey and Analysis," *Annual Review of Energy and the Environment* 18 1993, 397-478.), EMF Results, Stanford, 1994, Hourcade et al. (1996), J. Edmonds et al., "Return to 1990: The Costs of Mitigating United States Carbon Emissions in the Post-2000 Period," Battelle, October 1997; W. McKibbon and P. Wilcoxen, "A Better Way to Slow Global Climate Change," Brookings Institute, March 1997.

[35] M. Hamilton and C. Chandler, "Cures that Involve a World of Pain," *Washington Post*, 13 Nov. 1997.

[36] D. Montgomery, "Global Impacts of a Climate Change Treaty," *The Costs of Kyoto* (J. Adler, ed.), Washington, D.C.: Competitive Enterprise Institute, 1997, pp. 57-72.

[37] S. Brown et al., “The Economic Impact of International Climate Change Policy,” ABARE 1997.

[38] These estimates are robust across different modeling runs. The EMF compares a diverse group of economic models employing different methodologies. Standardizing these models by assuming common exogenous parameters yielded similar results. This suggests that the choice of method is secondary to the choice of values for population growth, per capita income, energy intensity, and technical progress.

[39] W. Nordhaus and J. Boyer, *Requiem for Kyoto: An Economic Analysis of the Kyoto Protocol*, Yale University, photocopy, 29 June 1998.

program is announced early and maintained indefinitely, even though a government will be hard pressed to maintain consistent control over the decades; many models focus on long-term equilibrium and ignore the short-run adjustments such as the oil shocks of the 1970s. There are good reasons to believe that any international or domestic emission trading program or Clean Development Mechanism will have significant transaction costs due to market friction. Some economists think these factors would raise cost estimates by a factor of one to four. This factor would cause Kyoto to reduce GDP by 1-10 percent from baseline. For comparison, the US now spends about two percent of GDP on all environmental programs combined.[40]

Finally, what about the common charge that modelers habitually overestimate the costs of environmental regulations, and thus it is likely that the costs of Kyoto are also too high by definition. This blanket assertion is not supported by the facts. Granted economist did predict the control costs for sulfur dioxide could be $1500 per ton, when today a ton actually costs $100. And good reasons exist as for this gap—unanticipated technology breakthroughs, railroad deregulation, many permits were given out for free. Ray Squitieri at the Department of Treasury has compiled the actual evidence. He finds that costs just as often on the low side. For instance, predictions straddle actual costs for asbestos, coke ovens, vinyl chloride regulation; numerous unpredicted changes in technology and the economy occurred to lower the cost of CFCs, cotton dust, SO_2 control; recall that the National Ambient Air Quality Standards were estimated to by achieved by 1977, but these standards are still not attained in 75 areas with 75 million people.

[40] Discussions with Ray Squitieri, US Department of Treasury.

V. What You Choose to Believe

How one sees the benefits and costs of Kyoto depends on what one chooses to believe about the nature of three elements that underlie climate protection—the cusp of a catastrophe, the degree of flexibility, and the origins of technological advance.[41]

The Cusp of Catastrophe

What you choose to believe about the benefits of Kyoto depends on how you perceive the risk of catastrophe. If you believe disaster is imminent, emission reductions cannot come soon or fast enough. If you don't, it is hard to justify the likely costs of the Kyoto protocol without global trading. Reliable information is needed to guide people from their diffuse priors about catastrophe. Whether the information will be forthcoming between now and potential ratification fights is unclear.

Numerous unanswered questions persist about the structure of atmospheric systems and their potential thresholds. As Schelling and many others note, uncertainties abound. We do not know which regions will get warmer or cooler; which will get wetter or drier; which will get stormier or calmer. Climate policy debates eventually reach the point in which the modelers is asked whether he or she has accounted for the likelihood of that a change in the ecosystem will be discontinuous—a catastrophe. Most modelers acknowledge their models do not address the potential for discontinuous shocks, like a sudden shift in the Gulf Stream due, or an unraveling of the web of life due to the loss of some keystone species.

