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Rose, Adam and Peterson, Thomas D. and Zhang, ZhongXiang

Pennsylvania State University, Pennsylvania State University, East-West Center

February 2006

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Regional Carbon Dioxide Permit Trading in the United States: Coalition Choices for Pennsylvania

Adam Rose, Thomas D. Peterson, and ZhongXiang Zhang*

Abstract
An overview is given of the growing number of regional associations in which states have entered into voluntary arrangements to limit greenhouse gas (GHG) emissions. In particular, in the Regional Greenhouse Gas Initiative (RGGI), a number of northeastern states have joined to create a regional GHG cap and trade program, beginning with the utility industry. Analysis is made of the five key issues relating to these current and potential climate action associations: the extent of the total and individual state mitigation cost-savings across all sectors from potential emission permit trading coalitions; the size of permit markets associated with the various coalitions; the relative advantages of joining various coalitions for swing states such as Pennsylvania; the implications of the exercise of market power in the permit market; and the total and individual state/country cost-savings from extending the coalition beyond US borders. It is shown that overall efficiency gains from trading with a system of flexible state caps, with greater overall cost savings increasing with increasing geographic scope.

I. Introduction

In the aftermath of the U.S. Presidential decision not to join the Kyoto Protocol, action on climate change mitigation policy formulation has shifted to local, state, and regional governments, as well as the U.S.

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* The authors are, respectively, Professor of Energy, Environmental, and Regional Economics, The Pennsylvania State University; Adjunct Professor and Senior Research Associate, Center for Integrated Regional Assessment, The Pennsylvania State University; Senior Fellow, Research Program, East-West Center. The authors wish to thank Judi Greenwald and Billy Pizer for their helpful comments on an earlier draft of this paper and to Dan Wei for her research assistance. The views expressed in this paper are solely those of the authors and do not necessarily represent the organizations with which they are affiliated.

Senate. In 2001, the six New England Governors joined five Eastern Canadian Premiers (NEG/ECP) in the formulation of a voluntary climate change agreement to reduce greenhouse gases (GHGs) in the transborder region to 1990 levels by 2010 and ten percent below 1990 levels by 2020, and to identify longer-term pathways to reductions by 2100.[1] Through this agreement, states and provinces are encouraged to take individual and collective action across all emitting sectors toward a regional goal. More recently, Connecticut, Massachusetts, New Jersey, New York, and five other northeastern states led a Regional Greenhouse Gas Initiative (RGGI) to create a regional GHG emission cap and trade program for the electric power sector, with several other states acting as formal or informal observers.[2] The states of California, Oregon, and Washington announced the formation of the West Coast Global Warming Initiative[3] in 2003 to organize and motivate action in the region. Other states and provinces of Canada and Mexico may in the future be invited to join this effort.[4] In 2005, fifteen western states participating in the Western Regional Air Partnership (WRAP) began informal discussion of climate change issues, including technical information development.[5] In 2006 the states of Arizona and New Mexico formed a Southwest Climate Change Initiative to enable cooperative actions between these and potentially other neighboring states in the future.[6] In addition, Arizona recently entered a similar cooperative agreement with the State of Sonora, Mexico.[7]

One scenario for multi-state climate change agreements would have the momentum of these and other cooperative actions, including trading blocs, extend to a nationwide arrangement. However, regional characteristics and preferences might lead to a more fragmented, and hence potentially less economically efficient and less environmentally beneficial outcome. On the other hand, by affiliating regionally, these states may be able to capture and motivate regional opportunities for near and mid-term climate actions of great similarity that otherwise would lag. The Northeast and Western States are clearly aware of the benefits of actions to mitigate against vulnerability to climate change, including

1. The NEB/ECP agreement requires five-year scientific updates to clarify long-term targets and timetables. While specific years have not been specified for compliance, some environmental groups haves suggested a default of 2050 as the third time period of the agreement.

2. Webcast Briefing: Regional Greenhouse Gas Initiative (RGGI) (March 18, 2005).

3. West Coast Climate Initiative, http://www.ef.org (last visited Mar. 1, 2006).

4. In addition, all eighteen Western States recently agreed to a regional goal of 30,000 megawatts of renewable power generation by 2015. Western Governors Clean and Diversified Energy Initiative, http://www.westgov.org (last visited Mar. 1, 2006).

5. The Western Regional Air Partnership is a program of the Western Governor's Association, www.westair.org.

6. Actions by the two states are likely to begin once each has completed a comprehensive state GHG plan, now underway. *See* www.azclimatechange.us and www.nmclimatechange.us.

