Climate Economics Chair
Paris-Dauphine University
CDC Climat

Carbon Markets and Prices
Research Initiative

CGEMP
Université Paris Dauphine

Workshop: PRICING CARBON IN EUROPE AND IN THE US

Paris-Dauphine University - Tuesday 9th November 2010

8.30 - Registration & Welcome Coffee

9.00 Welcoming words
Patrice Geoffron (Paris-Dauphine University-CGEMP)

9.10 Preliminary contribution: Pricing carbon after Copenhagen
Christian de Perthuis (Paris-Dauphine University, Climate Economics Chair (CEC))

➲ Session 1: Pricing carbon in the US - Chairman: F. Convery (University College Dublin)

9.30 Where are we with the Bill in the US Congress?
Tim Profeta (Duke University, Nicholas Institute)

9.50 EPA analysis of US cap-and-trade legislation
Bella Tonkonogy (Environmental Protection Agency (EPA))

10.10 Discussion

10.30 - Coffee Break

11.10 Applying the MIT model to assess the impact of US federal legislation
Sebastian Rausch (MIT Sloan)

11.30 Domestic US policy and international climate negotiations
Jonathan Wiener (Duke University, Nicholas Institute)

11.50 Discussion

12.20 Special Address
Laurent Batsch (President of Paris-Dauphine University)

12.30 - Lunch

➲ Session 2: Pricing carbon in Europe - Chairman: J.M. Chevalier (CGEMP)

14.00 Where are we with the EU-ETS third period transition?
Peter Zapfel (European Commission, DG Climate)

14.20 Combining cap-and-trade with offsets: lessons from registries' data analysis
Raphaël Trotignon (CEC)

14.40 Discussion

15.00 - Coffee Break

15.20 Preliminary results from the ZEPHYR EU-ETS model
Suzanne Shaw & Stephen Lecourt (CEC)

16.00 Combining cap-and-trade with carbon taxes: lessons from EU experiences Frank Convery (University College Dublin)

16.20 Discussion

16.40 Special end contribution: Towards hybrid schemes?
Denny Ellerman (European University Institute)

17.00 - Workshop End

The Climate Economics Chair, under the scientific guidance of Christian de Perthuis, aims to develop **applied research and to stimulate didactic innovation in the field of climate change economics.**

The Climate Economics Chair's team of researchers forms part of **an international network of centers of excellence, working in conjunction with carbon market professionals and policy makers.**

An initiative of CDC Climat and Paris-Dauphine University

Paris-Dauphine University is one of the first academic institutions to have developed research in the field of climate change economics, through its Centre of Geopolitics and Raw Materials (LEDa-CGEMP) and its Master in Energy-Finance-Carbon launched in 2009.

CDC Climat is a subsidiary of the Caisse des Dépôts dedicated to the fight against climate change. It has developed a recognized research team, CDC Climat Research, bridging public research and the business world. CDC Climat has provided support to the PREC[1] team through the Finance and Sustainable Development Chair.

In 2010, CDC Climat decided to deepen its collaboration with Paris-Dauphine University through the creation of the Climate Economics Chair, which succeeds the PREC. CDC Climat is sponsor as well as research partner of the Chair. The Climate Economics Chair falls under the auspices of a not-for-profit research foundation.

[1] Programme de Recherche sur l'Economie du Climat (in English, Research Program on Climate Change Economics)

Activities of the Climate Economics Chair

Development of innovative research initiatives

The Climate Economics Chair develops applied research programs, called “research initiatives” intended to help create new knowledge regarding the link between climate change and the functioning of economic systems.
The approach of the Chair lies in the French tradition of positive economics, emphasizing analysis and evaluation of existing or developing policies and economic instruments in the field of climate change.

A forum for debate and exchange of ideas

The Climate Economics Chair contributes to the dissemination of scientific research by organizing conferences and meetings open to professionals and researchers. For example, it established a knowledge-sharing network for researchers via its Friday Lunch Meetings (FLM).

Teaching and training

Researchers of the Climate Economics Chair participate in the teaching activities of the Master in Energy-Finance-Carbon at Paris-Dauphine University and several other specialized masters. The Chair is also a host institution for interns and PhD candidates.

Organization of the chair

Orientation committee

The orientation committee sets the development priorities of the Chair based on the recommendations of the scientific board. It comprises representatives from founding members of the Chair as well as the presidents of the scientific board and the steering committee. It is chaired by Patrice Geoffron of Paris-Dauphine University.

Scientific board

The scientific board assesses the scientific research conducted under the framework of the Chair and advises on new developments proposed by the steering committee.

The scientific board is chaired by Christian de Perthuis, professor of economics at Paris-Dauphine University, and brings together researchers recognized within the international scientific community: **Dominique Bureau** (Economic Council for Sustainable Development), **Jean-Marie Chevalier** (Paris-Dauphine University), **Frank Convery** (University College Dublin), **Denny Ellerman** (European University Institute in Florence and the Sloan School of Management at MIT), **Pierre-André Jouvet** (University Paris-Ouest Nanterre), **Jonathan Wiener** (Nicholas School of the Environment at Duke University).

Steering committee

The steering committee implements the work program of the Chair, as defined by the orientation committee. It is responsible for setting up academic and professional partnerships. It also aims to propose new developments in accordance with the general theme of the Chair. The steering committee is chaired by Anaïs Delbosc, senior research fellow at CDC Climat Research.

Focus on the first research initiative: Carbon prices and markets

The first research initiative developed by the Chair deals with the analysis of carbon prices and markets. The current program of the Chair is composed of three other research initiatives: "Agriculture, food, and forestry", "Long-term investors and climate change", and "Mobility in a low-carbon society".

Context and objectives

The research initiative "carbon prices and markets" builds on the research program "Evaluation of the EU Emissions Trading Scheme" (EU ETS) which led to the publication of a reference book on carbon pricing in Europe[2].

The initiative constitutes a new three-year research program to assess the impacts of a carbon price and the conditions for establishing carbon prices worldwide. Topics to be researched include: the functioning of the EU ETS; emerging carbon markets, with priority placed on advances in the U.S. and China; international and domestic project-based mechanisms; and, the implementation of a carbon tax to complement permit market mechanisms.

The development of innovative tools

With the experience gained via the previous research program, our team develops three analytical tools:

- The **"volumes and carbon prices" database** which contains data on prices, emissions and transaction volumes for GHG emissions.
- The **Zephyr model** which simulates emission allowance prices in the EU ETS; innovative in its architecture and potential uses.
- The **CO_3 Index** that provides an indication of the carbon price distribution in regional and worldwide economies.

Public dissemination of research

The research produced by the Chair is public. It is disseminated via the**, "Information and debates" and "Research" publications** of the Chair.

The ensemble of work developed will be compiled into a body of work on the price of carbon, to be published in French and English in 2013.

Seminars and conferences are also planned:

- **International academic conferences**, in collaboration with our international partners. The first, "Pricing carbon in Europe and in the US", is slated for November 9th 2010 at Paris-Dauphine University.

- **Annual Conference of the Chair,** where the results of the Chair's research and its synthesis report are presented to a large audience of decision-makers.

[2] Ellerman D. Convery F., De Perthuis C., et alli, (2010) Pricing Carbon. Cambridge University Press.

Research Team

Core team:

Christian de Perthuis	Team director
Guillaume Bouculat	Forests, agriculture and climate change
Stéphane Buttigieg	Carbon in financial strategies
Jérémy Elbeze	Carbon taxes
Natalie Frank	U.S. Climate Policy
Stephen Lecourt	Zephyr Model (non-power sector)
Suzanne Shaw	Zephyr Model
Boris Solier	Carbon and electric power markets
Raphaël Trotignon	Carbon volumes and prices database
Wen Wang	Chinese climate policy

Partner teams:

CDC Climat Research	Carbon Finance
LEDa – CGEMP – Dauphine	Energy and CO_2
Duke University	Carbon price in the U.S.
MIT – CEEPR	Modelling
University College Dublin	Carbon taxes and markets
Universitat de València	CO_2 allowances as a financial asset

Support the Climate Economics Chair

The Climate Economics Chair is an **initiative open** to other partnerships, either as a sponsor of one of our research initiatives or as a sponsor to the Chair itself, alongside CDC Climat.

The Chair is managed by a not-for-profit research foundation. Financial contributions of sponsors are eligible for various fiscal measures to encourage public research in France.

Supporting the Chair can also take the form of financing a thesis, for example through a CIFRE contract, or via the secondment of a researcher.

Please visit the Chair website www.prec-climat.org in which you will find a presentation of the activities of the Chair, updates, as well as a compilation of our publications.

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Speaker Information

Laurent Batsch, Paris-Dauphine University
Professor Laurent Batsch degreed from the École normale supérieure (Cachan) and earned a PhD in Management from Université Paris-Dauphine. Since 1999, he is Professor at Université Paris-Dauphine, also called 'Dauphine', where he teaches corporate finance. He created the Master in Real Estate Management ('Master 246'). His main publications and essays include '*the Growth of Industrial Firms*' and '*Financial Capitalism*' where he highlights the new economics paradigm of the financialization of firms strategies. Since his inception as President of Université Paris-Dauphine in 2007, he played a proactive role in a French University with the accreditation of the renown EQUIS label, the launch of the Dauphine Foundation enabling the University to collect private funds, the creation of several Chairs, the settlement of the Univeristy abroad with Dauphine-Tunis, the establishment of a second campus in the financial center of La Défense and the alliance with major research schools in Paris.

Frank Convery, University College Dublin
Professor Frank Convery, is Director of the Earth Sciences Institute and of Urban Institute Ireland, University College Dublin (NUID- UCD). He has a long history in European environmental economics and policy work and has been involved in numerous successful European research projects, including as co-ordinator of research networks on market based instruments and emissions trading. As a member of the Scientific Committee of the European Environment Agency (EEA) he chaired the committee overseeing the reports the Agency commissioned and published on the uses of environmental taxation and voluntary approaches in environmental policy. He is Honorary President of the European Association of Environmental and Resource Economists, and served as a member of the High Level Group of Environmental Economists advising the European Commission. He served as chairperson of the Sustainable Energy Authority of Ireland, and chairs Comhar Sustainable Development Council. He is co-author of *Pricing Carbon*, Cambridge University Press, 2010.

Jean-Marie Chevalier, Paris-Dauphine University
Jean-Marie Chevalier is a Professor of Economics at the ParisDauphine University where he directs the Centre de Géopolitique de l'Energie et des Matières Premières (CGEMP) and the Master of Industrial Economics. He is also the Director of the Cambridge Energy Research Associates (Paris Office). He has worked for Elf Aquitaine and the Energy Department of the World Bank. He has taught industrial economics and energy economics at the University of Algier, Rabat, Grenoble and Paris XIII, as well as the Insitut d'Etudes Politiques of Paris and the Ecole Nationale d'Administration. For many years, Jean-Marie Chevalier was also an administrator of the Banque Nationale de Paris.

Christian de Perthuis, Paris-Dauphine University, Climate Economics Chair (CEC)
Professor of Economics at University Paris-Dauphine, his research focuses on the economics of climate change. He leads the Climate Economics Chair, a joint initiative between CDC Climat and Paris-Dauphine University and is a member of the CEEDD, the advisory committee of the French minister of the Environment**.** Author of several articles and books he is co-author of “Pricing Carbon” with Denny Ellerman and Frank Convery. His next book, “Economic choices in a warming world” will be published beginning of 2011 by Cambridge University Press.

Denny Ellerman, MIT and European University Institute
Dr. Ellerman is an internationally recognized expert on energy and environmental economics with a particular focus on climate policy, emissions trading, and interactions with energy markets. He is part-time professor at the Robert Schumann Centre for Advanced Studies at the European University Institute in Florence, Italy, and is retired from MIT, where he was for many years a senior lecturer and executive director of the Center for Energy and Environmental Policy Research and of the Joint Program on the Science and Policy of Global Change. Denny He is a co-author of the leading books on the US SO_2 and the EU CO_2 Allowance Trading Programs, *Markets for Clean Air: The US Acid Rain Program* and *Pricing Carbon: The European Emissions Trading Scheme*. He has a Ph.D. in political economy and government from Harvard University.

Patrice Geoffron, CGEMP – Paris Dauphine
Patrice Geoffron holds a PhD in Industrial Organization. He is Professor of Economics in Paris-Dauphine University and the Director of the CGEMP (Research Center in Energy and Raw Materials Economics). He is involved in the management of the Master Energy – Finance – Carbon and of the Climate Economics Chair. Previously, Professor Geoffron held the position of Vice-President of Paris-Dauphine University, in charge of International Policy.

Stephen Lecourt, Climate Economics Chair (CEC)
Stephen Lecourt is a Researcher at the Climate Economics Chair of Paris-Dauphine University and CDC Climat. His area of research focuses on emissions and abatement modeling of non-electricty sectors. Lecourt holds a Master's degree in Energy and Environmental Economics from ParisTech, a Master's in Aerospace Engineering with a specialisation in automatic control systems from ISAE – SUPAÉRO, the French Graduate School of Space and Aeronautics, and a Bachelor's degree in Mechanics and Engineering from Université Pierre et Marie Curie. He is currently pursuing a PhD in Economics at Paris-Dauphine University.

Tim Profeta, Duke University
Tim Profeta is the founding Director of the Nicholas Institute for Environmental Policy Solutions at Duke University. Since its inception in 2005, the Institute has grown into a major nonpartisan player in key environmental debates, serving both the public and private sectors with sound understanding of complex environmental issues. Prior to his arrival at Duke, Profeta served as counsel for the environment to US Senator Joseph Lieberman. Profeta has also served as visiting lecturer at Duke Law School, where he taught a weekly seminar on the evolution of environmental law and the Endangered Species Act. He has also co-taught a course on Corporate Sustainability and Climate Change with the Duke Executive Education Program. Profeta earned a law degree from Duke University, and an undergraduate degree from Yale University.

Sebastian Rausch, MIT
Sebastian Rausch is a Research Scientist at the Joint Program on the Science and Policy of Global Change at the Massachusetts Institute of Technology. His research focuses on applied policy analysis using computable general equilibrium modeling in the areas of climate and environmental economics, public finance, and international trade. Recent work involves developing a regional economic-energy model for the U.S. to assess the implications of U.S. climate and energy policy. Rausch received a BA and MA in economics from the University of Bonn, and a PhD in economics from the University of Duisburg-Essen and the Ruhr Graduate School in Economics, Germany. He obtained his post-doctoral education in economics at MIT.

Suzanne Shaw, Climate Economics Chair (CEC)
Suzanne Shaw is a Researcher at the Climate Economics Chair of Paris-Dauphine University and CDC Climat. Her areas of specialisation include climate and energy policy analysis, and their impact on energy technology economics and alternative energy diffusion. Her current work focuses on the dynamics within the European Union Emissions Trading Scheme (EU ETS) permit market, and the strategies of the electricity sector in the face of the EU ETS climate policy. She led the first stages of the development of the Zephyr EU ETS model, a major tool developed within the Chair for EU ETS policy analysis. Suzanne holds a Bachelor in Chemical engineering and Masters' degrees in Environmental Sustainability and in Energy and Environmental Economics. She is currently pursuing a PhD in economics at Paris-Dauphine University.

Bella Tonkonogy, U.S. EPA
Bella Tonkonogy is an analyst in the Climate Change Division of the U.S. Environmental Protection Agency, Office of Air & Radiation. Her portfolio includes the analysis of Congressional climate legislation and international actions to mitigate climate change. Recently, she was the lead contributor for EPA to a White House-led Interagency Report on International Competitiveness and Emission Leakage, developed in response to a Senate request. Prior to joining the Climate Economics branch, Ms. Tonkonogy negotiated corporate greenhouse gas reduction goals and assisted corporations with the development of greenhouse gas mitigation plans through EPA's Climate Leaders program. She holds a Bachelor's degree from the University of California-Berkeley and a Master's degree from Imperial College London.

Raphael Trotignon, Climate Economics Chair (CEC)
Raphael Trotignon holds a MSc in Energy and Environment Engineering from Ecole des Mines de Nantes and a MSc in Energy and Environment Economics from AgroParisTech, during which he has been a visiting researcher at MIT Center for Energy and Environment Policy Research. He worked for three years at CDC Climat Research and is now a PhD student of Paris Dauphine University at the Climate Economics Chair. His research concentrates on the ex post analysis of the EU ETS using data from the European central registry (CITL), and aims at identifying compliance behavior of EU ETS participants over 2005-2010 (trading, use of banking and borrowing, Kyoto credits imports). He published several articles on the subject. He's also the author of two books (Pearson Ed, in French only): "Understanding Climate Change", and "Understanding the stakes of energy" with Boris Solier.

Jonathan B. Wiener, Duke University

Jonathan B. Wiener is the William R. and Thomas L. Perkins Professor of Law, as well as professor of environmental policy and professor of public policy studies, at Duke University. He has been a University Fellow of Resources for the Future (RFF) since 2002. He has been a visiting professor at Harvard Law School (2010 and 1999), the University of Chicago Law School (2007), Sciences Po (2008), and EHESS and CIRED (2005-06) in Paris. In 2008 he served as President of the Society for Risk Analysis (SRA), and in 2003 he received the Chauncey Starr Young Risk Analyst Award from the SRA for the most exceptional contributions to the field of risk analysis by a scholar aged 40 or under. From 1989 until he came to Duke in 1994, he served in the US Government during both the first Bush and Clinton administrations, as senior staff economist for environmental and regulatory matters at the White House Council of Economic Advisers (CEA), as well as at the White House Office of Science & Technology Policy, the U.S. Department of Justice, and the Americorps National Service program. In those capacities he helped negotiate the Framework Convention on Climate Change, assisted in the IPCC, and attended the Rio Earth Summit. From 1987-89, he served as a law clerk to Judge Stephen G. Breyer on the U.S. Court of Appeals in Boston, and to Judge Jack B. Weinstein on the U.S. District Court in Brooklyn, NY. He received his A.B. (1984, economics) and J.D. (1987) from Harvard University, where he was an editor of the Harvard Law Review.

Peter Zapfel

Peter Zapfel is head of policy coordination in DG Climate Action at the European Commission. After joining the Commission in 1998 he worked for two years in the DG for Economic and Financial Affairs. Since 2000 he is with DG Environment. He has represented the Commission as a delegation member in several UN climate negotiation sessions. For several years he was responsible for the economic assessment of climate policy. He has been involved in the Commission’s work on emissions trading since 1998. He has coordinated DG Environment’s EU ETS team for over two years and in particular the Commission's assessment of national allocation plans for phase 2 of the EU Emission Trading Scheme. Prior to his current assignment he was assistant to the deputy director-general of DG Environment. He holds academic degrees from the University of Business and Economics in Vienna, Austria, and the John F. Kennedy School of Government at Harvard University.