Some observers view the increased temperature over the past century as well within the bounds of natural variability. Others such as Vice President Gore have been known to point out the evidence of global warming keeps "piling up, month after month, week after week. How long is it going to take before these people in Congress get the message?"[42] John Holdren, a member of the president's scientific advisory committee, agrees: "every day the evidence becomes more persuasive that global warming is underway." But daily weather and seasonal means are highly variable making it a real challenge to discern trends; that is, separating signals from natural noise.

But does this mean that society is on the cusp of catastrophe? Not necessarily—the doomsayers have a terrible track record. In addition, numerous risk perception studies have revealed that people commonly overestimate the chance that they will suffer from a low probability/high severity event, e.g., a nuclear power accident.[43] When the outcome is potentially very bad, people inflate the chance that the outcome will be realized. Policymakers are not immune to this human fallibility either. Overestimation of

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[41] Also see R. Repetto and D. Austin, *The Costs of Climate Protection*, WRI 1997.

[42] J. Warrick, "'People are Sweltering,' says Gore, Tying Record Heat to Global Warming," *Washington Post*, 15 July 1998.

[43] Lichtenstein, S. et al. "The Judged Frequency of Lethal Events," *Journal of Experimental Psychology* 1978, 4, 551-578; Viscusi, W. K, *Fatal Tradeoffs*, Oxford University Press, 1992.

risk can multiply throughout the general public. For example, people pondering the storage of nuclear waste can transform images of a fortified storage facility containing sanitized, air-tight receptacles into an abandoned dump site teeming with rusty, leaking vats of toxic material. The images induce vivid perceptions, both of which can persist in a community, causing considerable disagreement about how to regulate the risk.

Experience tells people little about low-probability risks like climate change. They must rely on outside sources of information to help them make judgments about the likelihood that a bad event will actually come to pass. And if that outside information stresses severity without giving some notion of the odds, people systematically bias their risk perceptions upward. Other evidence suggests that when people are given good news with the bad, the bad news often dominates.[44]

Of course, sticking ones head in the sand is not particularly useful either. Climate protection is viewed as hedging against uncertainty—i.e., planet insurance.[45] As such, it is important that we understand the range of potential impacts, not just the expected value.[46] Peck and Teisberg explore how risks of large losses affect the estimated costs of given climate protection strategies.[47] Working off of Nordhaus's survey of expert opinions about the odds of losses,[48] they create eight states of nature by assigning either a "high or low" value to three key parameters that reflect uncertainty—the probability of a loss, the climate sensitivity, and the utility discount rate. The results suggest that the optimal policy under uncertainty is about the same as the policy for the lowest-loss state of nature. This occurs in part because the lowest-state receives the greatest likelihood of coming to pass. Also a probabilistic damage function based on the mean relative pessimism from the same expert opinion survey suggests that under the extreme damage scenario opined by natural scientists, the climate protection is six times more stringent than that of Nordhaus's original prediction. [49]

Again using the same opinion survey as the starting point, a third integrated model constructs an empirical relationship between carbon emission accumulation and the odds of a catastrophe.[50] More carbon emissions without a disaster in one year leads to a greater chance of a catastrophe the next year. The results suggest that the odds that a

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[44] For example, Fox et al., "Consumer Preferences for Irradiation given Alternative Information," Working paper, Kansas State University, July 1998.

[45] See for example, A. Blinder, "Needed: Planet Insurance," *New York Times*, 22 October 1997.

[46] The economics literature on catastrophes include M. Cropper, "Regulating Activities with Catastrophic Environmental Consequences," *Journal of Environmental Economics and Management* 3, 1976, 1-15; H. Clarke and W. Reed, "Consumption/pollution Trade-offs in an Environment Vulnerable to Pollution-related Catastrophic Collapse," *Journal of Economic Dynamics and Control* 18, 1994, 991-1010; O. Eismont and H. Welsch, "Optimal Greenhouse Gas Emissions under Various Assessments of Climate Change Ambiguity," *Environmental and Resource Economics* 8, 1996, 129-140.

[47] S. Peck and T. Teisberg, "Uncertainty and the Value of Information with Stochastic Losses from Global Warming," *Risk Analysis* 16, 1996, 227-235.