7. Actions between Arizona and Sonora are likely to begin following the completion of statewide climate plans in each, now underway.

potentially serious impacts on forests, agriculture, coastal systems, water resources, tourism, and economic infrastructure. Proactive states may be seeking potential first mover competitive advantage for new programs and technologies for reward under future national law. They also prefer that the federal government be clearly aware of their needs and opportunities under potential federal legislation in the future, and do not want their voices left behind. The northeastern and west coast states are generally not major hosts to fossil fuel extraction (unlike many states of the interior West or Midwest) and are relatively less dependent on fossil fuel electricity generating capacity than are other states (although they depend heavily on imports of fossil-based power supply). Interestingly, while some of the northeastern states have been more open to production-based approaches to emissions reductions, as opposed to consumption-based approaches that would hold them responsible for energy imports, others in the northeast seek consumption-based approaches that are more likely to engender cooperation from high energy production states providing power to the region. West Coast states have generally favored consumption-based approaches to emissions standards in the electric power sector for the same reason. Both northeastern and west coast states are typically low to moderate in forecasted emissions growth in comparison to higher growth regions,[8] and they have typically enacted more emissions control measures than average.

Potentially, this contrasts with the situation in the South Central, Southwest, Intermountain, and North Central States. These have tended to have higher economic and population growth rates, fewer or less stringent control measures, stronger energy lobbies, and have been more hesitant to join the existing climate action coalitions until recently.[9] One reason that new states may have so far resisted entrance into emerging cap and trade programs of the Northeast and West Coast is that current policy proposals could position them as permit buyers rather than sellers under traditional cap and trade control programs, particularly under production-based vs. consumption-based controls. Although involvement in a multi-state cap and trade system would lower their mitigation cost in contrast to voluntary unilateral action, individual South Central, Southwest, Intermountain, and North Central States might still be inclined to explore other policy designs (such as electricity load-based systems) and coalition configurations that enable them to be permit sellers or to be buyers at lower cost. By entering coalitions of states with

8. Growth rates for coastal states of the northeast and west coast average about 33 percent for the period 1990-2020. For example, while Arizona has an estimated emissions growth rate of 147 percent in this same period and New Mexico's rate is estimated at 64 percent. (data and discussion *available at* www.azclimatechange.us/ewebeditpro/items/O40F7959.pdf).

9. Recently, governor-appointed climate change advisory groups charged with developing statewide GHG plans in Arizona and New Mexico have tentatively agreed to explore regional and or national cap and trade approaches in the future, along with numerous other mitigation policies in all sectors (*see* www.azclimatechange.us and www.nmclimatechange.us).

more consonant baselines and GHG mitigation cost curves, or with states willing to mutually recognize comparable levels of effort that are indexed off of growth baselines instead of fixed base year amounts, they surmise that they are likely to be better off. They might also band together as a single permit purchasing entity, or as smaller regional clusters, to exercise monopsony power to lower the costs of permits.[10]

Also, although traditional regional associations, based in great part on history and geography, so far are pursuing forward movement on climate mitigation, conditions unique to the benefits and costs of GHG mitigation may call forth new alliances among states. In the modern world of rapid transportation and communication, and in the case of a "globally mixed" pollutant, future coalitions need not even be confined to contiguous states. For example, Oregon has recently joined the RGGI discussions as a formal observer (in addition to exploring a statewide cap and trade program independently), and invitations have been extended to California, Washington, and North Carolina.

Interestingly, exploration of regional climate action coalition possibilities has also extended far beyond U.S. borders. The RGGI coalition is discussing whether its members should be allowed to buy permits from the European Union. The West Coast States are examining various GHG reduction opportunities with Pacific Rim countries, Canada, and Mexico, including both Kyoto signatories and non-signatories. Although the Kyoto Protocol currently restricts signatories from buying permits from non-participants, this obstacle might be overcome through further negotiation.[11] One incentive is that this may be a way of obtaining U.S. involvement in Kyoto or future UNFCCC commitment periods by working directly with willing state governments in lieu of the current, recalcitrant presidential administration. At the same time, there may be a disincentive to some U.S. states who stand to be major permit sellers in a purely U.S. arrangement, but whose offer price might be undercut by other countries.