Summary

Through the Copenhagen Accord, the U.S. has committed to a reduction in GHG emissions from 2005 levels in the range of 17% by 2020, in conformity with legislation. This paper summarizes the status of climate policy in the U.S. as of the Fall of 2010, focusing specifically on EPA's role in the economic analysis of climate legislation and the results of its most recent analysis of the U.S. Senate's American Power Act. The status of greenhouse gas (GHG) regulations under the U.S. Clean Air Act is also discussed.

Policymaking in the United States

The challenge of producing a comprehensive national legal framework to reduce greenhouse gas emissions in the United States should be understood in the context of its particular geographic, economic, and institutional circumstances. The large land area comprising the United States, as well as the system of strong checks and balances that characterize the federal government, largely explain the tendency for climate change initiatives to begin at the local or regional level. This section presents a geographic and political context of the United States.

At a total land area of 9.2 million km^2, the space that any national-level low carbon program in the United States would cover is vast. A wide variety of distinct geographies are contained within U.S. borders: Atlantic and Pacific oceans, the Gulf of Alaska and the Gulf of Mexico, two major mountain chains, a sub-tropical region, a large desert in the southwest, and the frigid plains of the north-central region, among others.

It is perhaps this geographic, as well as subsequent cultural, diversity that has expressed itself through the federal nature of U.S. governance. Each U.S. state is represented by two elected representatives in the Senate, each population-defined locality being further represented by an elected official in the House of Representative. The Senate and the House of Representatives comprise the bicameral Congress, the legislative branch of the US. Proposals (bills) become laws after both the House and the Senate pass their own versions of a bill and reconcile the differences between the two.

U.S. governance is also characterized by a strong system of checks and balances between its three branches: legislative, executive, and judiciary. The President reviews bills approved by Congress and may prevent a bill from becoming law if (s)he finds it particularly flawed. Congress may then modify the bill such that it is favorable to the President or, if sufficiently strong support for the original version exists, may force the bill to become law despite the President's objection.

Other than the power to block a bill from becoming national law if insufficient congressional support for it exists, the United States President has no official direct influence in creating new laws. Government agencies and departments, such as the Environmental Protection Agency and the Department of Energy, as part of the executive branch of government, also do not have an official direct voice in the Congress. The unique characteristics of the U.S. political system help to explain the particular challenges of passing national laws related to climate change.

U.S. Climate Change Legislation

The Obama Administration is fully supportive of advancing clean energy and of United States commitments to contribute to global reductions in greenhouse gas emissions. The most effective way to drive a clean energy transformation is to make it cost-effective to invest in renewable energy, energy efficiency, and other home-grown, climate-friendly technologies through, for example, a market-based policy approach that changes the incentives for investment. The cap and trade mechanism, which has been successfully used in the U.S. to dramatically reduce acid rain at a fraction of the expected costs, provides the incentives for new, clean energy technologies. This policy can drive the energy sector transformation and lower the emissions causing climate change at the minimum possible cost because it does not rely on government mandating every specific action, but instead rewards the creativity of those in the private sector who can seek out and exploit the lowest cost opportunities for doing so.

The United States made significant progress on the road towards a comprehensive climate policy with the passage of the American Clean Energy Security Act (ACES) in June 2009 in the U.S. House of Representatives. ACES is a comprehensive energy and climate mitigation package that includes a greenhouse gas emissions cap and trade mechanism. Corresponding to the U.S. commitment at Copenhagen, the Act calls for a reduction of GHG emissions by 17% by 2020 and by 83% by 2050, both measured relative to the 2005 level.

While ACES, supported by President Obama, represents a success in moving forward a low carbon agenda, the U.S. Senate has been unable to agree on its version of a climate mitigation bill, the American Power Act.

EPA's Economic Analyses of Climate Change Legislation

The U.S. Congress has repeatedly requested the EPA to compare different forms of proposed legislation. The EPA, in its analyses of the economic impacts of climate change policy, has made use of some of the most advanced computable general equilibrium (CGE) models that are currently available.

EPA analysis mainly focuses on modeling the cap-and-trade policies outlined in proposed legislation. With time, EPA has also been able to incorporate a few additional provisions into its models, such as energy efficiency standards. However, while formal modeling can shed light on the key aspects of the cap-and-trade policy, it cannot replicate every aspect of private decision-making and therefore will not capture the impact of certain details. For this reason, modeling results are instructive in highlighting the magnitude and direction of impacts and the way they may change under different conditions but should not be interpreted as precise estimates of what will occur once a policy has been implemented.

For its Congressional analyses, EPA uses two separate computable general equilibrium (CGE) models: IGEM and ADAGE. CGE models are structural models: they build up their representations of the whole economy through the interactions of multiple agents (households, firms, government, and countries, for example), whose decisions are based upon optimizing economic behavior in the context of a given policy environment. The models simulate a market economy where, in response to a new policy, prices and quantities adjust so that all markets clear (i.e., economic equilibrium). These models are especially well-suited for capturing long-run equilibrium responses and the unique characteristics of specific sectors of the economy. The general equilibrium framework of these models allows EPA to examine both the direct and indirect economic effects of proposed legislation, as well as the dynamics of how the economy adjusts in the long-run in response to climate change policies.

The NCGM, FASOM, GTM, and MiniCAM models are used to provide information on abatement options that fall outside the scope of the IGEM and ADAGE models. These models generate mitigation cost schedules for various abatement options, such as land-use and non-CO_2 gases. Finally, the IPM model gives a detailed picture of the electricity sector in the short-run (through 2025), complementing the long-run (through 2050) equilibrium response represented in the CGE models.

EPA's Analysis of the American Power Act

The U.S. Senate's American Power Act (APA) of 2010 establishes a multi-sector cap-and-trade program with delayed phase-in for the industrial sector and an alternative compliance program for the transportation fuels and refined petroleum products sectors, and creates other incentives and standards for increasing energy efficiency and low-carbon energy development and consumption. Caps are similar to those set in ACES. Like in ACES, banking provisions provide an important cost containment mechanism.

EPA's economic analysis of the APA models the multi-sector cap-and-trade program, the alternative compliance program for the transportation fuels and refined petroleum products sectors, the competitiveness provisions, and many of the energy efficiency provisions of the APA. Sensitivity analyses are conducted to examine the impacts of technology development, the pace of international action, and the availability of international and domestic offsets on the results. The APA cost estimates do not account for the benefits of avoiding the effects of climate change (or, stated from a different perspective, the no-policy scenario does not include estimates of the costs of climate change induced damages).

Widespread international actions by developed and developing countries are assumed over the modeled time period. International policy assumptions are consistent with the agreement among G8 leaders at the July 9, 2009 Major Economies Forum “to reduce their emissions 80% or more by 2050 as its share of a global goal to lower emissions 50% by 2050.” Group 1 countries (Kyoto group less Russia) follow an allowance path that is falling linearly from the simulated Kyoto emissions levels in 2012 to 83% below 2005 in 2050. Group 2 countries (rest of world) adopt a policy beginning in 2025 that caps emissions at 2015 levels, and linearly reduce emissions to 26% below 2005 levels by 2050.

While there are important differences between the American Power Act (APA) and the House passed bill ACES (H.R. 2454), the modeled impacts of the APA are very similar to those of ACES:

- Estimated allowance prices under the two bills differ on the order of 0-1%.
- The percentage reductions represented by the emissions caps are identical beginning in 2013.
- Both bills allow for 2 billion tons of offsets in each year.
- Both bills contain provisions to prevent emissions leakage and to address competitiveness concerns.
- The Cost Containment Reserve provisions of the APA provide a greater level of price certainty than do provisions in H.R. 2454’s Strategic Reserve Allowance Program by, among other things, allocating a greater share of allowances to the reserve. This higher level of price certainty comes at a slightly higher cost to the APA over H.R. 2454.
- The APA’s approach to cover GHGs from the transportation fuels and refined products sectors does not impact modeled allowance prices.

Allowance Prices

EPA’s analysis finds that allowance prices under both the APA and H.R. 2454 are projected to be $16 to $17 per metric ton CO_2 equivalent (tCO_2e) in 2013 and $23 to $24/ tCO_2e in 2020 in the core APA scenario. Across all scenarios modeled without constraints on international offsets, the expected allowance price ranges from $12 to $22/$tCO_2e$ in 2013 and from $17 to $32/$tCO_2e$ in 2020 (see Figure 1).

<u>Offsets</u>:
Offsets have a strong impact on cost containment. While the APA allows for up to one billion tons of international offsets each year, EPA has included scenarios that limit the availability of international offsets in order to demonstrate the impact these provisions of the bill have on costs. If international offsets were not allowed, the allowance price would increase 34 to 107 percent relative to the core policy scenario, and household consumption losses would increase 31 to 114 percent, the large range due to the differing international offset core scenario usage projections of EPA’s two models. Additional sensitivities show that if the availability of international offsets to the U.S. is simply delayed 10 years, then allowance prices increase by only one percent.

The annual limit on domestic offsets is never reached in the core scenario. Domestic offset usage averages approximately 0.6 billion tCO_2e in each year. This represents approximately 19 percent of cumulative GHG abatement from all sources under the bill (see Figure 2). The limits on the usage of international offsets (accounting for the extra international offsets allowed when the domestic limit is not met) are not reached. International offset usage averages between 0.6 and almost 1 billion tCO_2e each year in the core scenario. This represents 18 to 29 percent of cumulative GHG abatement from all sources under the bill.

Impact on Consumers:

The APA has a relatively modest impact on U.S. consumers, assuming the bulk of revenues from the program are returned to households lump-sum. Average household consumption is reduced, relative to the no-policy case, by 0.0 – 0.1% in 2015, by between 0.0 – 0.2% in 2020, by 0.2 – 0.5% in 2030, and by 0.9 – 1.1% in 2050. Despite the expected decrease in consumption over the no-policy case, average household consumption is still expected to rise over the period of analysis: the average consumption growth rate from 2010-2030 under the core scenario is expected to be between 2.5% and 2.8%. The net present value of the annual household consumption loss averages $79 to $146 for each year. These costs include the effects of higher energy prices, price changes for other goods and services, and impacts on wages and returns to capital. Cost estimates also reflect the value of some of the emissions allowances returned to households, which offsets much of the APA's effect on household consumption.

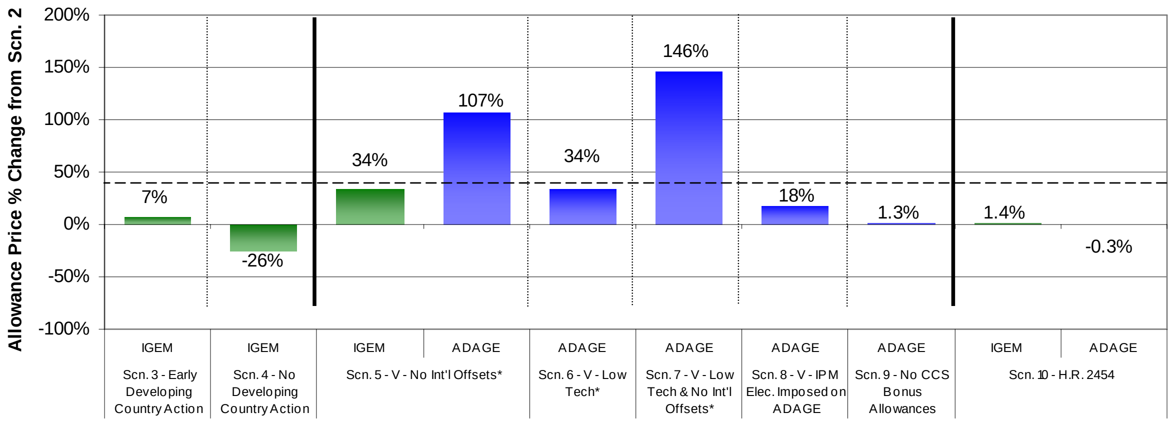
If auction revenues that are modeled as being returned to households lump sum were instead directed to particular funds, the expected reduction in household annual consumption and GDP would likely be greater. However, such revenues could be used to lower existing distortionary taxes and thus reduce policy costs.

Competitiveness:

Competitiveness and emissions leakage are topics explicitly addressed in the December 2, 2009 interagency report on ACES, "The Effects of H.R. 2454 on International Competitiveness and Emission Leakage in Energy-Intensive Trade-Exposed Industries."[3] Consistent with prior EPA modeling of this issue in its June 23, 2009 analysis of ACES, the economic modeling in the interagency report shows that the allowance allocations in ACES can essentially eliminate any adverse effect that a cap-and-trade program would otherwise have on energy-intensive trade-exposed industries' international competitiveness, and can thereby prevent emissions leakage that might otherwise arise if such a program were to reduce the competitiveness of U.S. industry.

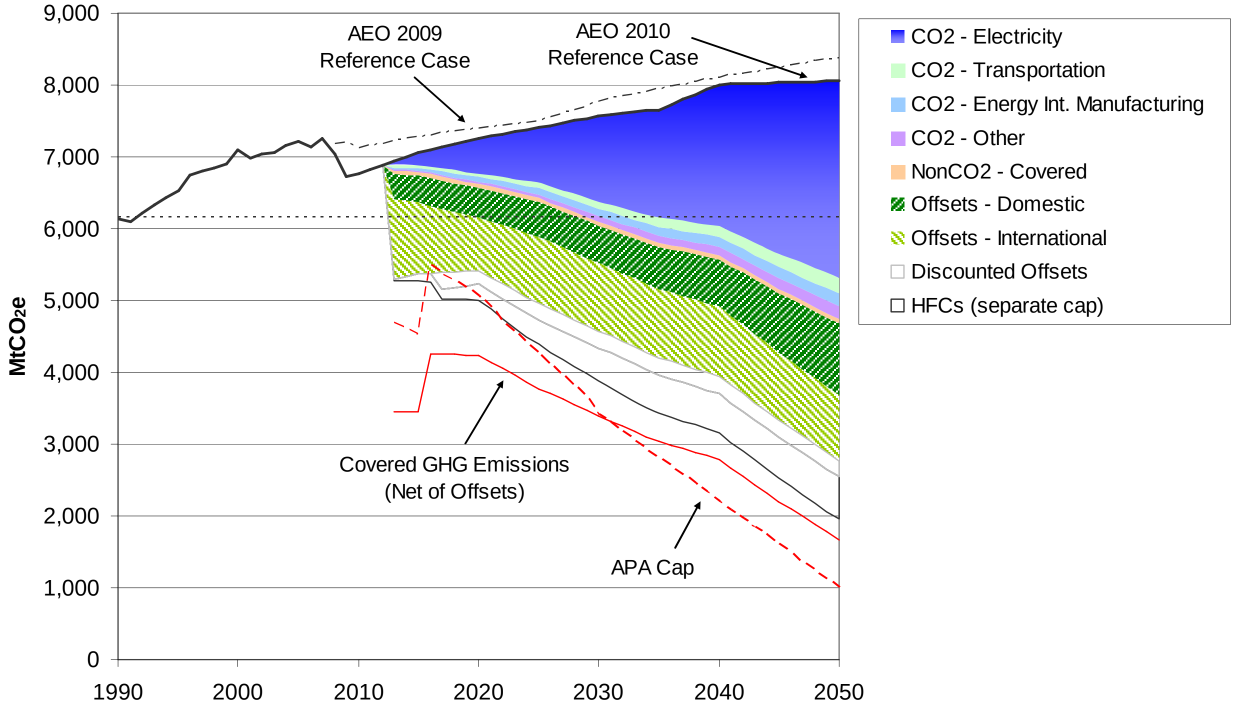
The modeling also concludes that, even in the absence of the allowance allocations in H.R. 2454, on average, the bill's impact on the competitiveness of energy-intensive trade-exposed industries would be relatively limited. However, some industries would experience greater impacts than others. While this analysis contains a set of scenarios that cover some of the important uncertainties when modeling the economic impacts of a comprehensive climate policy, other uncertainties remain that could significantly affect the results.

Figure 1. GHG Allowance Prices & Sensitivities in APA



[3] The interagency report is available at www.epa.gov/climatechange/economics/economicanalyses.html.

Figure 2. Total US GHG Emissions & Sources of Abatement: Reference and Core APA Policy Scenario



Climate Change and the Clean Air Act (CAA)

With no agreement among members of the Senate on a bill, and with membership of Congress dependent on the results of elections to occur in early November 2010, the fate of a near-term national comprehensive policy on climate mitigation remains unclear. While limited by the actions of Congress, the President has made a number of decisions that will lead to lower GHG emissions, including the passage of incentives for renewable energy and energy efficiency in the American Recovery and Reinvestment Act of 2009, release of executive orders that direct federal government agencies to carry out climate mitigation actions, and movement via the EPA to regulate GHG emissions under the Clean Air Act.

In 2009, the Environmental Protection Agency issued a Rule requiring reporting of greenhouse gas emissions from approximately 10,000 U.S. facilities, approximately 85% of total U.S. GHG emissions. Under the rule, suppliers of fossil fuels and industrial GHGs, manufacturers of vehicles and engines, and facilities that emit 25,000 metric tons or more per year of GHGs are required to submit annual reports to EPA. Compiling comprehensive and accurate data on GHG emissions from U.S. sources lies at the cornerstone of U.S. climate mitigation efforts. Annual reporting began in 2010, with the data to be submitted and made available to the public in mid-2011.

The Clean Air Act, a federal law passed by the U.S. Congress in 1970, also established the Environmental Protection Agency as the steward of environmental health in the country. Under the CAA, EPA sets quantity limits on certain air pollutants. U.S. states are obligated to develop State Implementation Plans that outline how each state will control air pollution under the CAA. If a state does not fulfill its responsibilities under the CAA, the EPA can issue sanctions against the state and may take over enforcing the CAA in that area.

In 2007, the United States Supreme Court decided that greenhouse gases are subject to consideration for regulation under the CAA, obligating the U.S. EPA to review evidence of harm to the U.S. public from GHG emissions. In December 2009, the EPA released its final "Endangerment Finding," which found that GHG emissions are harmful to the public and subject to limits under the CAA. The U.S. EPA is in the process of a series of rulemakings that limit greenhouse gas emissions.

In April 2010 the EPA and the U.S. National Highway Traffic Safety Administration (NHTSA) jointly released a final rule that sets the first ever harmonized GHG and fuel economy standards for light-duty vehicles of model years 2012-2016. The rule thus covers 60% of GHG emissions from the transportation sector. EPA is in the process of extending regulations beyond 2016 and developing a rule that covers heavy-duty vehicles.