[48] W. Nordhaus, "Expert Opinion on Climatic Change," *American Scientist* 1994, 45-51.

[49] T. Roughgarden, Quantifying the Damage of Climate Change: Implications for the DICE Model, Stanford University, 14 March 1997.

[50] J. Gjerde, S. Grepperud, and S. Kverndokk, *Optimal Climate Policy under the Possibility of a Catastrophe*, Statistics Norway, February 1998.

catastrophe occur by about 2100 range from 4 to 63 percent depending on how emissions affect the odds of a loss. While this range does not reduce our uncertainty much about the odds of disaster, the framework is a worthy one deserving more attention in future modeling efforts. Plus commissioning a newer, updated expert opinion survey seems most worthwhile given the lessons learned over the last decade about the workings of the climate system.

Finally, uncertainty about the underlying physical processes and random variability requires policymakers to decide whether to control for potential catastrophe now or wait for more information about the climate. Kyoto reduces emissions, and consequently causes learning to slow down because less information now exists about the cause-and-effect. An integrated assessment model with endogenous learning shows that uncertainties about the climate system are resolved in 90-160 years, far longer than most people expect.[51] A tradeoff exists between emission policy and learning—the more emission reductions, the less learning about the system under study. Policies of climate protection based on a presumption of complete information can be off by as much as 25 percent in either direction once learning is accounted for. Elements of truth exist in both sides of the debate. Policymakers would serve a more useful role as arbiters that help reconcile risk perceptions, rather than inflame the differences. People with a sane expectation of rationality should demand no less.

The Degree of Flexibility

What you choose to believe about the costs of Kyoto can be framed by focusing on if and how you think the flexibility provisions will come to pass, what we assume about future policy regimes, and how many nations will actually be included in any exchange system. The costs to meet a policy depend on a firm's legal ability to use low cost carbon reductions and how quickly society wants to change the energy systems and capital structure of the US economy. A stringent, inflexible carbon policy will induce greater economic burden than a loose, flexible policy. Obviously more flexibility and more trading partners can reduce costs, as a firm can search out the lowest-cost alternative. One can expect the opposite with inflexible rules and few trading partners. It is estimated that any agreement without the cost flexibility provided by trading will at least double the US costs.

Flexibility can be measured as the ability to reduce carbon at the lowest cost, either domestically and internationally, including so-called "when and where" flexibility—which assumes a world emissions budget could be spent optimally over space and time to capture all potential intra- and inter-temporal efficiencies. This would allow the banking and borrowing of allowable carbon emissions. Providing a firm or nation more flexibility to reach a given target and timetable also will reduce costs. Almost all studies of the costs of Kyoto already presume that carbon reductions are implemented domestically with well-designed, cost-effective policy tools like a carbon

[51] D. Kelly and C. Kolstad, "Bayesian Learning and Accumulation of Stock Externalities," UC-Santa Barbara, 1996.

tax or tradable permits system. International flexibility is also key for US firms to meet domestic targets at lower cost by financing the upgrading of inefficient energy facilities in developing countries. Limiting such opportunities for flexibility – due to poor policy design, inherent problems in administering international policies, or lack of interest on the part of other countries – will mean potentially much higher costs. The key is to distribute emissions internationally so as to minimize the costs of climate policy.

The Kyoto protocol established a narrow coalition of developed nations who now must reach out to the developing countries to join later. This approach begins with a narrow participation by a limited set of nations in a relatively ambitious agreement that involves considerable costs and hence requires fairly sophisticated policy instruments. People have to judge the odds that developing nations will eventually join the protocol. The most contentious issue in Kyoto was how to encourage or pressure developing nations to commit to emission reductions. The US pushed for a voluntary system, but the EU maintained that discussions on developing countries should only begin after the developed nations took the lead. China, Brazil, and other nations stopped several efforts in Kyoto to create a voluntary opt-in process for the developing nations to adopt binding commitments. China also successfully opposed putting the issue on the agenda for COP-4 in Buenos Aires in November. The difference in outlook is obvious—the developing nations are looking into the future and seeing the other side of the Environmental Kuznets Curve; the developed nations are looking at today and seeing the steep climb up the same Curve. Rich nations got rich through carbon, poor nations want the same opportunity. Who can blame them.