The purpose of this paper is to analyze several important issues relating to current climate action coalitions in the U.S., potential coalitions among the states, and the choices facing Pennsylvania. These issues include:

10. Note that permit allocations may be assigned first to either state governments or individual emitters. If assigned to states, a government agency may be the official trading entity on behalf of emitters within its jurisdiction, or the agency may just in turn distribute the permits directly to emitters. Monopsony power might arise in either instance. Even if permits are assigned directly or indirectly to emitters, states are the negotiating parties in RGGI, in part on behalf of the emitters within their borders. States with a large number of permit buyers can wield additional influence on the baseline permit allocation to their constituents or with respect to the permit price. All of these outcomes will be beneficial for the states likely to be large permit buyers and a departure from the competitive outcome. Thus, the results below represent an approximation of some of the possibilities of executing market power of various types.

11. One embassy representative of a European nation reacted to the barriers of including individual or a group of U.S. states in the Kyoto agreement as "ninety percent political, and ten percent legal."

1. How large are total and individual state mitigation cost-savings across all sectors from potential emission permit trading coalitions?

2. What is the size of permit markets associated with the various coalitions?

3. What are the relative advantages of joining various coalitions for swing states such as Pennsylvania?

4. What are the implications of the exercise of market power in the permit market?

5. What are the total and individual state/country cost-savings from extending the coalitions beyond U.S. borders?

We will use models of interregional and international permit trading developed by Rose and Stevens,[12] Zhang,[13] Loschel and Zhang,[14] and Rose and Zhang.[15] These models are based on finding equilibrium/optimum solutions to permit exchanges given a set of GHG emissions forecasts and mitigation cost functions for each trading entity and overall emission caps, as well as various institutional constraints. The results should prove useful to climate policy-makers, business leaders, and environmental groups in their decisions about whether and how to participate in voluntary climate action planning arrangements.

II. Background

In 2001, Governor Pataki launched a comprehensive state climate change mitigation planning process following the decision of the incoming Bush administration to withdraw from negotiation on the Kyoto Protocol. Prior to that time many states had formulated GHG plans without high-level political involvement, public input, or intensive cost-benefit analysis. Since that time several other states have followed suit, including Arizona, California, Connecticut, Massachusetts, Maine, New Mexico, North Carolina, Oregon, Rhode Island, and Puget Sound (Washington). The governor of Montana recently announced formation of a statewide planning process to establish a state GHG plan as well. New Jersey had developed a partial plan prior to 2000 and began updates toward a comprehensive approach. Wisconsin and Oregon had also

12. Adam Rose & Brandt Stevens, *An Economic Analysis of Flexible Permit Trading in the Kyoto Protocol*, 1 INT'L ENVTL. AGREEMENTS: POL., L. & ECON. 219 (2001).

13. ZhongXiang Zhang, *The Design and Implementation of an International Greenhouse Gas Emissions Trading Scheme*, 18 ENV'T & PLAN.: GOV'T & POL'Y 321 (2000).

14. Andreas Loeschel & ZhongXiang Zhang, *The Economic and Environmental Implications of the U.S. Repudiation of the Kyoto Protocol and the Subsequent Deals in Bonn and Marrakech*, 138 WELTWIRTSCHAFTLICHES ARCHIV 711 (2002).

15. Adam Rose & ZhongXiang Zhang, *Interregional Burden-Sharing of Greenhouse Gas Mitigation in the United States*, 9 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 477 (2004).

developed plans with partial implementation. In addition to the NEG/ECP, RGGI and West Coast Global Warming Initiatives, other regional efforts indirectly related to GHG mitigation have been formed. These include: the Clean and Diversified Energy initiative of 18 western states to expand energy efficiency and renewable energy use; the Western Renewable Energy Generation System (WREGIS) to track renewable energy used to meet renewable energy portfolios in 11 western states; and the Powering the Plains initiative of five northern great plains states and the Province of Manitoba to expand alternative energy supply sources and technologies and track their implementation. The U.S. Senate has voted twice on pending legislation to establish a national greenhouse gas mitigation policy through the Global Climate Security Act of 2003, sponsored by Senators McCain and Lieberman. This bill is expected to be the basis of long term national policy formulation in Congress, together with new actions by state governments.

In addition to comprehensive planning efforts, U.S. states have developed and/or enacted a remarkable variety of individual climate policy actions, often through reform of energy policy, transportation policy, resource management, land use, or air quality programs. Together they constitute a portfolio of over 200 specific actions across all sectors and include: renewable portfolio standards, system benefit funds, appliance standards, building codes, smart growth programs, state procurement programs, power plant offset requirements, forest and farm conservation programs, waste to energy programs, and other measures. Implementation mechanisms include a variety of voluntary and mandatory approaches, including market based cap and trade programs.[16]