The May 2010 “Tailoring Rule” aims to phase in GHG reduction obligations for smaller businesses by setting a threshold of 75,000 – 100,000 tons per year above which facilities will be subject to GHG regulation under the Clean Air Act in the near term. Roughly 70% of GHG emissions from stationary sources will be regulated upon implementation of the Tailoring Rule.

For More Information

U.S. 2010 National Communication: http://unfccc.int/resource/docs/natc/usa_nc5.pdf

EPA:
Climate Change: http://epa.gov/climatechange/index.html
Climate Economics: http://epa.gov/climatechange/economics/index.html
GHG Regulations: http://epa.gov/climatechange/initiatives/index.html

INTRODUCTION

In this contribution to the symposium on "Local Property, Global Justice: Law and Resources in the Era of Climate Change," I examine a property theory approach to the international legal structure of climate change regulation. My analysis proceeds in three parts. Part I frames the discussion by describing the tragedy of the climate commons and the menu of regulatory instruments available to solve this global problem. Part II outlines the choice between the two most prominent regulatory instruments on the current menu: prices (taxes) versus property (a cap and trade system). Part III argues that the difficulty of engaging participation in international regulatory schemes means that the cap and trade system is better suited than a tax system to solving the problem of global climate change. I conclude that a property-based instrument has distinct advantages over a price based instrument to protect the global climate commons at the international level.

THE TRAGEDY OF THE CLIMATE COMMONS AND POTENTIAL SOLUTIONS

The planet is suffering a tragedy of the climate commons.[4] Emissions of greenhouse gases (GHGs) pose external harms. Emissions emanating from anywhere on the planet mix globally in the atmosphere and cause global impacts, although those impacts vary regionally. The atmosphere is being treated as an open-access disposal site for GHGs. Abatement of GHG emissions is costly to the actors who undertake abatement, and the benefits of abatement are spread globally, so each actor faces an incentive to continue emitting – that is, to free ride on others' abatement efforts. The result is that abatement is underprovided compared to the global optimum.

The fundamental legal question, as in any tragedy of an open-access resource problem, is how best to restrict access. To solve the tragedy of the climate commons, the international community has a choice of regulatory instruments for environmental protection. The menu of options available includes regulatory instruments that restrict GHG-emitting conduct (such as regulations mandating, or forbidding, the use of particular technologies); instruments that restrict the quantity of access to the commons to dispose of GHGs (such as property rights, performance standards, and cap and trade systems); instruments that set the price of access to the commons to dispose of GHGs (such as taxes or liability rules that charge a price for each use of the resource); instruments that use information disclosure on GHG emissions to influence behavior; and instruments that attempt to engineer the climate directly.[5]

Historically, U.S. domestic environmental law often chose to regulate conduct by instructing firms to adopt particular designs or technologies to reduce pollution.[6] Examples of such conduct standards include requirements to install scrubbers to reduce air pollution, to install filters to reduce water pollution, or to avoid the use of certain types of fish nets.

More recently, the United States increasingly has used a second type of policy tool: quantity or property instruments that solve the tragedy of an open-access resource by limiting the quantity of access to the resource. In principle, this means dividing the resource, parceling it, and privatizing it in some way. For land, the U.S. legal system typically prevents open-access overuse by spatially dividing the resource into limited-access parcels (what we call private property). Such spatial parceling does not work very well for managing pollutants in the atmosphere or fish in the oceans. For mobile resources, the quantity/property instrument to limit access takes the form of a use right, not a fixed possessory right.

[4] For the classic exposition of tragedies of open-access resources, see generally Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243 (1968), *available at* http://www.sciencemag.org/cgi/content/full/162/3859/1243. For a more detailed application to the global climate problem, see generally RICHARD B. STEWART & JONATHAN B. WIENER, RECONSTRUCTING CLIMATE POLICY: BEYOND KYOTO (2003) [hereinafter STEWART &WIENER, RECONSTRUCTING CLIMATE POLICY].

[5] For a more complete taxonomy and analysis of climate policy instruments, see generally Jonathan Baert Wiener, *Global Environmental Regulation: Instrument Choice in Legal Context*, 108 YALE L.J. 677 (1999) [hereinafter Wiener, *Global Environmental Regulation*]. The contributions by my colleagues in this symposium session focus on cap and trade and related offset systems. *See* Annie Petsonk, '*Docking Stations': Designing a More Welcoming Architecture for a Post-2012 Framework to Combat Climate Change*, 19 DUKE J. COMP. & INT'L L. 433 (2009) (arguing that docking stations can be a means of increasing the participation of major emitting nations in cap-and-trade programs); David Driesen, *Linkage and Multilevel Governance*, 19 DUKE J. COMP. & INT'L L. 389 (2009) (arguing that limiting linkage of different cap-and-trade markets while increasing efforts to stimulate innovation would better accomplish the goals of the cap-and-trade program).

[6] *See* Wiener, *Global Environmental Regulation*, *supra* note 2, at 705-06.

A limited use right could be created by a regulatory performance standard that limits overuse but (in contrast to conduct instruments) allows users "how" flexibility in choosing the methods of compliance or abatement. Examples of performance standards are regulations that set a maximum allowable amount of pollution or fish caught over a period of time.

Alternatively, such a limited use right might be made transferable among users, through a tradeable allowance, marketable permit or transferable quota system—all names for a cap and trade system. These instruments limit the quantity of access to the open-access resource, while providing users both "how" flexibility in choosing the methods of compliance and also "where" flexibility in choosing the location of abatement across users. If costs of abatement vary across methods and across users, then these two types of flexibility ("how" and "where") can improve the cost-effectiveness of the regulatory policy. "When" flexibility can also be afforded by letting sources shift their abatement effort over time, or by allowing banking and borrowing of allowances over time. For climate change, with wide variation in the costs of abatement across firms, sectors and countries, a cap and trade system could reduce costs very substantially compared to fixed performance standards and even more compared to central conduct standards.[7]

A third type of regulatory instrument relies on prices to limit access. A price instrument limits access to the open-access resource not by telling actors what to do nor how much they may do, but by telling actors the price they must pay to do it. Examples of price instruments include taxes on emissions, or subsidies to reduce emissions, or liability rules that impose monetary damages on emissions as nuisances.

A fourth type of instrument is information disclosure, which force actors to report or reveal their emissions or other risk-related behavior. Examples include the Toxics Release Inventory, and proposals for a GHG Emissions Inventory.

A fifth type of instrument seeks not to reduce emissions of GHGs, but to manage the heat balance of the planet directly through geoengineering projects, such as mirrors put into orbit around the earth, or sulfate aerosols injected into the upper atmosphere to try to cool the planet. The choice of regulatory instruments for environmental protection should always be based on a pragmatic evaluation of which instruments will yield the best results. In discussing the strengths and weaknesses of any regulatory instrument, it is always necessary to ask, compared to what alternative?

THE CHOICE BETWEEN TAXES AND TRADING

In this section, I focus on the choice currently being debated between a GHG tax (price instrument) and a GHG cap and trade system (quantity/property instrument) as alternative tools to limit emissions, especially at the international level. Many (though not all) economists favor taxes rather than cap and trade as an instrument to regulate greenhouse gas emissions.[8] These economists argue that taxes produce at least two major advantages. First, taxes contain costs, because setting the tax lets firms know what the price per unit of emissions will be. If the true cost of abatement turns out to be higher than the tax, firms will pay the tax instead of undertaking the abatement, and thereby the tax sets the upper limit on costs. The downside is that it is unclear what the emissions result will be. (Some say that cap and trade hides the cost while taxes make the cost explicit; but one could equally say that taxes hide the emissions result while cap and trade makes the emissions result explicit.) Many economists argue that in the tradeoff between the risk of

[7] *Id.* at 716.

[8] Economists favoring taxes include, for example, William D. Nordhaus, *To Tax or Not to Tax: Alternative Approaches to Slowing Global Warming*, 1 REV. ENVTL. ECON. & POL'Y 26 (2007) (favoring taxes); Ian. W. H. Parry & William A. Pizer, *Emissions Trading Versus CO2 Taxes Versus Standards*, *in* ASSESSING U.S. CLIMATE POLICY OPTIONS: A REPORT SUMMARIZING WORK AT RFF AS PART OF THE INTER-INDUSTRY U.S. CLIMATE POLICY FORUM 79 (2007) (favoring taxes), *available at* http://www.rff.org/rff/Publications/upload/31809_1.pdf.

Economists favoring cap and trade include, for example Robert N. Stavins, *A Meaningful U.S. Cap-and-Trade System to Address Climate Change*, 32 HARV. ENVTL. L. REV. 293 (2008) (favoring cap and trade); Nathaniel Keohane, *Cap and Trade, Rehabilitated: Using Tradable Permits to Control U.S. Greenhouse Gases*, 3 REV. ENVTL. ECON. & POL'Y 42 (2009) (favoring cap and trade).

cost escalation (under cap and trade) and the risk of emissions escalation (under taxes), it is better to limit costs and to tolerate some emissions escalation.[9]

Second, some economists often prefer pollution taxes on the ground that they raise revenues,[10] which can in turn be used to replace and reduce other more distortionary taxes on labor and capital – as Al Gore says, we should "tax what we burn, not what we earn."[11] Others see this revenue as a source of funding to invest in clean technology projects.

Neither containing costs nor raising revenues, however, should be understood as a fundamental objection to cap and trade. They are both important considerations. But cap and trade systems can be designed to meet both of these objectives.

Cap and trade systems can be designed to contain costs in several ways. First, the stringency of the cap obviously affects costs. Second, given a cap, the design of the trading system can help avoid cost escalation. Most directly, the "how" and "where" flexibility in cap and trade systems keep costs low by allowing firms to find the least-cost methods and locations of abatement. Third, a broader and thicker market enhances the cost-effectiveness of trading by engaging lower-cost abatement opportunities. Extending the cap and trade market to include all sectors of the economy, and to include international participants,[12] will further ensure cost-effectiveness. Fourth, allowing "when" flexibility through multi-year budgets, banking, and borrowing can further reduce costs.

Fifth, a cap and trade system can be modified by adding price ceilings and price floors, ensuring that the cap and trade market will operate within a constrained range of prices. (These price ceilings and floors can be set to rise over time.) A pure price ceiling on a cap and trade system is known colloquially as a "safety valve," because it enables sources to purchase unlimited additional allowances at the price ceiling, thereby preventing the market price from rising too high.[13] In effect, the safety valve converts that cap and trade system into a tax at the price ceiling; it removes the cap at that price. This is attractive to those concerned about cost escalation, but worrisome to those concerned about emissions escalation.[14] On the other hand, the addition of a price floor ensures that the market price for allowances will not fall too low, thus ensuring some pressure to reduce emissions. Modifying a cap and trade system by applying both a price ceiling and a price floor might be an attractive compromise. The combination of upper and lower bounds on allowances prices could reduce price volatility and associated investment uncertainty, lower the expected cost of the cap and trade system, and ensure at least some incentive to reduce emissions. This symmetric

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[9] *See* PARRY & PIZER, *supra* note 5, at 83 (suggesting that a cap and trade program with cost-containment mechanisms represents a compromise between cost escalation and emissions escalation). This line of argument derives from the classic paper by Martin L. Weitzman, *Prices vs. Quantities*, 41 REV. ECON. STUD. 477 (1974).

[10] *See* Lawrence H. Goulder, *Environmental Taxation and the Double Dividend: A Reader's Guide*, 2 INT'L TAX & PUB. FIN. 157 (1995); Lawrence H. Goulder et al., *Revenue- Raising versus Other Approaches to Environmental Protection: The Critical Significance of Preexisting Tax Distortions*, 28 RAND J. ECON. 708 (1997); Lawrence H. Goulder et al., *The Cost-Effectiveness of Alternative Instruments for Environmental Protection in a Second-Best Setting* (Nat'l Bureau of Econ. Research, Working Paper No. 6464, 1998); Ian W. H. Parry, *Pollution Taxes and Revenue Recycling*, 29 J. ENVTL. ECON. & MGMT. S64, S65, S76 (1995). *But see* Wallace E. Oates, *Green Taxes: Can We Protect the Environment and Improve the Tax System at the Same Time?*, 61 S. ECON. J. 915 (1995) (questioning the validity of the double-dividend argument).

[11] *See* John M. Broder, *House Bill for a Carbon Tax to Cut Emissions Faces a Steep Climb*, N.Y. TIMES, Mar. 7, 2009, at A13 (quoting Al Gore), *available at* http://www.nytimes.com/2009/03/ 07/us/politics/07carbon.html.

[12] I am referring here to an international system of cap and trade policies, not to a U.S. cap and trade policy linked to offset credits purchased in countries without caps. Such uncapped offset credits, like the Clean Development Mechanism (CDM) under the Kyoto Protocol, can further reduce costs, but they are less effective at reducing actual emissions because the credits come from countries without caps. *See* STEWART & WIENER, RECONSTRUCTING CLIMATE POLICY, *supra* note 1, at 74, 90-92.

[13] *See, e.g.*, William A. Pizer, *Combining Price and Quantity Controls to Mitigate Global Climate Change*, 85 J. PUB. ECON. 409, 431 (2002).

[14] An additional problem with a price ceiling, particularly in the international context, is strategic: if multiple countries have safety valve policies that authorize them to sell extra allowances, and if these allowances can satisfy obligations in multiple countries, then as emitters seek to purchase the lowest-priced extra allowances they can find worldwide, country governments will compete to sell allowances at lower prices – that is, to lower their safety valve price ceilings, thus further relaxing the constraint on emissions. *See* STEWART & WIENER, *supra* note 1, at 90-92.

approach could even lower costs so much that it enables policy makers to adopt a more stringent cap at a lower cost than an unmodified cap and trade system.[15]

An alternative to a price ceiling is to create a limited reserve of additional allowances, which could be sold once the market price rises to a trigger price. This limited quantity reserve is similar to a safety valve, except that the quantity of the reserve is not unlimited as it would be under a pure price ceiling, or it can be seen as a limited opportunity to borrow against future allowance allocations for current use.[16] A limited quantity reserve would pose less risk of emissions escalation than a pure price ceiling.

Furthermore, cap and trade systems can be designed to raise revenues by selling or auctioning the allowances. Cap and trade is a quantity instrument (limiting emissions) that derives from a property approach (parceling temporary use rights) to solving the tragedy of the climate commons. These use rights can be given away by the government to historical users (called "grandfathering"), but they can also be sold to users. In a sale or auction of GHG emissions allowances, the state earns the revenues from the allocation of use rights in the public commons, rather than awarding the scarcity value of those use rights to private emitters for free.[17] The Obama administration's first budget, introduced in February 2009, projects significant revenues from auctioning GHG allowances.[18] Under an international cap and trade system, presumably the choice of whether to auction or otherwise distribute allowances would be left to each country to decide.

Thus, cost containment and revenue generation are not fundamental differences between a tax and a cap and trade system. But there is a key difference, as I discuss in the next section.

PRICES, PROPERTY, AND PARTICIPATION

The deeper distinction between taxes (price instruments) and cap and trade (quantity/property instruments) lies in their different abilities to engage effective participation. At the international level, there is no global sovereign to select a policy and compel compliance.[19] We must act, if at all, with current institutions. A basic principle of international law is that treaties bind countries only by their consent. Thus, an effective climate treaty must engage countries' participation – and engaging participation is powerfully influenced by the choice of the regulatory instrument.

Global Emissions

Central to the choice of regulatory instrument and the challenge of attracting participation is the fact that greenhouse gases mix globally in the atmosphere – a crucial reason that GHG emissions pose a tragedy of the climate commons. Because GHG emissions from anywhere on the planet affect the planet globally, any effective regulatory framework will require participation by multiple countries to produce the global public good of climate protection. Emissions from major developing countries, unconstrained under the Kyoto Protocol, have been rising rapidly.[20]

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[15] *See* Dallas Burtraw, Karen Palmer & Danny Kahn, *A Symmetric Safety Valve*, (Resources for the Future Discussion Paper 09-06, Feb. 2009), *available at* www.rff.org; Cedric Philibert, *Price Caps and Price Floors in Climate Policy: A Quantitative Assessment* (Int'l Energy Agency, Dec. 2008).

[16] *See* Brian C. Murray, Richard G. Newell & William A. Pizer, *Balancing Cost and Emissions Certainty: An Allowance Reserve for Cap-and-Trade* (Nat'l Bureau of Econ. Research, Working Paper No. 14258), *available at* http://www.nber.org/papers/w14258. The allowance reserve could operate automatically when the market price rises to the trigger price, or the allowance reserve could be managed by a "Carbon Fed" board with the power to authorize additional allowance sales or greater use of offset credits. *Id.* at 20.

[17] *See* Gerald Torres, *Who Owns the Sky?*, 18 PACE ENVTL. L. REV. 227, 281-82 (2001).

[18] OFFICE OF MGMT. & BUDGET, EXECUTIVE OFFICE OF THE PRESIDENT, A NEW ERA OF RESPONSIBILITY: RENEWING AMERICA'S PROMISE 21 (2009), *available at* http://www.white house.gov/omb/assets/fy2010_new_era/A_New_Era_of_Responsibility2.pdf ("Through a 100 percent auction to ensure that the biggest polluters do not enjoy windfall profits, this program will fund vital investments in a clean energy future totaling $150 billion over 10 years, starting in FY 2012.").

[19] Some highly concerned about climate change might seek to establish a coercive world government, but even if that could be done (with all its drastic disadvantages), it would likely take too long to be relevant to solving the climate problem.

[20] *See* Jonathan B. Wiener, *Climate Change Policy and Policy Change in China*, 55 UCLA L. REV.1805, 1807-10 (2008); INTERNATIONAL ENERGY AGENCY, WORLD ENERGY OUTLOOK 2008 (2008).