Kyoto runs the risk that the developing countries will never join later because the costs of doing so will be too high. By increasing the relative costs of carbon in the narrow coalition, carbon-intensive industries will be tempted move to developing countries, thereby making these economies even more carbon-dependent as they try to grow their way past the real health problems they face now.[52] Their addiction to carbon-based growth increases the costs of joining the treaty. The suppliers of carbon-intensive energy will look for existing markets and will create new markets. If developing countries do not alter their emissions path, global emissions levels will continue to increase even if all the developed nations completely eliminate all their emissions. Without China or India and the rest of the developing world, the Kyoto protocol will not work. The Administration has indicated that they would not submit the protocol to the Senate until "meaningful participation" from developing nations was obtained. Unskilled as I am in affairs of state, my guess is that the debate over whether climate change policy is really backdoor foreign aid will stall serious proposals to pay for meaningful participation over the next decade.

Second, we need to work through the details how the system would be designed before alternative policies can be usefully evaluated.[53] The Kyoto protocol does not have

[52] One guess is that carbon leakage would probably be between 10 and 50 percent. See T. Rutherford, "International Competitiveness and National Plans," University of Colorado, 1995.

[53] See the recent ideas by R. Hahn and R. Stavins, "Thoughts on Designing an International Greenhouse Gas Trading System, JFK School of Government, Harvard University, September 1998.

a set position as to what either a domestic or international trading system would look like. This is serious since we would essentially be creating a new global currency—the "carbo." The global economy would be under the thumb of the institution that controlled the supply of the carbo. Would we give control over to a quasi-independent institution like the Federal Reserve? Would we turn over the carbo supply to Allen Greenspan? Society would want to turn over the supply to someone who understands how to keep the economy from stagnating, which is not likely to be the administrator of a federal environmental ministry.

What is curious about carbon emissions trading is that its biggest supporters have often been the environmental activists rather than economists. The environmental community prefers emissions trading over carbon taxes because the quantity of carbon flowing into the atmosphere is fixed, thereby shifting risk from the environment to the economy in the form of price uncertainty. Some advocates have pushed for relatively high transaction costs that would limit the cost-savings of a trading system; others have argued for a flexible system that allows for banking and borrowing of permits. But many economists have questioned the feasibility of carbon trading because the international market is likely to be thin as most nations have indicated inaudible interest in the system, and the costs of monitoring and enforcing the system are likely to be high.

Defining the rules for flexibility incentive systems is wide-open. One way to explore the nature of trading is to testbed alternative systems in laboratory markets prior to actual field implementation.[54] Experimental economists could play an important role in reducing the associated uncertainty. This holds for joint implementation and the Clean Development Mechanism as well. A testbed carbon emission trading system designed in laboratory markets can evaluate the institutional factors that will influence the effectiveness of carbon trading. Experimentalists can consider how flexibility in trading, imperfect information, multi-gas trading, links between domestic and international trading, and other factors affect the potential efficiency of trading.

A serious effort is vital to understand what aspects of emission trading can reduce the costs of climate change policy. The effort should first design and parameterize a market that reflects the costs and productivity of the countries or regions expected to participate in a emission trading initiative as suggested in the Kyoto Protocol. Researchers can then use the parameters of the nations to design World Wide Web market experiments; to testbed various trading proposals that have been described to meet the Kyoto Protocol objectives using the market parameterization; to evaluate the robustness of emission trading market institutions to market “frictions"- impediments to efficient, cost-minimizing market outcomes; and to evaluate how the scope of the market affects market performance.