New York was the first state in the recent era to seriously consider state-based cap and trade programs.[17] As a result of state and regional modeling of these potential programs,[18] the state government and a broad array of stakeholders concluded that a regional approach was preferable to a unilateral state approach due to potential competitiveness impacts and displacement (also known as "leakage") of emissions from imported power, in addition to the likely efficiency gains from including more low-cost sources. In 2003, the state of Connecticut launched the Connecticut Climate Change Stakeholder Dialog (CCCSD) to provide recommendations to Governor Rowland to meet or exceed targets of the

16. For a discussion of examples of these actions, *see* Thomas D. Peterson, *The Evolution of State Climate Change Policy in the United States: Lessons Learned and New Directions*, 14 WIDENER L.J. 81 (2004). For a summary of nearly 200 local government initiatives, *see* Carolyn Kousky & Stephen H. Schneider, *Global Climate Policy: Will Cities Lead the Way?* 3 CLIMATE POL'Y 359 (2003).

17. NYSERDA launched the New York Greenhouse Gas Task Force for Governor Pataki in 2001 and formed a stakeholder process that delivered recommendations to the Governor in 2003.

18. ICF Consulting's Integrated Planning Model (IPM) of the electricity sector was deployed to examine several cap and trade scenarios in New York and the surrounding region. Results suggested significant potential for electric power imports in response to constraints on New York power generators.

NEG/ECP. During the course of intensive deliberations by this group, new modeling was conducted of potential state and regional cap and trade scenarios for the power generation and consumption sector.[19] Results again suggested major displacement of in-state emissions reductions from power exports, and led stakeholders to recommend (unanimously) that the state pursue cap and trade policies at the broadest geographic level possible, and to explore alternate mechanisms to address power imports. In particular, generation performance standards and consumption-based standards were recommended for further review. During this same period New Jersey began to explore the prospects of a regional renewable portfolio standard among Pennsylvania, New Jersey, and Maryland, which are connected by the PJM Independent System Operator.

As a consequence of the modeling results and stakeholder inputs of these and other state planning processes, several states expressed interest in regional discussion of a cap and trade program. New York Governor Pataki invited ten other states to join in regional discussions, and, when eight accepted, the Regional Greenhouse Gas Initiative (RGGI) was born. This interstate dialog set a goal of developing program recommendations and policy design by April 2005, including stakeholder input and a variety of technical analysis and modeling. Preliminary results of this modeling have recently become available and provide similar results to earlier modeling done in New York and Connecticut. The configuration of states (the definition of "region") and level of effort expected of each state are key variables in this process. The role that Pennsylvania plays is critical. Earlier modeling from the Connecticut dialog suggested a substantial level of low-cost, high-emissions coal-based power export from Pennsylvania and the Eastern Interconnect under a production-based Northeastern cap that did not include generators outside the region.[20]

One key result of modeling in the Northeastern States was a definition of forecasted "baselines" of emissions through 2020. Significant differences exist between states that affect mitigation costs, levels of effort against common targets, and credit market positioning. For instance, modeling in New York predicted a 17 percent *reduction* in carbon emissions below 1990 baseline levels by 2020, whereas modeling in Connecticut predicted a slight *increase* over the same period. These differences are due to multiple factors, including the treatment of imports and exports of energy, and have a crucial impact on multi-state target negotiations where equity is concerned.[21] Future modeling efforts must explore alternate baseline setting methods (such as baseline growth),

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19. IPM was used to develop a reference case for the state and region and evaluation of six cap and trade scenarios.

20. Webcast Briefing: Regional Greenhouse Gas Initiative (RGGI) (March 18, 2005).

21. *See, e.g.,* Adam Rose & ZhongXiang Zhang, *Interregional Burden-Sharing of Greenhouse Gas Mitigation in the United States*, 9 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 477 (2004).

state configurations, control strategies, and a broader set of trading sectors than the current exclusive focus on electricity generation, if displacement effects are to be minimized, rules are to be fairly negotiated, and emission purchase/sale patterns are to be clearly understood.

III. The Model

Our model is based on well-established principles of the ability of unrestricted permit trading to achieve a cost-effective allocation of resources in the presence of externalities.[22] In the context of the RGGI, where a strict cap implies unique GHG emission reduction requirements, the individual state and overall regional optimization can be accomplished without explicit consideration of the benefits side of the ledger (i.e., it yields "efficiency without optimality"). It simply requires equalization of marginal costs of all entities with the equilibrium permit price.[23] This ensures minimization of total net compliance costs for each region and minimization of total abatement costs for the nation as a whole.[24] For purchasing states, compliance costs are equal to own abatement cost plus the cost of permits, whereas for selling regions, compliance costs are equal to own abatement cost minus the revenues from selling permits.[25] States with marginal mitigation costs above the permit price will buy permits, while states with marginal mitigation costs below the permit price will sell permits. Both will be better off as a result, with purchasing states reducing their net costs of mitigation and selling states reaping a profit from the sale of permits. For the region as a whole, permit sales and purchases balance.