Moreover, partial action, in the form of a regulatory regime that covers only some emitting countries, is vulnerable to the problem of "leakage": cross-national movement of emissions-intensive activities.18[21] Leakage could occur through relocation of specific facilities, or through changing relative prices in the world economy which induce shifts in emissions-intensive activities. Economic studies of how the world economy would respond to partial regulation suggest that leakage could be quite significant. For example, the MIT Joint Program on the Science and Policy of Global Change, which has developed a very extensive integrated assessment model, has found that leakage rates could be very high, even exceeding 100%, depending on the stringency of the cap or tax and depending on which countries are covered.[22]

Leakage exceeding 100% means that partial regulation by some countries (such as the US and Europe) would actually contribute to more GHG emissions, not less, by shifting emitting activities to other countries. To see how this could happen, it is useful to look at the micro level. There is anecdotal evidence that leakage already is occurring from Europe (seeking to restrict its GHG emissions) to China (where GHG emissions have been growing rapidly). A

December 2007 front page story in the *New York Times* attributed a reduction in Germany's emissions, restricted under European policies, to leakage.[23] According to the article, German steel factories were dismantled, shipped to China, and rebuilt there, where steel manufacturing emits three times more carbon dioxide per ton of steel because of a different fuel mix and inefficiencies in production.[24]

Leakage also imposes political costs. Leakage renders receiving countries like China more GHG-intensive and thus more reluctant to restrict emissions. At the same time, the fear of leakage inhibits countries like the United States from adopting restrictions on their own greenhouse gas emissions. Such political costs explain, for example, why the U.S. Senate voted 95-0 not to ratify a treaty like the Kyoto Protocol in 1997 for fear of leakage of industry and jobs.[25]

<u>Participation</u>

Thus, the pivotal criterion for achieving an effective international regulatory regime for climate change is whether the international community can accomplish sufficiently broad participation. Participation need not include every single country in the world, but the great majority of current and future major emitting countries must participate in the regime for it to be effective. Such participation might require as few as the top twenty or thirty emitting countries. This still poses the significant challenge in a post-Kyoto treaty

(currently being negotiated) of adding the major developing countries (including China, India, Brazil, Indonesia, Mexico, South Africa, Korea, and others), as well as the United States, to the set of countries that were obliged to limit their emissions under the Kyoto Protocol (including Europe, Japan, Canada, Australia, and Russia)

The consent voting rule in international treaties is quite different from the voting rule we have for the adoption of most environmental regulation, most property rule systems, and most legal systems. Consider the spectrum of voting rules running from unitary fiat at one end, where one autocratic ruler can choose the regulatory policy; through majority rule in the middle, where 50% plus one of a polity can choose a regulatory rule; to consent and even unanimity at the other end of the spectrum.[26] Along that spectrum, more and more votes are required to adopt a policy. Recruiting these votes requires showing that it is in the interest of each actor to endorse or join the proposal.

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[21] *See* STEWART & WIENER, *supra* note 1, at 39, 88.

[22] *See* Mustafa H. Babiker, *Climate Change Policy, Market Structure, and Carbon Leakage*, 65 J. INT'L ECON. 421, 441 (2005) ("[T]he global carbon leakage rate is found to range. . . [as high as] 130%, in which case a policy to limit carbon emissions in the OECD has the perverse effect of increasing global emissions.").

[23] *See* Joseph Kahn & Mark Landler, *China Grabs West's Smoke-Spewing Factories*, N.Y. TIMES, Dec. 21, 2007, at A1 ("[T]he same hulking blast furnace, dismantled and shipped piece by piece from Germany's old industrial heartland to Hebei Province, China's new Ruhr Valley. The transfer, one of dozens since the late 1990s, contributed to a burst in China's steel production, which now exceeds that of Germany, Japan and the United States combined. It left Germany with lost jobs and a bad case of postindustrial angst. . . . China's less efficient steel mills, and its greater reliance on coal, meant that it emitted *three times as much carbon dioxide per ton of steel* as German steel producers." (emphasis added)).

[24] *See id.*

[25] *See* Byrd-Hagel Resolution, S. Res. 98, 105th Cong. (1997). After this vote, the Clinton-Gore administration never submitted the Kyoto Protocol to the Senate for ratification.

[26] For a more detailed discussion, see Wiener, *Global Environmental Regulation*, *supra* note 2.

Thus, for example, obtaining a majority coalition requires persuading members of Congress that they should vote in favor of a particular regulatory policy. Obtaining consent to a treaty requires persuading governments of each country to adopt that treaty. Such voting requirements have a fundamental implication for the design and the choice of regulatory instruments at the international level, as well as at the national level.[27] The comparison of taxes to cap and trade typically assumes a voting rule of unitary fiat - what James Buchanan has called a supposed benevolent despot who will choose the normatively efficient instrument.[28] Such analysis recommends the instrument that maximizes aggregate net benefits to society. In the international law arena, however, no unitary fiat actor exists. There is no global sovereign. As a result, the solution has to engage cooperation and participation by countries, and it must do so on terms that governments find attractive - otherwise they will decline to join.

As with any international policy problem, there are ways of using sticks and ways of using carrots to achieve the policy goal. Here I will not dwell at length on sticks; military coercion to reduce GHG emissions is unlikely, and trade sanctions tend to be ineffective because they are often not credible (given the harms they inflict on the imposing country's own consumers) and because target countries often rally to resist and deflect them. And if trade sanctions were effective, they might undermine rather than enhance the target country's economic capacity to remake its economy on a low-GHG emissions path.

In the absence of effective sticks, the key issue is carrots, including the direct benefits of climate protection, and side payments provided by the international regime. The question is thus not just which regulatory instrument to choose, but how to pair the necessary inducements that attract countries to participate with the regulatory instrument. On this question, property (cap and trade) and prices (taxes) perform quite differently.

Attracting China to participate in a GHG emissions limitation regime will not be easy. A main concern has been that China would not participate in a climate change treaty on the grounds that China's leaders thought the costs to China would be high and the benefits to China would be low or negative.[29] Yet there are indications that China's stance on the issue is now changing. China's leaders are seeing greater incentives to join a serious effort that limits its own greenhouse gas emissions, as well as those of other countries, for several reasons: first, the impacts of climate change in China are now looking more serious than earlier anticipated; second, the co-benefits in public health protection of limiting emissions from fossil fuel
production are growing; third, the Chinese government may be concerned about political instability arising from extreme weather events associated with climate change, against the backdrop of a history of dynastic change in China triggered by past climate changes and a public philosophy connecting natural disasters to regime change; and fourth, the strong interest of the Chinese government and people in prosperity can be promoted through the design of the international climate regime itself.[30]

The last point is crucial: the international regime must offer attractive reasons to China, and other major developing countries, to join and to implement effective policies. Otherwise their emissions will grow unabated and may accelerate due to leakage. Attracting their participation means offering a combination of benefits – in climate protection, reduction in co-pollutants, economic gains, national reputation, fairness, and side payments (as well as other benefits) – that justify the costs and make joining in the perceived national interest of each country.

At the international level, taxes are unlikely to attract participation. Taxes impose costs not only on emissions, but also on infra-marginal emissions – that is, they not only discourage emissions, but they also require parties to pay for their remaining unabated emissions. If a country views the benefits of joining a

[27] *See id.*; STEWART & WIENER, *supra* note 1.
[28] *See* James M. Buchanan, *The Constitution of Economic Policy*, 77 AM. ECON. REV.
243, 243 (1987) ("Economists should cease proffering policy advice as if they were employed by a benevolent despot, and they should look to the structure within which political decisions are made. . . . [We should] postulate some model of the state, of politics, before proceeding to analyze the effects of alternative policy measures.").
[29] *See* STEWART & WIENER, *supra* note 1; Cass R. Sunstein, *The World vs. the United States and China? The Complex Climate Change Incentives of the Leading Greenhouse Gas Emitters*, 55 UCLA L. REV. 1675, 1682 (2008).
[30]

climate treaty as small or even negative, then it is unlikely to adopt a tax on its own emissions, and even less likely to allow an international body to impose that tax on (and keep the revenues from taxing) the country's emissions.

To attract participation, a tax could be combined with some kind of side payment to repay the costs of the tax, such as direct government-to-government foreign aid. Foreign aid, however, is often an inefficient way to deliver resources. It is often distorted by corruption, and often undermines indigenous industry. If coupled with a tax on GHG emissions, foreign aid to repay the cost of that tax would undermine the incentive effect of the tax in reducing emissions. The essential feature of price instruments – that they restrict access to the commons by setting the price but not constraining the quantity of resource use – means that coupling taxes with side payments of cash will tend to offset the price instrument's effectiveness in reducing emissions. Indeed, pure payments to abate emissions can even turn out to increase net emissions by attracting more investment to the subsidized industry.[31]

This logic means that taxes combined with cash aid will be less effective at controlling emissions than pure taxes or than quantity/property instruments that cap emissions. This is not surprising, as the key point of the economics literature comparing taxes and trading, discussed above, was that taxes limit costs while letting emissions vary, whereas cap and trade limits emissions while letting costs vary. The pivotal new dimension at the international level, not addressed by that literature, is that a tax or cap and trade system cannot simply be imposed on emitters; countries must consent to be bound by a treaty, so they will often require side payments to attract their participation. The side payments, like subsidies to abate, introduce their own inefficiency. Combining side payments with taxes is less effective at limiting GHG emissions than using a cap and trade system to allocate side payments.

A better system to limit GHG emissions at the international level is a cap and trade system in which the allowance allocation delivers the side payment that attracts countries to join. Giving major developing countries "headroom" allowances amounting to some future growth in emissions would confer on them some of the scarcity rents in the new market for limited emissions use rights, which they could sell in the trading market to higher-cost abaters (firms in industrialized countries) at a profit. The developing countries would thereby reap the side payment attracting their participation, while still acceding to a quantity limit on emissions which prevents the perverse effect of side payments on aggregate emissions. China, for example, could be a net loser under a system of national caps or national taxes, but a net gainer under a system of cap and trade with allowance allocations that embody this principle. Thus, a quantity/property based cap and trade system can more effectively (or less inefficiently) combine emissions limits with side payments to attract participation than can a tax or pure subsidy approach.[32]

Empirically, the quantity/property approach to engaging participation appears to have proven more successful than the price approach. During the 1990s the European Union tried to adopt an EU carbon tax, and failed in large part because it could not secure consent among its member states to adopt the same tax in poorer and richer countries alike. After a decade of pursuing this carbon tax unsuccessfully while denouncing cap and trade, the EU changed its position on instrument choice during 1998-2001 and successfully adopted the EU Emissions Trading System, using its "burden-sharing agreement" (in effect, an allocation of allowances) to attract participation by member states.[33] Similarly, the US used the allocation of allowances in its 1990 Acid Rain Trading Program to build the majority coalition for passage in

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[31] *See* WILLIAM J. BAUMOL & WALLACE E. OATES, THE THEORY OF ENVIRONMENTAL POLICY 211-28 (2d ed. Cambridge Univ. Press 1988) (1975) (noting that abatement subsidies would reduce emissions at each firm but increase the size of the polluting industry and observing that using subsidies could conceivably increase net emissions); Wallace E. Oates, *Economics, Economists, and Environmental Policy*, 16 E. ECON. J. 289, 290 (1990) ("[I]n a competitive setting, [abatement] subsidies will lead to an excessively large number of firms and industry output. . . . [I]t is even conceivable that aggregate industry emissions could go up!" (citations omitted)); Robert E. Kohn, *When Subsidies for Pollution Abatement Increase Total Emissions*, 59 S. ECON. J. 77, 84-85 (1992).

[32] For more detailed discussion, see Wiener, *Global Environmental Regulation*, *supra* note 2.

[33] *See* FRANK CONVERY, DENNY ELLERMAN, & CHRISTIAN DE PERTHUIS, THE EUROPEAN CARBON MARKET IN ACTION: LESSONS FROM THE FIRST TRADING PERIOD: INTERIM REPORT 7-8 (2008), *available at* http://web.mit.edu/globalchange/www/ECM_Interim Rpt_March08.pdf.

the Congress, and the Kyoto Protocol used the allocation of allowances to engage participation by Russia and Ukraine.[34]

The implications for global justice are direct. A cap and trade system would deliver both future climate protection benefits to vulnerable countries (which are often poor countries), and also side payments in the form of headroom allowances that will support their development goals, local industry, and prosperity in the near term through trade in a new global marketplace of investment in cleaner technology and land use conservation. It would do so through cost-effective transactions by competitive private market actors. By contrast, an international GHG tax system either will impose costs on developing countries (leading to their choice not to participate), or will be combined with side payments that undermine the climate protection effectiveness of the tax and that are delivered through government foreign aid. Government foreign aid, generally speaking, is less cost-effective than market trade, is often distorted by corruption, often undermines local industry, and can yield perverse increases in emissions. International cap and trade thus promises to be more cost-effective, less bureaucratic, more supportive of poverty alleviation, and more fair than an international tax system.

A caveat: The "clean development mechanism" (CDM) under the Kyoto Protocol, or other systems for purchasing GHG emission offsets via project-specific investments in abatement in countries without caps are not truly cap and trade systems and lack its key advantages. The CDM and similar offset programs are trading without caps. They may have helped somewhat in beginning the flow of financing to developing countries to help bend downward the trajectory of their future emissions. But their impact has been modest. And a formal cap and trade system could have both reduced emissions more and delivered greater economic and environmental benefits to developing countries. Payments for GHG emissions offsets in countries or sectors without caps – as occurs under the CDM – is vulnerable to within-country leakage, and could even increase aggregate emissions if emissions at the CDM project are reduced but aggregate emissions increase elsewhere in the recipient country and as investment is attracted to the subsidized sector. In addition, uncapped offset systems may also discourage countries from joining a formal cap and trade system. If the country can sell uncapped credits at a price that is almost as high as the price at which formal cap and trade allowances would sell, then there is less reason to accept the cap.[35] In a post-Kyoto treaty and in new US legislation, the CDM and offset programs should be folded into a formal international economy-wide cap and trade system.

<u>Implementation</u>

A further issue deserves attention: implementation after adoption. Countries might agree to a treaty, but do little to carry out its terms. Here again, the choice of regulatory instrument matters. Lower cost should make both adoption and implementation easier, so both taxes and cap and trade should be more successful than higher-cost instruments such as central conduct standards.

One concern might be that implementing and enforcing a cap and trade system would require a bureaucracy or institutional capacity that developing countries lack. But that concern applies to all instruments. It is true that a cap and trade system requires a monitoring and enforcement system to measure emissions, track allowances as they are acquired and traded, and impose sanctions on sources whose emissions exceed their allowance holdings in each period. Likewise, though, a tax requires a monitoring and enforcement system to measure emissions, calculate and levy taxes, check for cheating, and punish tax evaders. The extent of bureaucracy and institutional capacity needed to implement a cap and trade program seems no greater than, and could be considerably less than, that needed to implement a tax. Just think of the enormous enforcement machinery and time and expense of collecting taxes in the US.

There are two reasons to think that cap and trade, at least at the international level, is likely to enjoy more successful implementation and enforcement than taxes. The first reason involves what I have called "fiscal

[34] *See* Wiener, *Global Environmental Regulation*, *supra* note 2, at 754-55, 781-82. When the US withdrew from the Kyoto Protocol in 2001, the expected value of Russia's ability to sell its headroom allowances was undercut; this was one reason why Russia then hesitated for four years before joining the Kyoto Protocol, and bargained for additional inducements from the European Union.
[35] *See* STEWART & WIENER, *supra* note 1, at 74, 90-92.

cushioning."[36] Through myriad changes to their other policies (taxes, subsidies, tariffs, and the like), countries are likely to seek to cushion the burden on their domestic economies of emissions taxes or cap and trade limits. Under a GHG tax, such cushioning strategies will affect the level of emissions. A country could be in full nominal compliance with an agreed GHG tax, but, through cushioning tactics, it could minimize the actual effect of the tax on the domestic economy and thus could vitiate the effect of the tax on actual emissions. By contrast, under a cap and trade system, a country could use cushion tactics to shield its economy, but the quantity cap would still limit its actual emissions. (Instead, other distortions would be generated in its economy.)

The problem of fiscal cushioning can be seen as a principal-agent monitoring problem. The treaty regime will have more difficulty monitoring the actual efficacy of national GHG taxes, and less difficulty monitoring the actual efficacy of GHG caps. Amidst the numerous fiscal cushioning tactics being undertaken, it would be quite difficult for outside observers (the treaty regime) to monitor a country's actual implementation and forecast the true effect of a tax on GHG emissions, muddied as it would be by the fiscal cushioning tactics, and with no limit on emissions.[37] But it would still be straightforward for outside observers to monitor the actual implementation and true effect of a cap and trade system on GHG emissions, just by monitoring aggregate emissions compared to the cap. This difference derives from the basic difference between price instruments such as taxes and quantity/property instruments such as trading: the former work by setting the price but do not directly limit emissions, whereas the latter limit emissions and let the price vary in the market. And this difference derives from the reality of national sovereignty confronting regulatory regimes at the international level, where there is no centralized benevolent policy maker to choose the optimal instrument regulating firms, but only national governments adopting and implementing (or not) an agreed framework. Fiscal cushioning interferes directly with the effect of price instruments on the quantity of emissions, but not with the effect of quantity instruments on the quantity of emissions. In the presence of fiscal cushioning tactics in an international system, nominal compliance is not the same as true effectiveness, and real reductions in emissions are easier to monitor and enforce under quantity/property instruments than under price instruments.

The second difference in implementation relates to the political economy of regulation. Under a tax, every taxpayer has an incentive to lobby to relax or remove the tax. And the tax authority, seeking revenues, has an incentive to keep the taxed activity going strong and generating tax revenues, thus setting a revenue-maximizing tax that is lower (less stringent) than the optimal externality-controlling tax.[38] These forces combine to yield pollution taxes that are suboptimally low. Under cap and trade, by contrast, allowance holders quickly constitute a lobby in favor of keeping the allowances scarce – that is, in favor of enforcement of the cap – because lax enforcement means that their allowances lose value.[39] This helps overcome the concern about an enforcement deficit. More generally, it raises the question of revising the cap (or tax) over time. The climate change treaty regime and national legislation should build in mechanisms for adaptive management – for periodic review of the stringency of the cap and whether it should be tightened or loosened in light of new information.[40]

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[36] *See* Wiener, *Global Environmental Regulation*, *supra* note 2, at 785-88.

[37] *See* JOSEPH ALDY, EDUARDO LEY & IAN PARRY, A TAX-BASED APPROACH TO SLOWING GLOBAL CLIMATE CHANGE 26-28 (Resources for the Future Discussion Paper No. 08-26, 2008) (recognizing the problem of fiscal cushioning, and proposing complex monitoring regimes to try to salvage an international GHG tax from fiscal cushioning), *available at* http://www.rff.org/RFF/Documents/RFF-DP-08-26.pdf .

[38] *See* STEPHEN G. BREYER, REGULATION AND ITS REFORM 284 (1982) (suggesting that tax authorities may administer pollution taxes "with more of an eye toward increasing government revenues than protecting the environment"); Peter Bohm & Clifford S. Russell, *Comparative Analysis of Alternative Policy Instruments*, *in* 1 HANDBOOK OF NATURAL RESOURCE AND ENERGY ECONOMICS 395, 437 (Allen V. Kneese & James L. Sweeney eds., 1985) (finding that in practice, most pollution tax systems have been adopted to raise revenue rather than to deter pollution); Nathaniel O. Keohane et al., *The Choice of Regulatory Instruments in Environmental Policy*, 22 HARV. ENVTL. L. REV. 313, 314-15 (1998) (observing the political forces contributing to this result); *see generally* MIKAEL SKOU ANDERSON, GOVERNANCE BY GREEN TAXES (1994) (finding that pollution taxes in Europe have been low).