Third, carbon sinks are a wild card in the search for flexible, low-cost solutions. Recall that a carbon sink is a process that destroys or absorbs greenhouse gases, such as the absorption of atmospheric carbon dioxide by terrestrial (e.g., trees) and oceanic biota. The main anthropogenic sink is tree planting and other forest management actions. Soils

[54] See J. Shogren, "Lessons from the Lab," *Regulation*, Janaury 1998, 6.

and other types of vegetation also provide a potential sink. It is estimated that forests around the world contain about 830 Pg of carbon in their vegetation and soil, with about 1.5 times as much in soil as in vegetation. For the US, forests are an important terrestrial sink given that they cover about 750 million acres. Land use changes in the US have increased the uptake of carbon to an estimated 200 MMTCE.

A few studies have found that carbon sequestration through sinks could cost as little as $25/ton in the US for 150 MMTCE.[55] But serious uncertainties remain about how to measure and account for estimates of net carbon. For example, how forest management activities affect soil carbon is unknown, and since forest soils contain over 50 percent of the total stored forest carbon in the U.S., this difference can have a significant impact on estimates. And some researchers have shown that sinks are not as effective as predicted when one accounts for the interaction of forest reserves and the timber market. The more land that is set-aside for carbon sinks, the quicker the cycle of harvesting on other forestland, the less total net carbon sequestration.[56] Some fear that these ambiguities about sinks could divert attention from first-order priorities to second-order technicalities.[57]

Fourth, the costs of climate protection are also amplified by pre-existing distortions created by the existing tax system for labor and capital income. Labor and capital taxes distort behavior because they reduce employment and investment levels below what they would have been otherwise. Now add on a carbon tax (or permit) that discourages consumption and production, and you further reduce employment and investment, which then exacerbates the labor and capital tax distortions. One estimate is that this amplified distortion will inflate the control costs by some 400 percent.[58] One could reduce these extra costs by channeling the revenue from the carbon tax, if any existed, to reduce the labor and capital taxes, and thereby reduce the pre-existing distortions. Revenue recycling could shave control costs to 75 percent. But the political reality is that the odds of a tax or permit system that raises revenues to be recycled is as likely as seeing a Democratic Senator from Wyoming. Carbon permits most likely would be given away for free to producers because as it has been put by those wary of trying to sell a tax hike to Congress given the disastrous BTU tax experience: “if it don’t bring no revenue to the government, it ain’t no tax.”

Fifth, costs will increase if proposals to further restrict flexibility by requiring that nations do some fixed percentage of emissions cuts at home. The EU environmental ministers met after Kyoto to define a strategy to restrict US efforts to use emission trading to reduce the costs of hitting its target. Seeing trading as flight from responsibility, the EU drafted text for the next negotiations to prevent “loopholes” in the protocol. Although no consensus was reached, some ministers argued that 50 percent of

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[55] See for example R. Stavins, "The Costs of Carbon Sequestration: A Revealed-Preference Approach," *American Economic Review* (forthcoming).
[56] Discussion with Brent Sohngen, Ohio State University, August 1998.
[57] H. Jacoby, R. Prinn, and R. Schmalensee, Kyoto's Unfinished Business, *Foreign Affairs*, July/August 1998, pp. 54-66.
[58] I.W.H. Parry, Reducing Carbon Emissions: Interactions with the Tax System Raise Costs, *Resources*, summer 1997, 128, 9-12.

emission reductions must come from domestic cuts. Peter Jorgensen, spokesman for the EU commission, stated: "[a]s it is the leading emitter of greenhouse gases, the United States needs to take tough domestic measures…[the US] is going to try and buy its way out of its Kyoto commitments, and we are determined to prevent that from happening."[59] This quantity constraint of 50 percent do-it-domestic will inflate the costs to hit the target. "The burdens of global leadership are sometimes heavy, indeed."[60]

The Origins of Technological Advance

What you choose to believe about the origins of technological advance will color the costs of Kyoto. For any given target and set of policy provisions, costs decline when consumers and firms have more plentiful low-cost substitutes for high-carbon technologies. Engineering studies suggest 20-25 percent of existing carbon emissions could be eliminated at low costs if people switched to new technologies like compact fluorescent light bulbs, improved thermal insulation, heating and cooling systems, and energy-efficient appliances. Engineers argue that the origins of technological advance are firmly rooted in non-price responses—people do the right thing for the right reason. And once they understand the potential benefits of low-carbon technologies, they will just switch.