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22. *See, e.g.*, THOMAS H. TIETENBERG, RESOURCES FOR THE FUTURE, EMISSIONS TRADING: AN EXERCISE IN REFORMING POLLUTION POLICY (1985). Emission permit trading, or the "property rights" approach to environmental remediation stems from the Coase Theorem, which provides the rationale for permit trading: that externalities (such as pollution) can be efficiently eliminated (or a target reduction achieved) if enforceable property rights (emissions permits) can be assigned, regardless of the initial distribution of property rights or the final distribution of outcomes.

23. *See* ZhongXiang Zhang, *The Design and Implementation of an International Greenhouse Gas Emissions Trading Scheme*, 18 ENV'T & PLAN.: GOV'T & POL'Y 321 (2000); Andreas Loeschel & ZhongXiang Zhang, *The Economic and Environmental Implications of the U.S. Repudiation of the Kyoto Protocol and the Subsequent Deals in Bonn and Marrakech*, 138 WELTWIRTSCHAFTLICHES ARCHIV 711 (2002); Adam Rose & ZhongXiang Zhang, *Interregional Burden-Sharing of Greenhouse Gas Mitigation in the United States*, 9 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 477 (2004).

24. For a generalized optimization approach to the problem*, see also* Brandt Stevens & Adam Rose, *A Dynamic Analysis of the Marketable Permits Approach to Global Warming Policy: A Comparison of Spatial and Temporal Flexibility*, 44 J. ENVTL. ECON. & MGMT. 45 (2002).

25. WILLIAM D. NORDHAUS, MANAGING THE GLOBAL COMMONS (1994). The shape of the cost function for mitigating carbon emissions has been studied extensively. For example, Nordhaus found that the logarithmic functional form provided the best fit for the estimates of the marginal costs of mitigating a specific amount of carbon emissions among a number of economic modeling studies that he surveyed (a type of meta-analysis). *Id*. Nordhaus used an analytical model to further derive a logarithmic relationship between the marginal costs and the percentage reduction. *Id*. The cost function used in our study is thus $MCA_i = -\ln(1 - R_i)/\alpha_i, \quad i = 1, \ldots, n.$

The formal model consists of a set of marginal cost curves, one for each state, sets of constraints relating to initial permit allocations for individual states and total emission permit levels, and permit demand and supply balances. The objective function is to minimize the net cost of GHG mitigation across all states in a given permit trading coalition. The model is modified with respect to the assumption of "price-taking" behavior for conditions of market power on the buyer's side (monopoly) or seller's side (monopsony). The model is solved with the use of the General Algebraic Modeling System (GAMS).[26]

IV. Basic Results

Our simulations were performed with the model summarized in the previous section calibrated to the abatement cost functions for each state in the existing or potentially expanded RGGI trading bloc and various other potential coalitions in the U.S. The model incorporated the original state GHG caps equal to the NEG/ECP levels: GHG levels in 2010 equal to 1990 levels, and GHG levels in 2020 equal to ten percent below 1990 levels. During the course of recent negotiations, however, these targets were substantially reduced to minimize potential displacement and cost impacts.[27] In addition, the states of Massachusetts and Rhode Island dropped out of the agreement prior to its conclusion. We simulate some but not all of these changes as well. The model could readily be adjusted further with new state configurations, state targets, cost curves and emissions forecasts, as well as the use of a consumption based vs. production-based system.

The empirical base of the model is an extension of that developed by Rose and Stevens.[28] The major refinement in this present study was to specify mitigation cost functions for each of the states and the European Union. This was done for the states by adjusting the U.S. mitigation cost function in the Rose-Stevens model by parametric shifts for the states in direct proportion to their energy intensity weighted by the relative carbon content of the three major fossil fuels.[29] Thus, for

26. ANTHONY BROOKE, DAVID KENDRICK, & ALEXANDER MEERAUS, GAMS: A USER'S GUIDE (Scientific Press 1996) (1992).

27. The final draft model rule for RGGI establishes the following GHG reduction target: "RGGI will stabilize emissions from the power sector at approximately current levels from the start of the program in 2009 through the beginning of 2015. From 2015 through 2018 emissions will decline, achieving a 10% reduction in 2018. In addition, some of the program reductions will be achieved outside the electricity sector through emissions offset projects." Text of the draft rule is available at www.rggi.org/modelrule.htm.