[39] This political pressure can also help keep the total number of allowances from being raised. It may be too strict. An example is taxicab medallions in New York City: the city allocated just fewer than 12,000 taxi medallions in 1937, and, under pressure from medallion owners, forestalled the issuance of any additional medallions until 60 years later, when the city added just 400 in 1996. *A Revolution! New York's Cabs*, THE ECONOMIST, Feb. 2, 1996, at 21.

[40] Jonathan B. Wiener, *Radiative Forcing: Climate Policy to Break the Logjam in Environmental Law*, 17 N.Y.U. ENVTL. L.J. 210, 234-35 (2008).

CONCLUSION

At the international level, given the structure of international law, a quantity/property-based cap and trade system has distinct advantages over other instruments such as a tax: better incentives to engage participation and implementation, and better prospects to deliver both efficiency and justice. These are the crucial criteria for successful international response to the tragedy of the climate commons.

A tax may have advantages in cost containment under uncertainty. But a cap and trade system can contain costs through "how," "where," and "when" flexibility, through broad market scope, and perhaps (though this deserves further study, especially at the international level) through carefully designed modifications such as a combined price ceiling and price floor (set to rise over time). A tax can raise revenues, but so can allowance auctions.

Two decades ago, in 1990, Richard Stewart and I proposed a comprehensive international cap and trade system for climate change protection.[41] At that time, some in the Bush (father) administration disliked the cap idea, even though they were advocating cap and trade for acid rain control in the domestic Clean Air Act. Meanwhile, the EU and some environmental groups disliked the trading idea, even though the Environmental Defense Fund was a leading architect of cap and trade systems. The cap and trade idea was informally included in the 1992 Framework Convention on Climate Change (dubbed "joint implementation"), and then more formally authorized in the 1997 Kyoto Protocol's article 17 (as well as the uncapped offsets market of its CDM), but still faced strong opposition in Europe and elsewhere. Meanwhile the Berlin Mandate in 1995 exempted developing countries from emissions limits, thereby leaving their growing emissions unconstrained and also leaving them out of a cap and trade system from which the developing countries could have earned net gains. After 2000, the cap and trade idea was adopted in the EU ETS, and in the Lieberman-McCain bills and subsequent proposals in the US Congress. Some developing countries expressed interest in joining such a system.[42]

As we negotiate the post-Kyoto treaty regime toward the Copenhagen meeting in December 2009, the prospects for international cap and trade are looking brighter. The pivotal advantage of a quantity/property-based cap and trade system in engaging international participation is now coming to be widely recognized. As Al Gore put it recently, "For more than 20 years, I have supported a CO2 tax offset by an equal reduction in taxes elsewhere . . . However, a cap-and-trade system is also essential and actually offers a better prospect for a global agreement, in part because it is difficult to imagine a harmonized global CO2 tax."[43]

There is reason to be optimistic, given the history of the shift from central conduct standards towards cap and trade systems, such as the cap and trade systems adopted in the United States for acid rain and in Europe for GHGs. Europe's switch, from favoring taxes and denouncing cap and trade during the entire decade of the 1990s, to adopting the European Emissions Trading System, is particularly significant. (The ETS had some problems in its pilot phase, but it is being improved in its first full phase.) The new Obama administration has firmly backed a cap and trade approach.

In the larger context, global climate change is one of the major global issues on which the United States and China will need to construct a global geopolitical partnership over the coming decades. This is an opportunity for global strategy on a scale of centuries. China in a longer historical sense is returning to its former status as a great power; China represented about a third of world economic output before the European industrial revolution.[44] If the Chinese leadership takes a very long run perspective on its role in the world, and views the peaceful rise of China and its harmonious society as a very long term project, then the United States will need to engage China's participation to protect the global climate in that same

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[41] For the history, see Jonathan B. Wiener, *Something Borrowed for Something Blue: Legal Transplants and the Evolution of Global Environmental Law*, 27 ECOLOGY L.Q. 1295 (2001).
[42] *See* Petsonk, *supra* note 2.
[43] Broder, *supra*, note 8, at A13.
[44] *See* ANGUS MADDISON, CONTOURS OF THE WORLD ECONOMY 1-2030AD (Oxford Univ. Press 2007). Graphs depicting Maddison's data are posted on Greg Mankiw's Blog at http://gregmankiw.blo gspot.com/2006/09/milken-on-world-economy.html (covering 1820-2001), and on Catherine Mulbrandon, Visualizing Economics, at http://www.visualizingeconomics.com/ 2008/01/20/ share-of-world-gdp/ (covering 1500-2000).

long-term context. It will need to show how a cost-effective approach to climate protection can benefit China's long-term development. That is a project in which a creative American administration can take the lead to work together with China, Europe and others to construct a new world order that is successful for planetary protection as well as for world prosperity, alleviating poverty, freedom, and other crucial issues. It would mean constructing a new property regime to conserve the global commons. After centuries of the evolution of property law into its modern multifaceted elements, and several decades of designing regulatory instruments, including two decades of analyzing and advocating a quantity/property cap and trade instrument for climate protection, we have learned a great deal. Can we now protect the planet with a comprehensive cap and trade system? Yes we can.

Distributional Implications of Alternative U.S. Greenhouse Gas Control Measures[45]

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Abstract

We analyze the distributional and efficiency impacts of different allowance allocation schemes for a national cap and trade system using the USREP model, a new recursive dynamic computable general equilibrium model of the U.S. economy. The USREP model tracks nine different income groups and twelve different geographic regions within the United States. We consider allocation schemes motivated by recently proposed U.S. climate legislation applied to a comprehensive national cap and trade system that limits cumulative greenhouse gas emissions over the control period to 203 billion metric tons. We find that the allocation schemes in all proposals are progressive over the lower half of the income distribution and proportional in the upper half of the income distribution. Scenarios based on the Cantwell-Collins allocation proposal are less progressive in early years and have lower welfare costs due to smaller redistribution to low income households and consequently lower income-induced increases in energy demand and less savings and investment. Scenarios based on the three other allocation schemes tend to overcompensate some adversely affected income groups and regions in early years but this dissipates over time as the allowance allocation effect becomes weaker. Finally we find that carbon pricing by itself (ignoring the return of carbon revenues through allowance allocations) is proportional to modestly progressive. This striking result follows from the dominance of the sources over uses side impacts of the policy and stands in sharp contrast to previous work that has focused only on the uses side. The main reason is that lower income households derive a large fraction of income from government transfers, and we hold the transfers constant in real terms - reflecting the fact that transfers are generally indexed to inflation. As a result this source of income is unaffected by carbon pricing, while wage and capital income is affected.

INTRODUCTION

U.S. Senate proposals for cap and trade legislation and the House-passed Waxman Markey Bill focus on similar overall cuts in greenhouse gases. The biggest difference among them is how allowances, and the revenue from their auction, would be distributed. Different uses of revenue or different allowance allocations would not in the first instance affect the direct cost of achieving emissions reductions but they can have important implications for how costs are borne by different regions and among households of different income levels. Different uses of revenue may have indirect effects on the overall welfare cost of a policy to the extent revenue is used to offset other distortionary taxes. In addition the allowance allocation has efficiency impacts to the extent that it creates further distortions or prevents pass through of the full CO_2 price in some products, or is used in some way that does not create value for U.S. citizens. Rausch *et al*. (2009) investigated some generic allocation schemes with a multi-region, multi-household static general equilibrium model of the U.S., the U.S. Regional Energy Policy (USREP) model. Here we extend the USREP model to a recursive dynamic formulation and design allocation schemes intended to approximate more closely specific cap and trade proposals.

In extending the USREP model to a recursive dynamic formulation we borrow the dynamic structure of the MIT Emissions Prediction and Policy Analysis (EPPA) model (Paltsev *et al*. (2005)). With this extension we are able more closely to represent features of revenue use and allowance allocation in specific legislative proposals and contrast their distributional implications. As with previous analyses of greenhouse gas legislation conducted with the EPPA model such as that in Paltsev *et al*. (2009) we attempt to capture key features of the cap and trade provisions in the proposals but are not able to address many other provisions of the bills that deal with energy efficiency standards and the like. The

[45] This manuscript has been prepared for the Workshop on "Pricing Carbon in Europe and the US" held in Paris, France, on Nov. 9, 2010, organized by the Paris-Dauphine University. This manuscript is largely based on Rausch *et al.* (2010).
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added value here is that we can consider distributional effects of proposed legislation. We contrast the allowance allocation schemes of the House legislation (Waxman-Markey) with those of the Senate proposals of Kerry and Boxer and of Cantwell and Collins. As a result of negotiations in the Senate the Kerry-Boxer bill has stalled and been replaced by a discussion draft by Senators Kerry and Lieberman. The bill contains a variety of new features but is similar to Waxman-Markey in its allocation of allowance value. To isolate the effects of different allocation schemes, we formulate a cap and trade policy designed to limit cumulative emissions over the control period in all scenarios to 203 billion metric tons (bmt). The cap and trade provisions of the proposals we consider would lead to somewhat different cumulative emissions because of differences in the timing of reductions, sectoral coverage, and whether outside credits were allowed.

Waxman-Markey and Kerry-Boxer are part auction, part free allocation with a complex allowance and revenue allocation designed to achieve many different purposes. In contrast, Cantwell and Collins proposal auctions all allowances and distributes most of the revenue with a very straightforward lump sum allocation to individuals. Extending our analysis to distributional issues requires further interpretation, especially for those proposals with complex allocation schemes, of how allocation of allowances and auction revenue would actually occur if current proposals were implemented.

Our analysis shows a number of results. First, scenarios based on the Waxman-Markey and Kerry-Boxer (or Kerry-Lieberman) allowance allocation schemes are more progressive (i.e., a larger welfare loss is imposed on higher income households) in early years than scenarios based on the Cantwell-Collins proposal. We emphasize, however, that the overall distributional impact of these proposals depend on *all* the features of these legislative proposals and not just the cap and trade programs. Nonetheless the allowance allocation schemes are important determinants of the overall distributional impact of these bills. Second, scenarios based on the Cantwell-Collins allocation proposal have lower welfare costs due to lower redistribution to low income households and consequent lower income-induced increases in energy demand. Third, we find that the Waxman-Markey and Kerry-Boxer (or Kerry-Lieberman) allocation schemes appear to overcompensate some adversely affected income groups and regions early on, though this dissipates over time as the allocation scheme evolves to something closer to lump sum distribution. Fourth, the allocation schemes in all proposals are progressive over the lower half of the income distribution and essentially proportional in the upper half of the income distribution. Finally we find that carbon pricing by itself, ignoring the return of carbon revenues through allowance allocations, is proportional to modestly progressive. We trace our result to the dominance of the sources side over the uses side impacts of the policy. It stands in sharp contrast to previous work that has focused only on the uses side, and has hence found energy taxation to be regressive. It is worth pointing out that our model framework provides only an analysis of welfare *costs* of climate policy and does not attempt to incorporate any *benefits* from averting climate change. Any welfare changes reported in this paper therefore refer to changes in costs.

The remainder of this paper proceeds as follows: Section 2 briefly describes the recursive dynamic version of the USREP model. Section 3 discusses the legislative proposals we evaluate, mapping the allowance and revenue allocation in the Bills to specific distributional schemes in the model. Section 4 defines policy scenarios based on the proposed greenhouse gas control measures and investigates the distributional implications across regions and income classes of allocation scenarios reflecting our interpretation of proposed policies. Section 5 reports the results of a counterfactual analysis that allows us to trace the source of distribution effects we observe. Section 6 concludes.

A RECURSIVE-DYNAMIC U.S. REGIONAL ENERGY POLICY MODEL

USREP is a multi-region, multi-sector, multi-household computable general equilibrium model of the U.S. economy designed to analyze energy and greenhouse gas policies.

The overall model structure, database, calibration, and modeling assumptions of the USREP model are described in detail in Rausch *et al*. (2009, 2010). For sake of brevity, and to provide a rough sketch of the model, we focus discussion here on the dimensions of the model. The underlying state-level data base that combines Social Accounting Matrices with physical energy data provides flexibility in the regional detail of the model. Here we use the regional structure shown in **Figure 1**. This structure separately identifies larger states, allows representation of separate electricity interconnects, and captures some of the diversity among states in use and production of energy. **Table 1** provides an overview of the sectoral breakdown and the primary factors of production. Consistent with the assumption of perfect competition on product and factor markets, production and consumption processes exhibit constant-returns-to-scale and are modeled by nested constant-elasticity-of-substitution (CES) functions. A detailed description of the nesting structure for each production sector and household consumption is provided in Rausch *et al.* (2009). There are nine representative households in each region differentiated by income levels as shown in **Table 2**. Households across income classes and regions differ in terms of income sources as well as expenditures. State-specific projections through 2030 are from the U.S. Census Bureau (2009a).

Figure 1. Regional Aggregation in the USREP Model.

U.S. CAP AND TRADE PROPOSALS: ALLOWANCE ALLOCATION

Below we carry out distributional analyses of cap and trade policies based on alternative proposals for greenhouse gas control legislation currently under consideration in the U.S. These are the house-passed American Clean Energy and Security Act (H.R. 2454) sponsored by Reps. Waxman and Markey, the Clean Energy Jobs and American Power Act (S. 1733) a Senate bill similar to H.R. 2454 and sponsored by Senators Kerry and Boxer, and now replaced by the American Power Act (APA) draft bill by Kerry and Lieberman, and the Carbon Limits for America's Renewal (CLEAR) Act, a competing Senate Bill sponsored by Senators Cantwell and Collins. All proposals seek an overall reduction of GHG emissions in the U.S. to 83% below 2005 levels by 2050 with intervening targets. Cap and trade components of the bills cover most of the economy's emissions but not necessarily all of them, with other measures directed toward uncapped sectors. For example, estimates are that Waxman-Markey covers between 85% and 90% of emissions with a cap and trade system. Waxman-Markey has a slightly looser target for sectors covered by the cap and trade in 2020 than does Kerry-Boxer, issuing allowances at a level 17% below 2005 emissions in 2020, whereas the economy-wide goal is a 20% reduction by that date. Kerry-Lieberman would sell as many allowances as needed to refineries at a fixed price but would adjust over time to meet quantity targets. In our simulations of the effects of these bills, we assume the national goals are met, and we achieve them with a cap and trade system that covers all U.S. emissions except for land

Table 1. USREP Model Details: Regional and Sectoral Breakdown and Primary Input Factors.

Region[a]	Sectors	Primary Input Factors
Alaska (AK)	**Non-Energy**	Capital
California (CA)	Agriculture (AGR)	Labor
Florida (FL)	Services (SRV)	Land
New York (NY)	Energy-Intensive (EIS)	Crude Oil
New England (NENGL)	Other Industries (OTH)	Shale Oil
South East (SEAST)	Transportation (TRN)	Natural Gas
North East (NEAST)	**Energy**	Coal
South Central (SCENT)	Coal (COL)	Nuclear
Texas (TX)	Convent. Crude Oil (CRU)	Hydro
North Central (NCENT)	Refined Oil (OIL)	Wind
Mountain (MOUNT)	Natural Gas (GAS)	
Pacific (PACIF)	Electric: Fossil (ELE)	
	Electric: Nuclear (NUC)	
	Electric: Hydro (HYD)	
	Advanced Technologies	

[a]Model regions are aggregations of the following U.S. states: NENGL = Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island; SEAST = Virginia, Kentucky, North Carolina, Tennessee, South Carolina, Georgia, Alabama, Mississippi; NEAST = West Virginia, Delaware, Maryland, Wisconsin, Illinois, Michigan, Indiana, Ohio, Pennsylvania, New Jersey, District of Columbia; SCENT = Oklahoma, Arkansas, Louisiana; NCENT = Missouri, North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa; MOUNT = Montana, Idaho, Wyoming, Nevada, Utah, Colorado, Arizona, New Mexico; PACIF = Oregon, Washington, Hawaii.

Table 2. Annual Income Classes Used in the USREP Model and Cumulative Population.

Income class	Description	Cumulative Population for whole U.S. (in %)[a]
hhl	Less than $10,000 per year	7.3
hh10	$10,000 to $15,000 per year	11.7
hh15	$15,000 to $25,000 per year	21.2
hh25	$25,000 to $30,000 per year	31.0
hh30	$30,000 to $50,000 per year	45.3
hh50	$50,000 to $75,000 per year	65.2
hh75	$75,000 to $100,000 per year	78.7
hh100	$100,000 to $150,000 per year	91.5
hh150	$150,000 plus per year	100.0

[a]Based on data from U.S. Census Bureau (2009a).

use CO_2 sources (or sinks). All of these proposals including banking and limited borrowing provisions and hence the time profile of reductions described in the bills are better thought of as the time profile of allowance allocation, with actual emissions levels in each year determined by how allowances are banked or borrowed (to the extent borrowing is allowed). In our simulations we find that the allocations result in net banking with no borrowing. Of course, in actuality borrowing may occur to the extent that unexpected costs make it attractive to bring permits forward in time.

While the stated national targets are identical across the bills, the Cantwell and Collins proposal has no provision for the use of offsets from outside the capped sectors to be used in lieu of the cap.

Reductions similar in nature to the offsets allowed in the other bills are to be funded from a portion of the auction revenues that are subject to future appropriations. The other two proposals allow up to two billion tons per year of outside credits from a combination of domestic and foreign sources.