Economists disagree. They see the origins of advance as driven by changes in relative price. Even if new technologies are available, people do not switch unless prices induce them to switch. They are unwilling to experiment with new devices at current prices. People behave as if their time horizons are short, perhaps reflecting their uncertainty about future energy prices and the reliability of the technology. Plus factors other than energy efficiency also matter to consumers, i.e., quality and features, and the time and effort required to learn about a new technology and how it works.

The difference in views on the origin is revealed in the debate about the autonomous rate of improvement in the energy-to-GDP ratio underlying all models of climate economics. Modelers debate the appropriate rate of "autonomous energy efficiency improvement" (AEEI), the approximation of the rate of change in the energy/GDP ratio when energy prices remain relatively flat. Although historical evidence suggests that the autonomous change is about 0.5 percent per year, some people argue the announcement of the Kyoto protocol will prompt businesses to accelerate the implementation of energy efficient methods of production. This "announcement effect" has been argued to increase the autonomous rate to 2 percent per year or more. These significant leaps are hard to justify, however, after examining the evidence. The Climate Change Action Plan (CCAP) thus far has spent a half-a-billion dollars thus far to reduce carbon emissions in the US by about 14MMTCE. Given we have to reduce emissions by

[59] Europe Union Starts planning Strategy to Stress Domestic Action Under Kyoto Pact, *Daily Environment Report* 1060-2976/98, 31-3-98.
[60] J. Firor, "US Needs to Lead by Example in Reducing Emissions," *How Workable is the Kyoto Protocol*, Weathervane, www.weathervane.rff.org. March 1998

over 500MMTCE, one would have to believe in that we are on the cusp of a very steep s-shape diffusion curve.[61]

Economists remain wary of claims that alternative energy-saving technologies are readily available at no extra cost to consumers. People do not always take advantage of cost-effective, energy-efficient technologies that, in the long run, are good for both the pocketbook and the environment. At current prices, many consumers may not be willing to experiment with compact fluorescent light bulbs, improved thermal insulation, better heating and cooling systems, and energy-efficient appliances. Several studies have estimated that when consumers buy air conditioners, space-heaters, water-heaters, and refrigerators the pay-off predicted by the engineers does not come through.[62] Plus their implicit time horizon can be much shorter than the time horizon reflected in market interest rates. And even when they are presented with estimates of the likely future cost savings they pay more attention to immediate outlays. As our experience with the oil shocks of the 70s shows, choices do change when prices rise. Economists see the most effective way to curb excessive energy consumption is to raise its price to reflect the harmful effects on the environment of burning fossil fuels.

But at the White House conference on climate change last October, President Clinton made it clear that he did not think Americans would not tolerate higher energy taxes to combat climate change.[63] His answer was to promote new energy-efficient technologies rather than impose steep energy price increases. The President's plan to devote $6 billion for research subsidies and tax credits over the next five years. The Congressional Budget Office estimated that the US currently spends nearly $5 billion annually on programs directly or indirectly related to climate protection. The CBO also concluded that the effect of current programs and tax policies "on total emissions was unclear...[but] it would probably be small....Since most of the funds are spent to learn more about [climate change] and to improve energy efficiency in the future, the short-term effect is minimal."[64]

The theory of non-price policy response to technology adoption must recognize that preferences can prevent adoption to the levels predicted by engineering studies. High adoption rates will be realized once prices go high enough to eliminate the barrier, e.g., high carbon prices can provide the stimulus for some technologies to clear the barrier. Second, policies could be designed to try and eliminate barriers, but firms have found that these technologies are not cost-effective for them. Subsidies that increase their adoption will generate benefits less than the policies' costs.

Although economists do not see the average person switching energy sources just for the sake of switching, they do accept that the search for profits can create R&D

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[61] *United States Climate Action Report*—1997, Department of State, July 1997.

[62] For example, see G. Metcalf and K. Hassett, Measuring the energy Savings from Home Improvements Investments: Evidence form Monthly billing Data, NBER working paper 6074, June 1997.