28. *See* Adam Rose & Brandt Stevens, *The Efficiency and Equity of Marketable Permits for CO_2 Emissions*, 15 RESOURCE & ENERGY ECON. 117 (1993); Adam Rose & Brandt Stevens, *A Dynamic Analysis of the Marketable Permits Approach to Global Warming Policy: A Comparison of Spatial and Temporal Flexibility*, 44 J. ENVTL. ECON. & MGMT. 45 (2002).

29. The shift is accomplished by altering the α_i parameter value (see, e.g., equation 1). The basic α_i value is 0.00357 for the U.S. as a whole based on a synthesis of values in the literature, including a provision for technological change. Given the functional form, energy intensity and the parameter value have an inverse relationship. Thus, a state with an emission weighted fossil energy intensity half as large as the U.S. average would

example, higher cost states are Pennsylvania, Maryland, Delaware, and Maine, with relatively lower cost states being Massachusetts, Connecticut, and New York. This is an admittedly crude basis for mitigation cost specifications, and hence the results presented here should be taken only as generally illustrative of the issues at hand.[30] Alternate cost curves could be substituted in the model based on empirical results, expert judgment, or sensitivity analysis.

The results from preliminary simulations of a carbon cap and trade system under various geographic configurations are presented in Tables 1 through 3. All pertain to permit trading in various combinations of states in the Northeast U.S., including one simulation that adds the European Union to the mix, to achieve targets set forth by RGGI—carbon dioxide emission reductions to Year 1990 levels in each state by the Year 2010. Note that the analysis includes all potential carbon emitters and not just the electricity sector. Although the configuration of RGGI is currently limited to the latter, designers of the system, as well as policy-makers in other regions, gave serious consideration to expanding it to include other emitters and expect that future implementation phases would do so.[31] The analysis here then represents the ultimate extension

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have an α_i parameter value twice as large (0.00714). These relative weighted fossil fuel intensity values are proportional to the ratios of CO_2 emissions and GSP in Appendix A. The α_i parameter for the European Union is 0.00314, which is steeper than the U.S. average. Note also that, although the marginal cost curve has a logarithmic term, because α_i is in the denominator the overall function is essentially an exponential one, which exhibits the desired diminishing returns feature.

30. Note that our analysis has other limitations on the cost side and omits the benefits side completely. First, our cost functions are based on a synthesis of the professional literature and include primarily GHG mitigation strategies such as conservation, interfuel substitution, and other fuel and input substitution. This omits, for example, the alternative of reducing carbon in the atmosphere by various means of carbon sequestration, such as tree planting. Rose and Oladosu have shown that incorporating sequestration can greatly reduce the total cost of reducing CO_2. Adam Rose & Gbadebo Oladosu, *Greenhouse Gas Reduction in the U.S.: Identifying Winners and Losers in an Expanded Permit Trading System*, 23 ENERGY J. 1 (2002). Unfortunately, data are inadequate to specify regional distinctions in sequestration costs at this time. Likely regional differences in these costs could significantly affect the results presented here, though not in the near term, such as the Kyoto compliance period (2008-12), since it takes some time (to allow for tree growth) for this option to take hold. (The term, "mitigation," is sometimes used to cover the broader set of tactics, including sequestration, while abatement is sometimes used to cover the more narrow set. We use the terms as synonyms with the clear understanding that we have not included carbon sequestration.) We have omitted the benefits of GHG mitigation as well, which are also likely to have significant differential impacts across regions. *See, e.g.,* Barry D. Solomon & Russell Lee, *Emissions Trading Systems and Environmental Justice*, 42 ENV'T. 32 (2000). Benefit estimates are especially tenuous, and we have sought to illustrate major issues and the usefulness of our methodology with as strong a data underpinning as possible. The reader is referred to Rose and Stevens for insight into the difference that the inclusion of benefits makes in permit trading systems in the international domain. *See* Adam Rose & Brandt Stevens, *An Economic Analysis of Flexible Permit Trading in the Kyoto Protocol*, 1 INT'L ENVTL. AGREEMENTS: POL., L. & ECON. 219 (2001); Brandt Stevens & Adam Rose, *A Dynamic Analysis of the Marketable Permits Approach to Global Warming Policy: A Comparison of Spatial and Temporal Flexibility*, 44 J. ENVTL. ECON. & MGMT. 45 (2002). Of course, actual policy design must include some assessment of benefits.