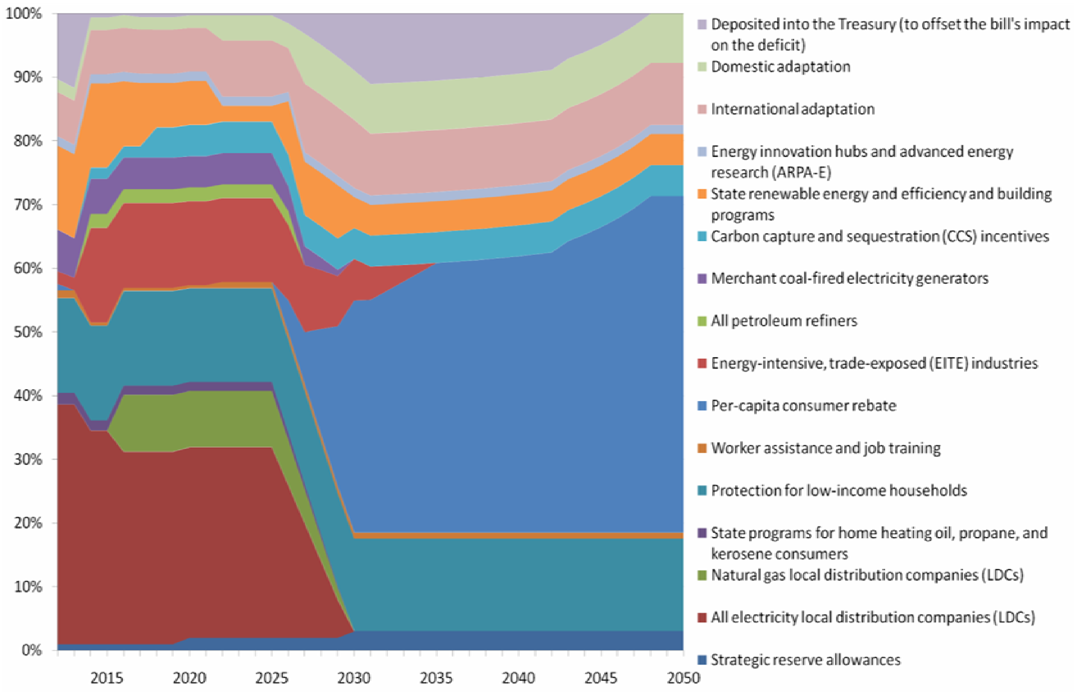

Figure 2. The Allocation of Allowance Value in the Waxman-Markey Bill.

Our main interest in this paper is the consequences of alternative distribution of allowances, and so we simulate the Cantwell-Collins allocation scheme allowing for the same level of outside credits as the other two bills. Any differences are the result of the allowance distribution mechanisms rather than the level of the cap.

The proposals are not always clear as to whether allowances are auctioned by some central Federal Agency and the revenue distributed or the allowances are distributed to entities who then can sell them. For example, designations to States could involve either a portion of allowance revenue or direct allocation of allowances leaving it up to the State to sell them into the allowance market. For our modeling purposes it does not matter whether it is revenue or the allowances that are distributed. We thus focus in our analysis on the allocation of "allowance value" in the different proposals to allow for distribution of allowances or the revenue from an auction.

Figure 2 shows the allowance allocation scheme as it is proposed in the Waxman-Markey bill. We do not show graphically the Kerry-Lieberman, Kerry-Boxer and Cantwell-Collins allowance allocation schemes here. The Cantwell-Collins bill calls for 75% of allowance revenue to be returned in a lump sum manner and 25% retained to meet several objectives but without specifying percentages for each. In terms of Figure 2, that bill would be simply two bars dividing allowance value among these two purposes. The allocation schemes in Kerry-Boxer and Kerry-Lieberman are similar to Waxman-Markey. The main difference is in terms of allowances set aside to offset the impact of the bill on the deficit. Waxman-Markey allocates at most 10% of the allowances for this purpose, in part directly and in part by directing how revenues obtained through early auction would be used, whereas Kerry-Boxer allocates a percentage that grows to 25%. The allocation of revenue for deficit impacts in Kerry-Lieberman is much closer to Waxman-Markey. The increasing share devoted to this purpose proportional reduces the allocation to all other purposes. For example, Kerry-Boxer is able to allocate less than 50% of allowance value directly to households through either the low income energy assistance or the consumer rebate fund—whereas Waxman-Markey is able to allocate about 65% to households by 2050 through these two programs.

Both Kerry-Boxer and Waxman-Markey have a small strategic reserve of allowances and both allocate a substantial portion of allowances to local electricity and natural gas distribution companies in early years on the basis that these regulated entities will turn allowance value over to ratepayers, thus offsetting some of the impact of higher energy prices. This turns these LDCs into the mechanism for distribution as opposed to a government auction agency as in Cantwell-Collins. The other bills transition to a system closer to Cantwell-Collins over time, replacing the LDC distribution with a consumer rebate fund. Both retain a separate allocation to focus specifically on low income energy consumers. Both also then distribute allowances to different industries that are expected to be particularly affected by the legislation, but these allocations phase out by 2030. Use of allowances as an extra incentive for carbon capture and sequestration is also identified in both. A next set of allowances are allocated to fund various domestic energy efficiency programs. The next grouping of allocations is for international mitigation and adaptation and for domestic adaptation programs. Waxman-Markey contains a large set of allowances in later years designated for prior year use. This use possibly reallocates allowances through time, allowing the possibility of Federal borrowing if allowance prices rise too much. Of more relevance here is that the bill prescribes about one-half of this allowance value to go to the Treasury to offset impacts on the deficit and the other half as a consumer rebate. These amounts are shown in Figure 2 combined with the other provisions that direct revenue to the Treasury and to the consumer rebate. That value is allocated in the year in which the allowances would be originally issued, i.e. assuming the Federal government does not borrow them or if it does, the income is not rebated immediately. The Kerry-Boxer bill does not have this provision.

We do not represent the many different programs to which these allowances or allowance value would go, and the exact recipients will depend on program decisions yet to be made. However, we approximate the impact on regions and households of different income levels by distributing the allowance value based on data we have within the model, and that approximates what we believe to be the intent of the different distributions or how they would tend to work in practice. The distributional instruments we have at our disposal in the USREP Model and the correspondence to allocations called out in the bills are given in **Table 3**. A more detailed discussion of our assumptions is avaible in Rausch *et al.* (2010).

Given this mapping of the allocation provisions in the various legislative proposals we construct **Figure 3** that is similar to Figure 2 but showing instead the allocation of allowance value mapped to the instruments we use in USREP. The distribution instruments for all of these uses, except Foreign and Government, direct revenue to households but the particular instrument determines how the allowance value is allocated among households in different regions and in different income classes. As modeled, allowance value allocated abroad has no value for U.S. households. In the proposed legislation, most of the allowance value distribution is a pure transfer but some of these program expenditures are intended to incentivize energy savings and the like. Our allocation approach treats all of these program expenditures as pure transfers. To the extent these programs overcome barriers that are not addressed by the CO_2 price, additional efficiency gains would reduce the welfare costs we estimate. To the extent these programs create double-incentives for particular activities, then they are redirecting abatement to activities that are not the most cost effective and that would increase the welfare cost we estimate. The assumption that they are pure transfers is therefore a neutral assumption. Furthermore, note that transfers of allowance value to households are treated as being non-taxable, with the effect of increasing how much allowance value must be set aside relative to a scenario where such transfers are taxed.

Allowances allocated to government reduce the need for capital and labor taxes to be raised as much to meet the revenue neutrality assumption we impose, and so affect the distribution to households based on how increases in taxes affect different regions and income classes.

SCENARIO DESIGN AND SIMULATION RESULTS

We distinguish two sets of scenarios that differ with respect to the underlying allowance allocation scheme. Scenarios labeled *TAAS* represent a Targeted Allowance Allocation Scheme that is based on the Waxman-Markey or Kerry-Lieberman proposal. The *TAAS_DR* scenario sets aside a larger amount of allowances for the purpose of Deficit Reduction (DR) as in the allocation rule proposed by Kerry-Boxer. Scenarios labeled *PCDS* model a simple Per Capita Dividend Scheme as is described in the Cantwell-Collins proposal.

For each of the proposed allocation schemes, we design two scenarios that differ with respect to how the
revenue neutrality requirement is met. Our base case assumption is that sufficient allowance revenue is withheld by the government to cover the deficit impact and the remaining revenue is allocated at the percentages shown in Figure 3. An alternative case, denoted *TAX*, assumes that only the amount of allowance revenue specifically designated for deficit reduction in the bills is allocated to the government. We then raise capital and labor taxes uniformly across regions and income classes (in percentage points) to offset revenue losses from carbon pricing. This is separate from any allowance revenue targeted to deficit reduction. All scenarios assume the medium offset case from the analysis carried out in Appendix C of Paltsev *et al.* (2009) with identical assumptions about supply and costs of domestic and international offsets. We further assume that offsets have a cost to the economy, and implement this assumption by transferring abroad the value of allowances purchases internationally. Our assumption is that the average cost of these credits is \$5 per effective ton of offsets of CO_2-e in 2015, rising at 4% per year thereafter.[46]

Also note that since we create more allowance revenue for the government by increasing the allowances to account for credits coming from outside the system, we assume that the income transferred abroad to account for permit prices is taken from the allowance revenue. Finally, our assumptions about the supply of offsets imply a 203 bmt cumulative emissions target for 2012-205, which underlies all of the scenarios we consider here.

Figure 4 presents the change in welfare relative to the *Reference* scenario, measured in equivalent variation as a percentage of full income[47], for the various bills. One key result we see is that the *_TAX* scenarios lead to higher welfare costs than the scenarios where a fraction of the allowance revenue is withheld to satisfy revenue neutrality. Considering the *TAAS* scenario, for example, the welfare cost is 1.38 percent of full income by 2050 under the lump-sum scenario and 1.60 percent under the tax scenario.

Similar results hold for *TAAS_DR* and *PCDS*. This occurs because the *_TAX* scenarios create more deadweight loss from capital and labor taxation. Many economists have focused on a double-dividend effect where allowance revenue is used to lower capital and labor taxes, but here we have the reverse effect. Not enough of the revenue is retained to offset the deficit effects of the bill so that capital and labor taxes need to be increased, thereby increasing the cost the bill.

Conditional on the treatment of revenue shortfalls, the three scenarios have very similar aggregate costs. *TAAS_DR_TAX* is somewhat less costly than *TAAS_TAX* because the former scenario reserves more of the allowance to offset the deficit and thus capital and labor taxes do not need to be increased as much. The costs of *PCDS* and *PCDS_TAX* are slightly lower than the *TAAS* scenarios. The lower costs of the *PCDS* scenarios at first blush are surprising. These scenarios retain less of the allowance value to offset the deficit, and hence in the *_TAX* case it requires somewhat higher increases in capital and labor taxes to offset the deficit. The lower costs in *PCDS* scenarios arise from the distributional outcomes as they affect energy expenditures and savings. In particular, *TAAS* and *TAAS_DR*, through the low income energy assistance programs allocate more of the revenue value to poorer households. Lower income households spend a larger fraction of their income on energy and they save less. Thus, the abatement effect of pricing carbon is offset to greater extent by an income effect among poorer households in the *TAAS* and *TAAS_DR* than in the *PCDS* scenarios*.* In addition, there is less saving and therefore less investment in *TAAS* and *TAAS_DR* because less is saved for each additional dollar allocated to poorer households. Note that our aggregate welfare estimates are a simple sum of the welfare of each income class across all regions. An aggregate welfare function that weighted the welfare of lower income households higher, giving welfare benefit to more progressive outcomes would change these results, showing better results for *TAAS* and *TAAS_DR.* How much to value more progressive outcomes is a normative judgment.

[46] The Waxman-Markey bill specifies that 1.25 tons of foreign reductions are required to produce 1 ton of effective offsets. The \$5/ton initial offset price means the actual payment per ton of foreign reduction is \$4. For all proposals analyzed, we treat offsets costs symmetrically.
[47] Full income is the value of consumption, leisure, and the consumption stream from residential capital.

Table 3. Correspondence between Proposals Allowance Value Allocations and Distribution Instruments in USREP.

ALLOWANCE RECIPIENTS	MODEL INSTRUMENT
Mitigating Price Impacts on Consumers	
All electricity local distribution companies (LDCs)	Lump-sum transfer to consumers. Allocated to regions based on GHG emissions (50%) and based on value of electricity consumption (50%). Within a region, allocated to households based on the value of electricity
Additional allowances for small electricity LDCs	Lump-sum transfer to consumers. Allocated to regions based on GHG emissions (50%) and based on value of gas consumption (50%). Within a region, allocated to households based on the value of gas consumption.
Natural gas LDCs	Lump-sum transfer to consumers based on value of gas consumption
State programs for home heating oil, propane, and kerosene consumers	Lump-sum transfer to consumers based on value of oil consumption (excluding oil consumed for transportation purposes)
Assistance for Households and Workers	
Protection for low-income households	Lump-sum transfer to households with annual income less than $30k.
Worker assistance and job training	Distributed to regions based on value of energy production (coal, crude oil and refined oil). Within a region, distributed across households base on wage income.
Per-capita consumer rebate	Lump-sum transfer based on per-capita.
Nuclear working training	Distributed to regions based on value of nuclear electricity generation. Within a region, distributed across households based on wage income.
Allocations to Vulnerable Industries	Lump-sum transfer based on capital income.
Technology Funding	Distributed to regions based on energy use (industrial and private). Within a region, distributed based on household energy consumption.
International Funding	Transferred abroad.
Domestic Adaptation	Distributed to government.
Other Uses	
Deposited into the Treasury (to offset the bill's	Distributed to government.

impact on the deficit)	
Grants to state and local agencies for transportation planning and transit[1]	Distributed to government.
Compensation for "early action" emission reductions prior to cap's inception	Distributed to households on a per capita basis
Allowances already auctioned in prior years	46% distributed to households on a per-capita basis, 54% distributed to government.
Strategic reserve allowances	Distributed to households on a per capita basis.

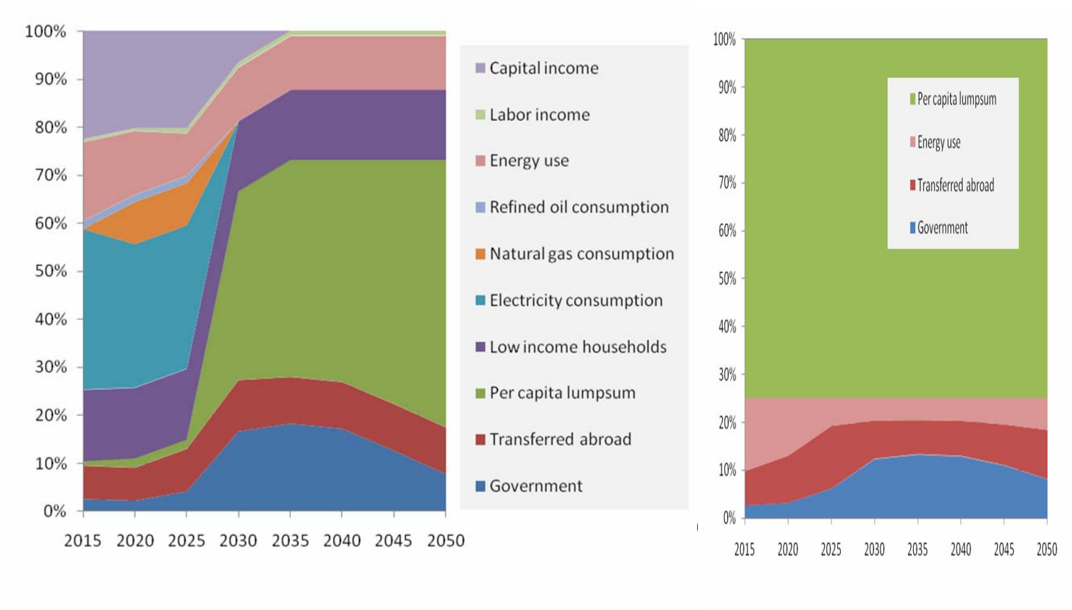

Figure 3. The Allocation of Allowance Value according to Model Distribution Instruments.

<u>Distributional Impacts across Income Groups</u>
Aggregate impacts obscure differential effects across households. Ideally we would construct a measure of the lifetime burden of carbon pricing and relate that to a measure of lifetime income. Our data do not allow us to do that. Our recursive-dynamic model has households of different income groups in each year but we have no data that allow us to track the transition of households from one income group to another. Instead we report burden impacts for different income groups at different points of time to show how the relative burden shifts over time.

Figure 5 shows the burden for a representative household in each income group for 2015, 2030, and 2050 for *TAAS* measured as equivalent variation Positive values indicate that a household benefits from the carbon policy. Households in the two lowest income groups, *hhl* and *hh10*, benefit in all periods as the return of permit revenue through various mechanisms more than offsets the higher cost of goods and services due to carbon pricing and any effects on their wages and capital income. Households *hh15* and *hh25* initially benefit but eventually bear net costs, *hh15* only in the final period. The effect of allocating an increasing amount of allowances on a per-capita basis is particularly strong for the lowest income group relative to higher income households since a dollar of additional revenue makes up a larger fraction of full income for these households. The five highest income households bear net costs throughout the period though the burden through 2030 is less than 1 percent of income for all income groups. Over time, the burden of the policy grows for wealthier households with the burden ranging from 1 to roughly 1.5 percent by 2050.

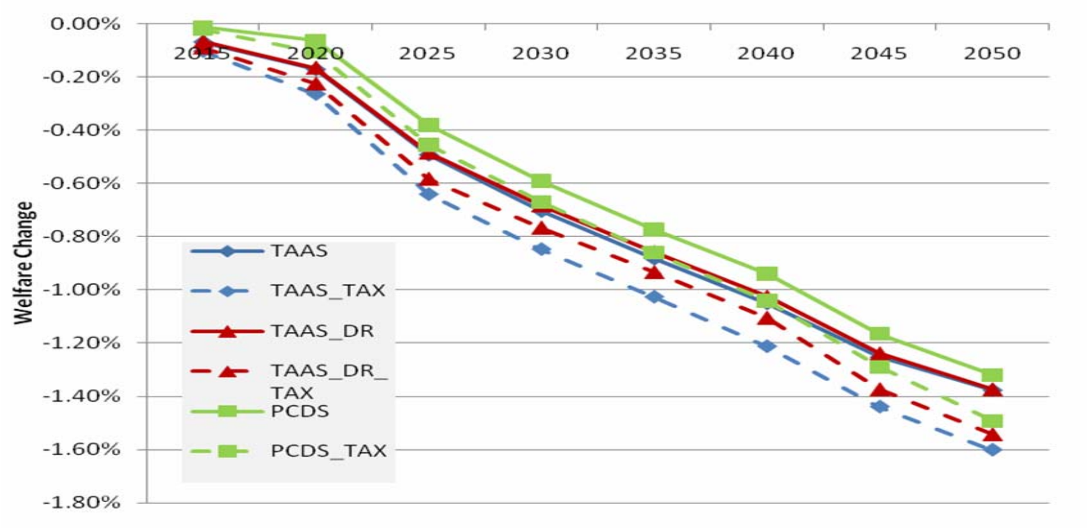

Figure 4. Welfare Change for Different GHG Control Proposals (U.S. Average).