[63] Anonymous, "Clinton Opposes Higher Energy Taxes to Curb Global Warming," *New York Times* 7 October 1997.

[64] Congressional Budget Office, *Climate Change: The Policy Challenge and Current Programs*, CBO August 1998.

breakthroughs that reduce the costs of backstop technologies.[65] These breakthroughs change the relative prices that can induce energy users to switch from fossil fuels to solar. Based on a Hotelling model of scarcity rents, for example, Chakravorty et al. show that if historical rates of cost reduction in the production of solar energy are maintained—30-50 percent per decade, more than 90 percent of the world's coal will never be used.[66] The world will make the transition to the backstop technology: to solar from coal and oil even without a carbon tax. Global temperatures will increase by 1.5-2 degrees Celsius by around 2050, and will then decline steady back to pre-industrial levels.

Finally, what you choose to believe about technology depends on how you think about the interaction of the technologies of risk reduction. Climate change discussions usually separate human responses to potential threats into two broad categories—mitigation and adaptation. By mitigating, humans reduce the *odds* that a bad event happens; by adapting, they reduce the *consequences* when a bad event actually does occur. But for the most part, the climate change literature has modeled mitigation and adaptation separately. This is unfortunate since significant interactions are likely to exist between how people choose to mitigate and adapt. These risk reduction strategies probably complement or negate each other. Understanding the interaction between the two can help formulation what you think of Kyoto. The benefits of mitigation will be lower the more people can adapt to the climate.

People can privately and collectively affect the threats they confront. This realization may have profound impacts on the formal evaluation of climate change policy. First, researchers need to rethink the traditional risk assessment-risk management bifurcation currently applied to the research and management of climate change risk. Second, we should also acknowledge that both private and collective risk reduction actions be considered in benefit-cost analysis and program evaluations to avoid the under-valuation of risk reductions. Third, researchers should also consider the implications of when a person passes along a risk to someone else across time and space.

VI. A Choice of Vision

A moderate "broad, then deep" approach with gradual emission reductions made sense before Kyoto and it still makes sense today.[67] Kyoto provides no additional benefits for the extra cost it will impose relative to this alternative benchmark. One might claim that this additional cost is the price of building international trust and securing a

[65] L. Goulder and S. Schneider, Induced Technological Change and the Attractiveness of CO_2 Abatement Policies, *Resource and Energy Economics* (forthcoming).

[66] U. Chakravorty, J. Roumasset, and K. Tse, Endogenous Substitution among Energy Resources and Global Warming, *Journal of Political Economy*, 105, 1201-1234.

[67] Hahn suggests a better first step would be a series of institution building exercises aimed at engaging developing nations in climate change policy (R. Hahn, *The Economics & Politics of Climate Change*, American Enterprise Institute, Washington, D.C., 1998). This approach could make sense, especially if one addresses the historical fact that once a problem is transformed into institutional rules, interest groups that invested in these rules will fight to keep them, regardless of the inefficiency. See B. Yandle, "Bootleggers, Baptists, and Global Warming," PERC Policy Series PS-14, November 1998.

politically credible "first step." This might well be the case. But it is not obvious to everyone that this step would not have occurred anyway, or that the billions of redirected dollars could not be spent more usefully on a dozen other environmental, health, or safety issues.

But whether one thinks this matters depends on what Thomas Sowell calls your choice of vision. People with an unconstrained vision believe we all have a vast untapped morality buried within waiting to emerge with the right direction. Thus solutions like the Kyoto protocol are primary; the trade-offs involved are secondary. As Sowell puts it, "every closer approximation to the ideal should be preferred. Costs are regrettable, but by no means decisive."[68] People with a constrained vision, however, weigh ideals against the costs of achieving them. Real incentives will be needed to get people to take on the goals of Kyoto intentionally. The concrete messages from economics is that the catastrophes have to be exceedingly likely for Kyoto to make sense. But for now and the foreseeable future, the uncertainties of climate change leave enough latitude so that whether you choose to believe the benefits justify the costs of Kyoto rests on your choice of vision.