31. Webcast Briefing: Regional Greenhouse Gas Initiative (RGGI) (March 18,

of this proposal. Of course, the implications of broader coverage are sensitive to various aspects of policy instrument design (e.g., upstream vs. downstream allocation of permits). However, we abstract from these subtleties at this point.[32]

The simulations are based on data presented in Appendix Table A for RGGI states, as well as analogous data for other U.S. regions and the European Union. The results, in terms of emission projections and mitigation cost levels are sensitive to the data sources and assumptions used, over which there is some variation in the literature, especially with regard to future emissions projections. However, the focus of the analysis here is on relative impacts across states, a condition that is less sensitive to precise projections or cost curves.[33]

The simulations to follow are ordered in an ascending manner in terms of geographic units included in the trading program. Simulations actually begin with an analysis of the outcome of confining trading to the original six New England states, then progresses to the current configuration of RGGI plus one observer state (Maryland), and then to the inclusion of Pennsylvania and the European Union. Although each progressive expansion of RGGI increases the gains from trade and lowers the per-unit cost of achieving the given emission reduction, some

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2005).

32. The main avenue for expansion beyond the current emissions and remediation scope of RGGI is "offsets." This refers to reductions in emissions outside the program that can count as reductions to emitters within it. Offsets can be viewed as partial trading, i.e., emitters can purchase or sponsor offsets but not sell them. At present serious consideration is being given to expanding beyond just the electricity sector to include natural gas efficiency, expanding beyond carbon dioxide to include landfill gas and SF_6 from electricity transmission, and expanding beyond current RGGI borders through participation in the Clean Development Mechanism (CDM) and including the European Union (EU). Future offsets include such GHGs as HFC-23 and coal mine methane (if Pennsylvania participates), as well as additional mitigation strategies such as soil sequestration. In addition, the geographic expansion has been referred to as "any location in the U.S. with an adequate carbon constraint." *Id.* Various studies have shown that making permit trading as comprehensive and flexible as possible can significantly lower mitigation costs (e.g., by as much as 75 percent over non-tradeable quotas on a single GHG). Of course, there are extensive design and implementation issues that must be addressed, e.g., the "trading ratio" between the various GHGs. Also, to be considered is the cost of managing and enforcing such broad agreements. Considerable economies of scale and scope do exists, but the best approach may be a sequential evolutionary one that capitalizes on successful experience, while maintaining partner cohesion and opportunities to fully engage the stakeholder process. *See, e.g.,* Nathan Collamer & Adam Z. Rose, *The Changing Role of Transaction Costs in the Evolution of Joint Implementation*, 9 INT'L ENVTL. AFFAIRS 274 (1997).

Other ways of expanding a trading program refer to its time horizon. Currently the plan is for a three-year compliance period in RGGI, so there is some implicit banking and borrowing of permits. Otherwise, banking over longer periods is allowed and early credit action is as well. These considerations add some flexibility in timing mitigation, though this opportunity has not been found to yield cost-savings anywhere near as large as those noted in the previous paragraph. Brandt Stevens & Adam Rose, *A Dynamic Analysis of the Marketable Permits Approach to Global Warming Policy: A Comparison of Spatial and Temporal Flexibility*, 44 J. ENVTL. ECON. & MGMT. 45 (2002). Moreover, it may make enforcement more difficult.

33. The emissions projections in this paper are near the upper bound of the range of projections by several other sources.

expansions yielded only very light improvements. On the other hand, while overall changes may be minor, the distribution of gains among individual states and the European Union vary much more significantly. This is primarily because each configuration is achieved at a different equilibrium permit price, and the individual pattern of trading is very sensitive to this variable.

A. New England States Only

The first set of simulations is for the New England States alone (Table 1), whose gross emissions in 2010 are projected to be 62 million tons of carbon (tC) and whose cap, equivalent to 1990 emission levels, is 45.2 million tC (see Appendix Table A). In this case, total mitigation costs in the absence of trading are estimated to be $2.072 billion, and permit trading lowers this amount by only a modest 4 percent to $1.988 billion. The permit market is rather thin given the narrow distribution of mitigation cost curves for these six states (i.e., the marginal cost of carbon mitigation does not vary much).

Given their relatively high mitigation cost curves, ME and NH are permit buyers and CT and RI sell a significant number of permits, while MA and especially VT sell very few. The equilibrium permit price is $68.02 per ton carbon, and the marginal mitigation costs for the latter two states are very close to this level ($67.89 for MA and $67.96 for VT), thereby significantly limiting their gains from trade.

Net cost comparisons before and after trading indicate the biggest winner is ME in both absolute and relative terms. The bottom line, however, is that all states are better off after trading, though only marginally so for some states, and even states that are relatively large buyers of permits have as much or more to gain, in both absolute and relative terms, than do permit sellers.