In all years the cap and trade policy combined with the *TAAS* allocation scenarios is sharply progressive over the first five income groups though the burden for each income group, except that of the lowest, grows over time as the policy begins to impose larger reductions in emissions. The difference in burdens over the lowest five income groups grows over time as does the spread between the burden for the lowest income group relative to the highest income group. The policy is essentially neutral over the top income groups in all periods, as we will show below over time sources side effects become more important in shaping the distributional outcomes than do uses side effects.

Note that Waxman-Markey allows considerable borrowing of allowances from the future by the Federal government if necessary to moderate CO_2 prices in the early years. If these were auctioned in earlier years then the allowance revenue would accrue to the government earlier and in principle it could be used earlier. We have assumed the revenue is only available when the allowances were originally scheduled to be auctioned. If borrowing occurred and the revenue was used as specified in the bill—to reduce deficit impacts and as a lump sum rebate to consumers - that could blunt some of the progressivity in earlier years.

Costs and distributional impacts for *TAAS_DR* are very similar to *TAAS* and so we do not report them here. Rather we turn to the *PCDS* in **Figure 6.** Like *TAAS* and *TAAS_DR*, *PCDS* has modest to negative burdens (positive gains in Figure 7) initially with burdens rising over time. In comparison to the former bills the burden spreads across income groups in any given year are smaller. Lower income households benefit in the early years but not as much as in *TAAS* and *TAAS_DR*. This is reflected in the flatter distributional curves for different years. By 2050 the *PCDS* scenario and the *TAAS* scenario have more similar distributional effects because by that time the allocation formula in *TAAS_DR* has become similar to that of the *PCDS*, with 65 percent of revenue distributed on per capita basis. The remaining difference is the continued allocation to low income consumers.

Distributional outcomes are altered when the full value of allowances is allocated as specified in the bills and revenue losses in the federal budget are instead made up by raising personal income tax rates. In general, the distributional burden across household groups is more progressive in the *_TAX* cases. Consider the burden snapshots for three different years as shown in **Figure 7** for *TAAS_TAX*. Lower-income households fare better under this approach with benefits to the lowest income group rising from 1 to about 1.5 percent of full income in 2015, while the highest income groups are only slightly affected. Lower income groups continue to do better – and in some cases are better off – when tax rates are raised to recoup lost tax revenues than when allowance value is withheld. In general they remain better off through 2050 because of the tax changes. By raising taxes to offset the deficit, more revenue remains available to be distributed, and the increase in transfers to lower-income groups more than offsets increases in taxation to these households.

The different treatments of revenue neutrality illustrates a classic equity-efficiency trade-off, where the withholding of allowances to preserve revenue neutrality yields higher efficiency but less progressive outcomes than if taxes are raised to maintain revenue neutrality in the government budget. The impact of climate policy on government tax revenues is significant and helps explain why the different approaches to maintaining revenue neutrality matter. The initial loss of tax revenue due to higher costs for firms and reduced economic activity is 31.3 percent of the value of allowances in 2015. The percentage begins rising in 2040 and by 2050, the loss in tax revenue rises to one-half. The high tax revenue loss is in part an artifact of the assumption in the model that fixes the path of government spending to match that of the reference (no policy) scenario. We refer to this as absolute revenue neutrality. Lower GDP growth increases the size of government relative to GDP and magnifies the loss in tax revenue relative to allowance value. We make this assumption because the government sector in USREP does not produce explicit public goods that have any welfare value. By keeping revenue neutral changes in government we do not release or consume more resources that otherwise would be available to private sector.

With absolute revenue neutrality, the need to make up substantial revenue losses leads to fairly large increases in marginal personal income tax rates under the tax-based make-up. In 2015, tax rates under *TAAS_TAX*, *TAAS_DR_TAX*, and *PCDS_TAAS* increase by 0.52, 0.34, and 0.48 percentage points, respectively. Respective tax rate increases in 2050 are 1.50, 0.79, 1.48 percentage points. The *TAAS_DR_TAX* increases are much less than the other two scenarios because more of the revenue is explicitly allocated to deficit effects of the proposal. This just illustrates one way to make up revenue losses. Other approaches could be undertaken that could enhance efficiency or equity goals.

Summing up, we find that the *TAAS* and *TAAS_DR* scenarios on the one hand and the *PCDS* scenarios on the other have quite different distributional impacts across households, especially in the early years of the program. In addition, policy decisions on how to close the budget deficit arising from decreased tax collections have both efficiency and distributional implications.

Using higher personal income taxes to close the deficit incurs an efficiency cost but increases the progressivity of the programs because more of the allowance revenue is available for distribution to households. We next turn to regional impacts.

<u>Distributional Impacts across Regions</u>

Policy makers have also expressed concern over the regional impacts of climate policy. In this section we explore how regional impacts change over time for the allocation scenarios we have designed.

Figure 8 shows the welfare impact of the *TAAS* scenario for each region. Initially California, Texas, Florida and states in the South Central, Pacific, and New England regions gain from the policy while other states suffer losses. By 2050 all states are bearing costs, ranging from about one-half of one percent (New England) to about one and three-quarters percent.

With absolute revenue neutrality, the need to make up substantial revenue losses leads to fairly large increases in marginal personal income tax rates under overall policy costs, and relative regional welfare differences are increasingly shaped by energy characteristics and income sources. This explains why welfare effects for Alaska become more negative over time both relative to earlier periods of the policy and in comparison to other regions. The Alaska case is an interesting one in that it is a small state

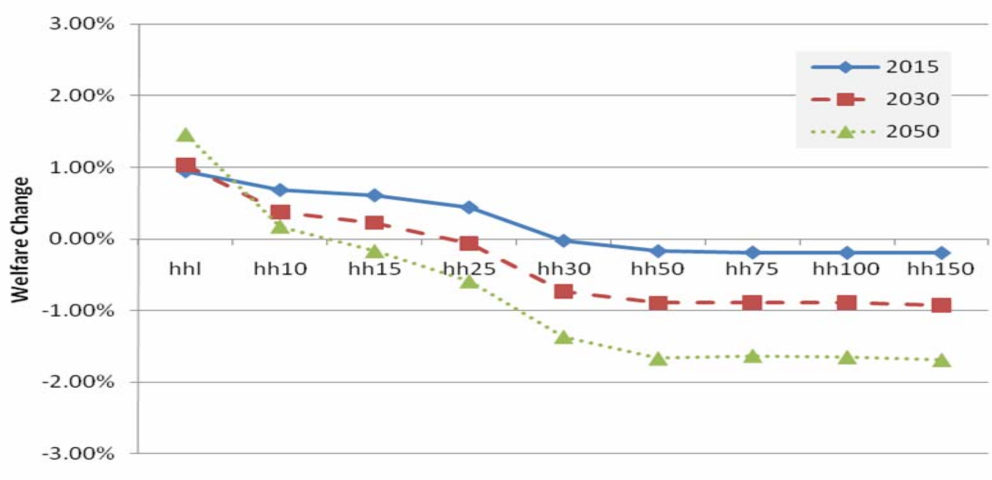

Figure 5. Welfare Change by Income Group, U.S. Average (Scenario *TAAS*).

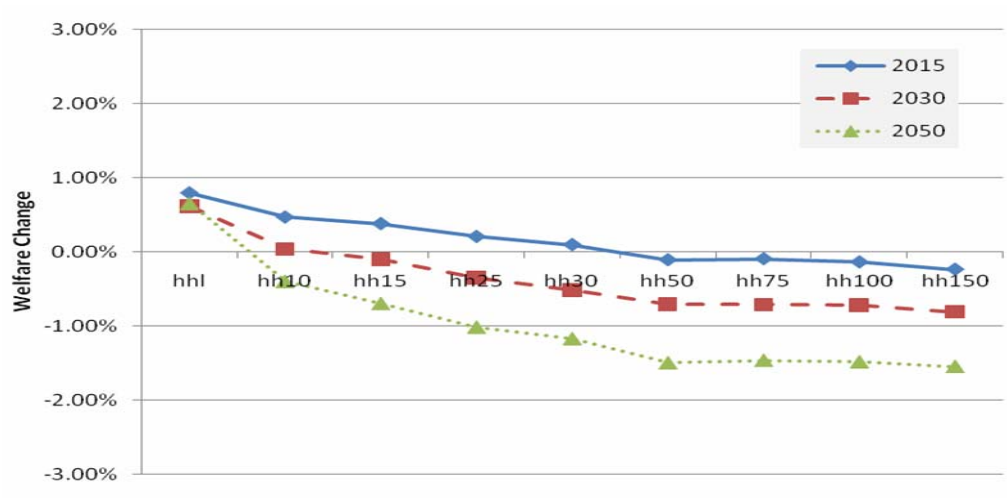

Figure 6. Welfare Change by Income Group, U.S. Average (Scenario *PCDS*).

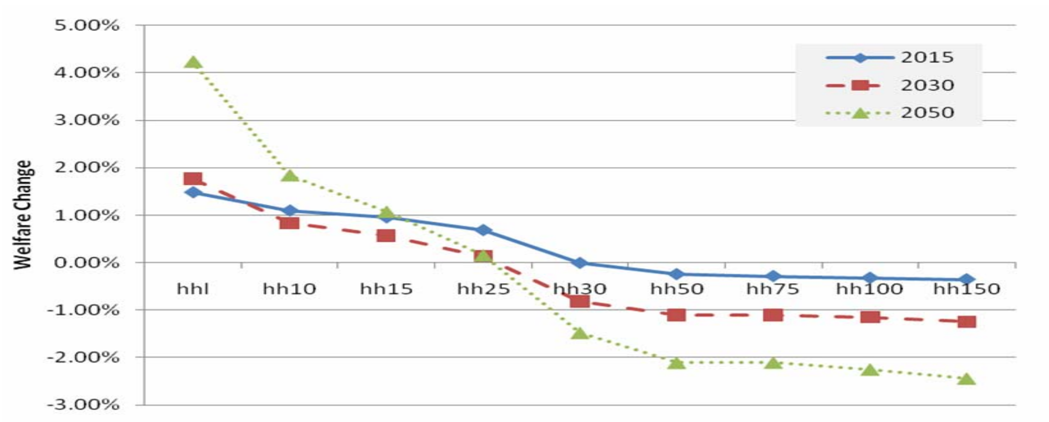

Figure 7. Welfare Change by Income Group, U.S. Average (Scenario *TAAS_TAX*).

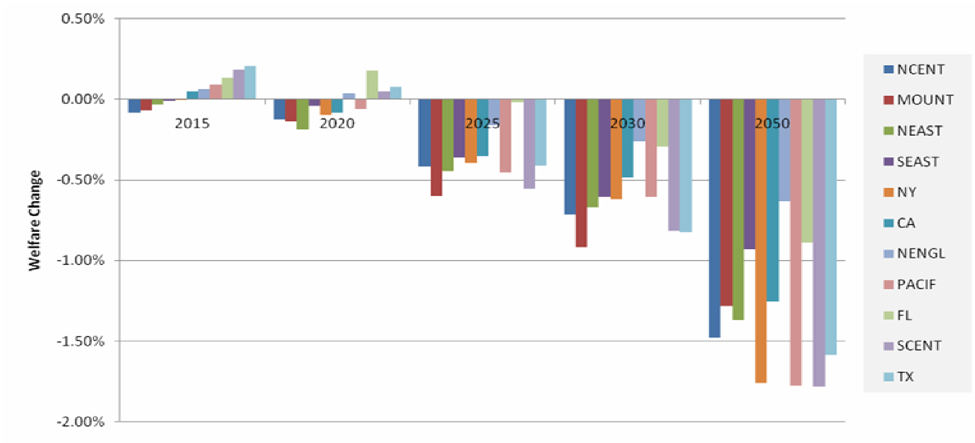

Figure 8. Welfare Change by Region (Scenario *TAAS*).

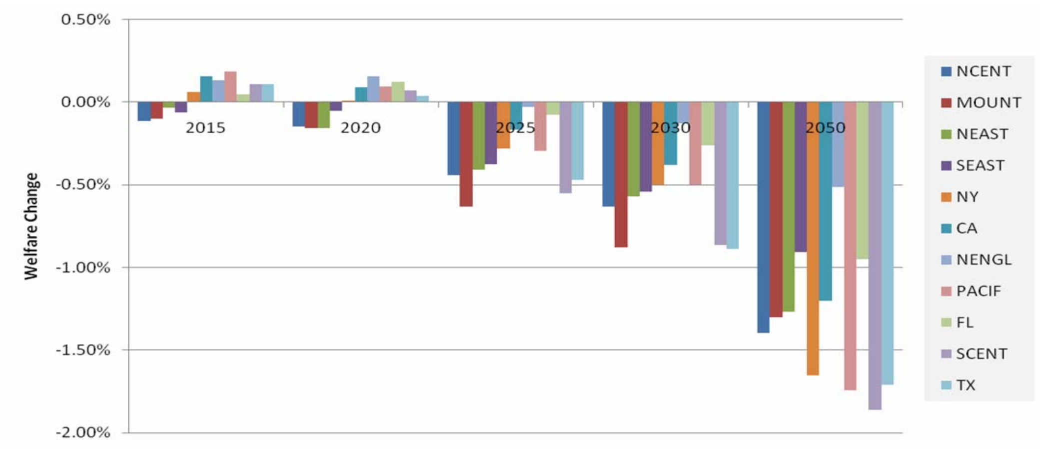

Figure 9. Welfare Change by Region (Scenario *PCDS*).

in terms of population and GDP with relatively unique energy use and production attributes. Our other regions, by aggregating more states, tend to average out so that there is less disparity. The Alaska results are illustrative of within region effects that we do not capture because of our aggregation.

Regional impacts under *PCDS* are less balanced initially (**Figure 9**). The standard deviation of welfare impacts under *PCDS* is slightly larger (0.11) than under the *TAAS* scenario (0.09). Recall that *PCDS* deliberately takes a per-capita approach premised on the view that regional disparities do not matter, while *TAAS* includes a number of provisions (such as LDC allocations) that are explicitly intended to address regional disparities. While the regional dispersion of welfare impacts is slightly larger under *PCDS*, one interesting result of this analysis is that the much simpler per-capita based approach is almost as effective in achieving a balanced regional outcome as the targeted allocation scheme. By 2050, the impacts under *PCDS* are quite similar to those under *TAAS*. Differential regional impacts due to differences in allowance allocation schemes dissipate over time. Section 7.1 provides a discussion of this effect.

Impacts under *TAAS_DR* are very similar to those under *TAAS* and are not reported here. Figure 15 also shows that the relative impacts across regions are fairly stable over the policy period under the PCDS allocation. South Central, North Central and Northeast states bear a larger impact of the policy though the maximum difference across the period is less than two percentage points.

We do not show here the *_TAX* scenarios because the results are broadly similar to the scenarios where a fraction of the allowance value is withheld to satisfy revenue neutrality. The main differences are that the overall welfare costs are larger for the U.S. as whole and thus regional losses tend to be somewhat larger. In terms of distribution, the *_TAX* cases tend to favor lower income regions (South and middle of the country) at the expense of higher income regions (mainly the east and west coasts) because higher income regions pay more taxes.

Summing up the regional results, all allocation scenarios lead to modest differential impacts across most regions. The *TAAS* and *TAAS_DR* proposals show greater gains to several regions in the initial years of the policy and higher costs to other regions than do the *PCDS* scenarios. One of the political economy realities of climate change is that the East and West Coast regions have pushed harder for climate legislation, while the middle of the country and much of south has resisted such legislation. With high energy intensity in these regions and the significant presence of fossil industry, one might expect greater economic impacts of GHG mitigation legislation in these regions. The Cantwell-Collins bill has not been subject to as much debate and negotiation as the other two bills, and has been able to retain a simple allocation formula. The much richer set of allocation mechanisms in Markey-Waxman and Kerry-Boxer are likely the result of negotiation among representatives of these regions. To the extent our analysis captures the regional distributional intent of these bills it suggests that the allocation formula are not completely effective in evening out regional effects. Some states like Texas and those in the South Central region that might have been expected to suffer higher costs have those costs blunted significantly and actually come out ahead in early years. Other regions such as the Mountain and North Central states remain the biggest losers in early years. Over time the allocation mechanisms evolve, and regional impacts are driven more directly by other factors.

SOURCES VERSUS USES SIDE IMPACTS OF CARBON PRICING

A well-established observation is that carbon pricing incorporates a regressive element because lower income households spend a higher proportion of their income on energy. Most estimates of the distributional impact of carbon and energy pricing focus on this “cost-push analysis” element of carbon pricing by using an Input-Output framework to trace price increases through a make-and-use matrix to evaluate the policy cost on different households based on expenditure shares (e.g., Dinan and Rogers (2002), Parry (2004), Burtraw *et al.* (2009) and Hassett *et al.* (2009)). Such an approach neglects behavioral responses to relative price changes and does not take into account sources side effects. Rausch *et al*. (2009) found that even in a static model the sources side effects were important in determining the distributional effects of carbon pricing. Here we repeat their counterfactual analysis in our recursive dynamic framework.

Figure 10 provides welfare impacts across income groups for three scenarios designed to disentangle the contribution of sources and uses side effects on welfare *across* the income distribution. The logic of our counterfactual analysis is as follows. If households in different income groups are characterized by identical income shares i.e., have equal ratios of capital, labor, and transfer income, then a change in relative factor prices affects all households equally. This counterfactual analysis isolates the distributional impacts of the uses of income effects of a policy. If households are assumed to have identical expenditure shares for all goods and services, a change in relative product prices produces an equal impact on consumers in different income classes. In that case, we isolate the distributional impacts by effects on sources of income of a policy. Any differential burden impacts of a policy across households from the counterfactual case that eliminates differences among households in how they spend their income are then determined by sources of income effects. Results that eliminate differences in income sources, allows us to focus on how uses side factors shape the relative burden of carbon pricing.

The two counterfactual cases do not eliminate these drivers of incidence but by eliminating household heterogeneity they suppress *differential* impacts across the income distribution. Harberger (1962) uses a similar analysis to identify the incidence of a corporate income tax. Note that as we measure the *real* burden, i.e., the change in equivalent variation, our incidence calculation is independent from the choice of numéraire.

Panel *a* shows results for 2015, panel *b* for 2030 and panel *c* for 2050. In each panel results for three cases are shown. The line labeled "carbon pricing burden" shows the welfare effect that combines income and expenditure heterogeneity.

This is the welfare effect, without any recycling, given observed income sources and expenditures shares as they vary among households. The line labeled "identical income shares" eliminates heterogeneity of income sources to isolate the uses side effect of the policy. The line labeled "identical expenditure shares" eliminates expenditure heterogeneity to isolate the sources side effect. A downward slope indicates a progressive result and an upward slope a regressive result.