Where to now? If climate change is really just about the developed world picking up the tab for benefits accruing to future generations in the developing world, there must be a better way—a more direct way—to do this than Kyoto. But if climate change is about more than this, we need to consider questions to forge a larger middle ground on benefits and costs. Find the price to induce the developing countries to come on board. Define the odds for catastrophe and surprise concepts. Quickly examine the nature of sinks to sort out whether the costs of measurement, verification, and enforcement problem exceed the benefits, thereby reducing the odds that this discussion degenerates into a sideshow distraction. Commission testbed studies on emission markets because effective institutional design requires no less; it worked for the spectrum markets, it can work for emission markets as well. Construct real case studies to understand what institution-building exercises work across developed and developing nations. Carefully evaluate the tradeoff frontier of flexibility and stringency within political constraints. Give more consideration to the incentives for technological progress created by different climate policies over the long term, including the opportunity cost of inducing innovation in climate protection versus other deserving goals. Finally, be vigilant that we aren't only talking to ourselves as we sharpen the benefit and cost estimates as events unfold and new research results come forth.

[68] T. Sowell, *A Conflict of Visions. Ideological Origins of Political Struggles*, New York: William Morrow and Company, 1987, p. 34.

Table 1: Total carbon dioxide emissions of Annex I Parties in 1990, for the purposes of Article 25 of the Kyoto Protocol [a]

Party	Emissions (Gg)	Percentage
Australia	288,965	2.1
Austria	59,200	0.4
Belgium	113,405	0.8
Bulgaria	82,990	0.6
Canada	457,441	3.3
Czech Republic	169,514	1.2
Denmark	52,100	0.4
Estonia	37,797	0.3
Finland	53,900	0.4
France	366,536	2.7
Germany	1,012,443	7.4
Greece	82,100	0.6
Hungary	71,673	0.5
Iceland	2,172	0.0
Ireland	30,719	0.2
Italy	428,941	3.1
Japan	1,173,360	8.5
Latvia	22,976	0.2
Liechtenstein	208	0.0
Luxembourg	11,343	0.1
Monaco	71	0.0
Netherlands	167,600	1.2
New Zealand	25,530	0.2
Norway	35,533	0.3
Poland	414,930	3.0
Portugal	42,148	0.3
Romania	171,103	1.2
Russian Federation	2,388,720	17.4
Slovakia	58,278	0.4
Spain	260,654	1.9
Sweden	61,256	0.4
Switzerland	43,600	0.3
United Kingdom of Great Britain and Northern Ireland	584,078	4.3
United States of America	4,957,022	36.1
Total	**13,728,306**	**100.0**

Data based on the information from the 34 Annex I Parties that submitted their first national communications on or before 11 December 1997, as compiled by the secretariat in several documents (A/AC.237/81; FCCC/CP/1996/12/Add.2 and FCCC/SB/1997/6). Some of the communications included data on CO2 emissions by sources and removals by sinks from land-use change and forestry, but since different ways of reporting were used these data are not included.

Source: REPORT OF THE CONFERENCE OF THE PARTIES ON ITS THIRD SESSION, HELD AT KYOTO FROM 1 TO 11 DECEMBER 1997 FCCC/CP/1997/7/Add.1. 18 March 1998.

Table 2. Annex B

Party	Quantified emission limitation or reduction commitment (percentage of base year or period)
Australia	108
Austria	92
Belgium	92
Bulgaria*	92
Canada	94
Croatia*	95
Czech Republic*	92
Denmark	92
Estonia*	92
European Community	92
Finland	92
France	92
Germany	92
Greece	92
Hungary*	94
Iceland	110
Ireland	92
Italy	92
Japan	94
Latvia*	92
Liechtenstein	92
Lithuania*	92
Luxembourg	92
Monaco	92
Netherlands	92
New Zealand	100
Norway	101
Poland*	94
Portugal	92
Romania*	92
Russian Federation*	100
Slovakia*	92
Slovenia*	92
Spain	92
Sweden	92
Switzerland	92
Ukraine*	100
United Kingdom of Great Britain and Northern Ireland	92
United States of America	93

*Countries that are undergoing the process of transition to a market economy.