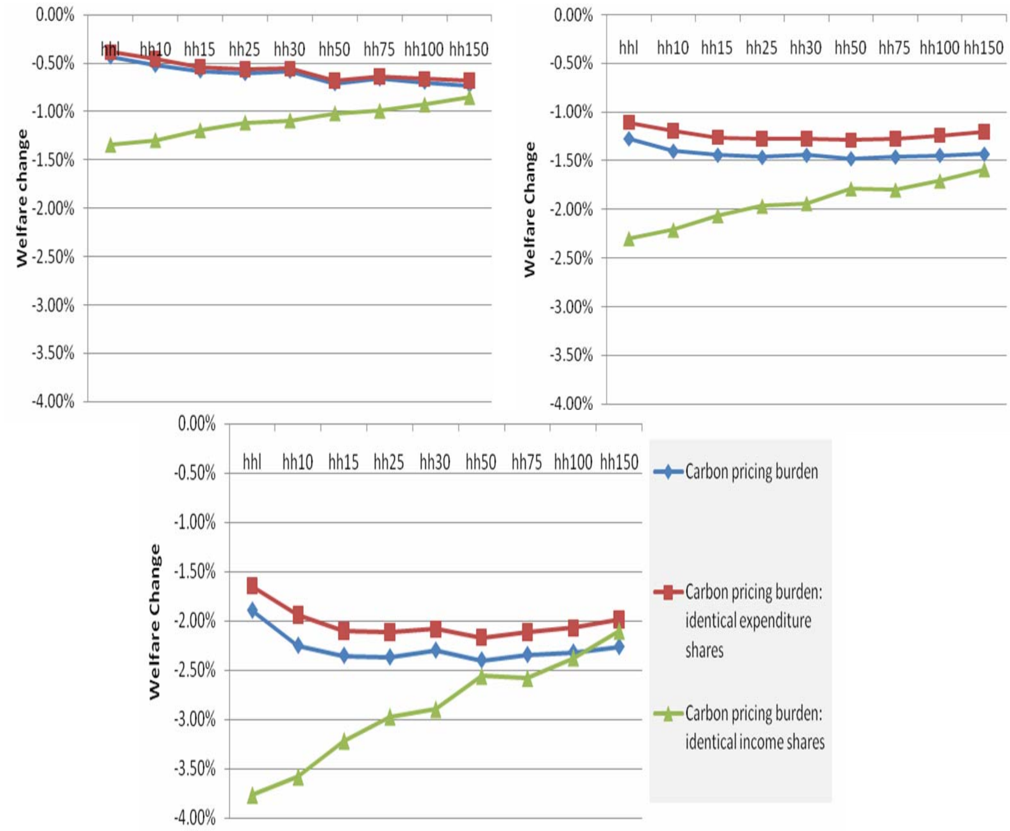

Figure 10. Relative Sources vs. Uses Side Impacts across Income Distribution.

To eliminate the muddying effect of allowance allocation we assume that the carbon revenue is not recycled to households.[48] Non-recycled revenue increases government spending on goods and services which, by assumption, is not utility enhancing. As a result, the costs to households are much larger because the allowance revenue is not available to them. Still, however, we see the striking result that carbon pricing is modestly progressive initially and, for income groups above the two lowest becomes essentially neutral by 2030. For the counterfactual analysis we hold real government transfers to households constant at the no-policy level.

[48] We also looked at a scenario in which we assume that additional government revenue is spent according to private sector consumption. We find that this has second-order effects only.

The uses side impacts are sharply regressive in all years in accord with previous analyses that focus on expenditure side burdens only. Sources side impacts, on the other hand, are modestly progressive in 2015 and essentially proportional in the other years. In all years, combined effects in the line “carbon pricing burden” track closely the line “identical expenditure shares”. This suggests that relative welfare impacts across the income distribution are largely driven by sources side effects.

Table 5 in Rausch *et al.* (2010) reports sources of income by income class for the base year, and helps to explain why sources side effects are modestly progressive especially at low income levels. The relative income burden of carbon pricing depends on the change in relative factors prices and on differences in the ratio for the sources of income for households. We find that the capital rental rate increases over time relative to the price for labor. As the capital-labor ratio slightly increases in income, just looking at the relative income burden from changes in capital and labor income would imply that the sources side is slightly regressive. This finding is in line with Fullerton and Heutel (2010) who find that the capital and labor income for the lowest income households falls proportionally more than average. What makes the source-side incidence modestly progressive to proportional is the fact that low income households derive a large fraction of income from transfers relative to high income households, and we hold transfers constant relative to the no policy baseline. Transfer income thus insulates households from changes in capital and labor income. This effect is strongest for the two lowest income households where transfers account for about 80 and 60 percent of income.

Figure 15 also suggests that especially in a dynamic setting, the sources side effect is more important in determining the welfare impact than is the uses side effect for a *given* income class. The intuition for this result seems fairly obvious — over time the impacts of an ongoing mitigation policy cumulate through effects on overall economic growth and are reflected in general wage rates and capital returns. The annual abatement costs become an ever smaller share of the economic burden of the policy, and so are less important in determining the overall impacts. Furthermore, because the fraction of income derived from transfers increases over time, we find that the progressivity of the sources-side effect also slightly increases for the five lowest income groups.

Overall, this analysis demonstrates that it can be misleading to base the distributional analysis on uses side factors only. The virtue of our general equilibrium framework is the ability to capture effects both from the uses of income and through the sources of income.

SUMMARY

There has been much attention on the overall cost and efficiency of current legislative proposals for addressing climate change in the U.S. In this paper we focus on the distributional effects of the policies taking account of both the higher energy costs that carbon pricing implies and the distribution of allowance value described in the bills. Secondarily we are also interested in any efficiency effects of the allowance allocation approaches in the different bills. To focus on the effect of allowance allocation, we used approximations of the allowance allocation features of current proposals, but represented here as a comparable, comprehensive cap on all emissions in the U.S. with the same level of external credits allowed across all allocation scenarios. We, therefore, did not represent other features of the bills many of which may have strong efficiency and distributional consequences. While we try to adhere to the text of the various pieces of legislation as closely as possible when allocating allowance value, we note that we had to rely on our own interpretation of legislative intent in places where allocation mechanisms were not completely defined in the bills..

Focusing on efficiency first, we find that retaining more of the revenue to offset the deficit impacts of the legislation, as does the Kerry Boxer bill, improves the efficiency of mitigation policy because labor and capital taxes need to be raised less to maintain revenue neutrality. Economic efficiency is improved if all deficit impacts are offset with revenue retained from the allowance auction. The trade-off is that it would leave less revenue to affect desired distributional outcomes.

We also find that the scenarios designed to approximate the Cantwell-Collins allocation proposal to be less costly than those we used to approximate the other bills. We trace this result to the fact that the Cantwell-Collins allocation proposal distributes less of the allowance value to poor households. In the other allocation schemes, more money for poorer households produces a greater income effect on energy demand, and as a result abatement is more costly. Poorer households also save less, and so more allowance value going to poor households leads to less savings and investment. Economists have widely acknowledged that there is an equity-efficiency tradeoff between schemes with lump-sum distribution and those that would cut labor and capital taxes, reducing the distortions they create. Here we find a more subtle equity-efficiency tradeoff, where even under lump sum distribution of revenue there is an efficiency gain to distributing value to wealthier households because less is spent on energy and more of the allowance value ends up as savings and investment.

Our analysis of distribution by income class and region show that the Waxman-Markey and Kerry-Boxer (or Kerry-Lieberman) allocation schemes address the distributional impacts of the policy by redistributing more of the allowance value to poorer households and to central and southern regions of the U.S. in the early years of the policy, shifting allowance value away from wealthier households and the coasts. In fact the bills redistribute to such a degree that they tend to result in net economic benefits for the poorest households and for some regions of the country such as the South Central states, Texas, and Florida that would generally be expected to bear the highest costs. The very simple per capita allocation scheme of Cantwell-Collins tends to be more distributionally neutral by income class but produces slightly less balanced outcome by region. Over time the distribution schemes matter less. In part this is because over time all these bills convert to a consumer rebate and so are more like the Cantwell-Collins allocation approach. However, over time more of the annual cost of the policy is the result of economic growth effects—reductions in past Gross Regional Product, savings, and investment. The annual abatement costs become a smaller share of the total costs, and the available revenue to alter distributional effects shrinks relative to this increasing cost.[49]

An important finding of this paper is that sources side effects of carbon mitigation proposals dominate the uses side effect in terms of determining distribution outcomes. In the near term, the distributional consequences of the carbon pricing can be significantly affected by the distribution of allowance value. Over the longer term, however, the overall growth effects are more important determinants of distribution and the revenue available from the allowance auction may not be sufficient to have much effect in changing distributional outcomes. This point is reinforced by the finding that carbon pricing by itself, i.e., when carbon revenues are not recycled back to households, is neutral to modestly progressive. This follows from the dominance of sources over uses side impacts of the policy and stands in sharp contrast to previous work that has focused only on the uses side. We find sources side effects to be modestly progressive to proportional because low income households derive a relatively large fraction of their income from transfers which insulates them from changes in capital and labor income.

We emphasize that our scenarios focused solely on the distributional implications due to carbon pricing and the allocation of allowance revenue, and that we did not attempt to model each bill in its entirety. More precise representation of the many programs described in these bills could give different outcomes and there is inevitable uncertainty in economic forecasts of this type. We also must admit significant limitations in our ability to forecast relative effects on regions over the longer term. Climate policy will dramatically change energy technologies, and regions that aggressively develop these industries and attract investment could fare better even if they currently are heavily fossil energy dependent. However, such regions must overcome the initially higher costs of their fossil energy dependence.

[49] As noted above, the share of allowances that must be held back for revenue neutrality in the out years falls if government spending as a share of GDP is held fixed. A priori it is not obvious which assumption on government spending is more realistic.

REFERENCES

Babiker, M., G. Metcalf and J. Reilly, 2003: Tax Distortions and Global Climate Policy. *Journal of Environmental Economics and Management*, *46*, pp. 269-87.

Babiker, M., A. Gurgel, S. Paltsev and J. Reilly, 2008: A Forward Looking Version of the MIT Emissions Prediction and Policy Analysis (EPPA) Model. MIT Joint Program on the Science and Policy of Global Change, *Report 161*, Cambridge, MA, available at: http://globalchange.mit.edu/files/document/MITJPSPGC_Rpt161.pdf

Ballard, C., 2000: How many hours are in a simulated day? The effect of time endowment on the results of tax-policy simulation models. Working Paper, Michigan State University.

Bento, A., L. Goulder, M. Jacobsen and R. von Haefen, 2009: Distributional and Efficiency Impacts of Increased Us Gasoline Taxes. *American Economic Review*, *99*(3), pp. 667-99.

Bovenberg, A. and L. Goulder, 2001: Neutralizing the Adverse Industry Impacts of CO_2 Abatement Policies: What Does It Cost? C. Carraro and G. E. Metcalf, *Distributional and Behavioral Effects of Environmental Policy.* Chicago: University of Chicago Press, pp. 45-85.

Bovenberg, A., L. Goulder and D. Gurney, 2005: Efficiency Costs of Meeting Industry-Distributional Constraints under Environmental Permits and Taxes. *RAND Journal of Economics*, *36*(4), pp. 951-71.

Browning, Edgar K. and William R. Johnson, 1979. *The Distribution of the Tax Burden*, Washington, DC: American Enterprise Institute.

Bull, N., K. Hassett and G. Metcalf, 1994: Who Pays Broad-Based Energy Taxes? Computing Lifetime and Regional Incidence. *Energy Journal*, *15*(3), pp. 145-64.

Burtraw, D., R. Sweeney and M. Walls, 2009: The Incidence of U.S. Climate Policy: Alternative Uses of Revenue from a Cap and Trade Auction. Washington, DC: Resources for the Future.

Burtraw, D., M. Walls and J. Blonz, 2009: Distributional Impacts of Carbon Pricing Policies in the Electricity Sector. Washington, DC: Resources For the Future.

Congressional Budget Office, 2009: The Role of the 25 Percent Revenue Offset in Estimating the Budgetary Effects of Legislation. Washington, DC: Congressional Budget Office.

Davies, J., F. St Hilaire and J. Whalley, 1984: Some Calculations of Lifetime Tax Incidence. *American Economic Review*, *74*(4), pp. 633-49.

Department of Energy, 2009: U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 1977 through 2007. Annual Reports, DOE/EIA-0216.

Dinan, T. and D. Rogers, 2002: Distributional Effects of Carbon Allowance Trading: How Government Decisions Determine Winners and Losers. *National Tax Journal*, *55*(2), pp. 199-221.

Dyni, J., 2006: Geology and Resources of Some World Oil-Shale Deposits. USGS Scientific Investigations Report 2005-5294, p 42.

Energy Information Administration, 2009: Annual Energy Outlook 2009. Washington, D.C., U.S. Energy Information Administration DOE/EIA-0383.

Friedman, M., 1957: *A Theory of the Consumption Function*. Princeton, NJ: Princeton University Press.

Fullerton, D.and G. Heutel, 2007: The General Equilibrium Incidence of Environmental Taxes. *Journal of Public Economics*, *91*(3-4), pp. 571-91.

Fullerton, D.and G. Heutel, 2010: Analytical General Equilibrium Effects of Energy Policy on Output and Factor Prices. NBER Working Paper 15788, Cambridge, MA.

Fullerton, D. and D. Rogers, 1993: *Who Bears the Lifetime Tax Burden?* Washington, D.C., Brookings Institution.

Grainger, C. and C. Kolstad, 2009: Who Pays a Price on Carbon? Cambridge, MA: National Bureau of Economic Research Working Paper No. 15239.

Hassett, K., A. Mathur and G. Metcalf, 2009: The Incidence of a U.S. Carbon Tax: A Lifetime and Regional Analysis. *The Energy Journal*, *30*(2), pp. 157-79.

Harberger, A., 1962: The Incidence of the Corporation Income Tax. *Journal of Political Economy 70*, pp. 215-40.

Hyman, R., J. Reilly, M. Babiker, A. De Masin and H. Jacoby, 2003: Modeling Non-CO_2 Greenhouse Gas Abatement. *Environmental Modeling and Assessment*, *8*(3), pp. 175-86.

Lyon, A. and R. Schwab, 1995: Consumption Taxes in a Life-Cycle Framework: Are Sin Taxes Regressive? *Review of Economics and Statistics*, *77*(3), pp. 389-406.

Metcalf, G., 1999: A Distributional Analysis of Green Tax Reforms. *National Tax Journal*, *52*(4), pp. 655-81.

Metcalf, G., 2007: A Proposal for a U.S. Carbon Tax Swap: An Equitable Tax Reform to Address Global Climate Change. Washington, DC: The Hamilton Project, Brookings Institution.

Metcalf, G., S. Paltsev, J. Reilly, H. Jacoby and J. Holak, 2008: Analysis of a Carbon Tax to Reduce U.S. Greenhouse Gas Emissions. Cambridge, MA: MIT Joint Program on the Science and Policy of Global Change Report No. 160.

Minnesota IMPLAN Group, 2008: State-Level U.S. Data for 2006. Stillwater, MN: Minnesota IMPLAN Group.

Morris, J., 2009: Combining a Renewable Portfolio Standard with a Cap-and-Trade Policy: A General Equilibrium Analysis. MS in Technology and Public Policy, MIT, Cambridge, MA.

Musgrave, R.A., 1959: The Theory of Public Finance. McGraw-Hill, New York.

NREL, 2009: Eastern and Western Wind Datasets. Available at: http://nrel.gov/wind/integrationdatasets/

Oakridge National Laboratories, 2009: Estimated Annual Cumulative Biomass Resources Available by State and Price. Available at: http://bioenergy.ornl.gov/main.aspx#Biomass%20Resources

Paltsev, S., J. Reilly, H. Jacoby, R. Eckaus, J. McFarland, M. Sarofim, M. Asadoorian and M. Babiker, 2005: The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Version 4. MIT Joint Program on the Science and Policy of Global Change, *Report 125*, Cambridge, MA, available at: http://globalchange.mit.edu/files/document/MITJPSPGC_Rpt125.pdf

Paltsev, S., J. Reilly, H. Jacoby and J. Morris, 2009: The Cost of Climate Policy in the United States. MIT Joint Program on the Science and Policy of Global Change, *Report 173*, Cambridge, MA, available at: http://globalchange.mit.edu/files/document/MITJPSPGC_Rpt173.pdf

Parry, Ian W. H. 2004. Are Emissions Permits Regressive. *Journal of Environmental Economics and Management* 47:364-387.

Pechman, J., 1985: *Who Paid the Taxes: 1966-85?* Washington D.C., Brookings.

Poterba, J., 1989: Lifetime Incidence and the Distributional Burden of Excise Taxes. *American Economic Review*, *79*(2), pp. 325-30.

Poterba, J., 1991: Is the Gasoline Tax Regressive? *Tax Policy and the Economy*, *5*, pp. 145-64.

Rausch, S., G. Metcalf, J. Reilly and S. Paltsev, 2010: Distributional Implications of Alternative U.S. Greenhouse Gas Control Measures. *The B.E. Journal of Economic Analysis & Policy*, 10(2). Available at: http://www.bepress.com/bejeap/vol10/iss2/art1

Rausch, S., G. Metcalf, J. Reilly and S. Paltsev, 2011: Distributional Impacts of a U.S. Greenhouse Gas Policy: A General Equilibrium Analysis of Carbon Pricing. *U.S. Energy Tax Policy*. ed. G. Metcalf, Cambridge University Press, MA.

Ross, M., 2008: Documentation of the Applied Dynamic Analysis of the Global Economy (ADAGE). Research Triangle Institute Working Paper 08-01.

Tuladhar, S., M. Yuan, P. Bernstein, W. Montgomery and A. Smith, 2009: A Top-Down Bottom-up Modeling Approach to Climate Change Policy Analysis. *Energy Economics*, *in press*.

U.S. Census Bureau, 2009a: American Community Survey 2006: Household Income in the Past 12 Months. Table B19001, accessed on 22 June 2009 via the American FactFinder website, http://factfinder.census.gov/

U.S. Census Bureau, 2009b: State Population Projections. Accessed on 11 January 2009, http://www.census.gov/population/www/projections/stproj.html

U.S. Environmental Protection Agency, 2009: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2007. Washington, D.C., Environmental Protection Agency EPA 430-R-09-004.

U.S. Geological Survey, 2009: USGS USCOAL Coal Resources Database. Available at: http://energy.er.usgs.gov/coalres.htm. and http://pubs.er.usgs.gov/djvu/B/bull_1412.djvu

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