B. RGGI States Plus Maryland.

The second set of simulations is for the nine original RGGI States plus Maryland, and will serve as a reference point for the subsequent simulations.[34] This configuration has projected emissions of 213 million tC, or more than triple that of the New England states alone, with NY being the largest emitter by far. At the same time, the four additional states have mitigation cost curves within the range of those of the original New England states, with NY having the lowest curve, but still higher than those of RI and CT (see Appendix Table A).

As shown in Table 2, total mitigation costs for the ten states before trading are $7.125 billion, and this total declines to $6.916 billion after trading, or only a 3 percent improvement. The minor overall gains from trade are due to the fact that the weighted average of the four additional states' mitigation cost curves are only slightly below the New England

34. At the time of this writing, a bill, with considerable support, is before the Maryland Legislature requiring that this state join the RGGI coalition.

states weighted average. This is also reflected in the equilibrium permit price for Case B of $69.13 per ton carbon, which is only 1.6 percent different, though higher, than in Case A.

Of course, the size of the permit market expands considerably, and all of the New England states engage in more permit trading than in Case A. However, in terms of net costs, only one of the New England states (Connecticut) receives an improvement, and then it is only slightly more than 1 percent, in Case B over net costs in Case A. All four of the additional states that make up the expanded RGGI area are better off as a result of joining the trading program (compare the "Before Trading Mitigation Cost" column and the "After Trading Net Cost" column of Table 2) but only slightly. MD reaps the greatest absolute gain ($51 billion) and DE the largest relative gain (12 percent). NY is the only one of the four additional states to be a permit seller, and at a level more than three times as high as the next highest selling state (CT). MD becomes the largest permit buyer by nearly twice as much as the next highest buying state (ME).

C. RGGI Plus Pennsylvania

The third simulation adds Pennsylvania to the RGGI plus Maryland configuration. This new entrant's carbon emissions are more than three times as high as MA and nearly twice as high as the entire New England region. Moreover, PA's marginal mitigation cost of $153.06 is more than twice as high as all of the New England States except ME. Total carbon dioxide emissions projections for the entire group are now about 309 million tC, about 45 percent higher than the overall total in Case B (see again Appendix Table A). Pennsylvania has a marginal mitigation cost curve significantly higher than the marginal cost curves of all the RGGI states (see Appendix Table A), thereby resulting in a new permit market equilibrium at $84.77, significantly higher than the prior simulation.

As shown in Table 3, total mitigation costs before trading are estimated to be $14.1 billion, but this time the overall cost savings is much higher than in Simulation 2 at 12.9 percent. Again all states are better off as a result of trading, with PA achieving the largest absolute gain ($1.3 billion) and RI again achieving the largest relative gain (23.5 percent). PA is the largest permit buyer (38.9 million tC), and NY is still the largest permit seller (23.7 million tC).

Compared to Case B, and owing to the higher permit price in Case C, all permit selling states are better off and all permit buying states are worse off. The biggest gainer from the inclusion of PA is CT in absolute terms and RI in relative terms. The biggest losers are MD in absolute terms and ME in relative terms. All New England states are better off than in Case A except ME.

Clearly, by the nature of the size of its emissions and relatively high cost of mitigation, PA dominates the market (91 percent of the permit purchases). Although it has much to gain from joining RGGI in comparison to a "go it alone" strategy (gains from trade of $1.3 billion), PA residents may be slow to appreciate the outflow of more than $3.3 billion annually for emission permit purchases. Also, given its dominance in the market on the buyer's side, PA could exercise its monopsony power (the ability of a large buyer to influence the permit price to its own advantage) to significantly lower the permit price, thereby reducing its permit expenditures, as well as the potential revenue of permit sellers. The detailed effects of this strategy will be explored next.

D. Expanded RGGI with Pennsylvania Exercising Monopsony Power

The fourth simulation includes the same states as the third but allows Pennsylvania to exercise its market power in light of its domination of the market on the buyer's side. The overall results (not shown in a detailed table) are not drastically different than those of Table 3.

By exercising its monopsony power, Pennsylvania is able to lower the permit price, but only slightly, from $84.77 to $82.09. This makes permit sales less attractive to sellers, and there is an overall reduction in permit transactions from a market of $3.649 billion to one of $3.079 billion. Pennsylvania purchases decrease by $635.9 million, but are offset a bit by permit purchase increases by MD, ME, and DE.[35]

Total net costs for all states after trading are increased but only by $42.9 million, or 0.35 percent; this is a measure of the efficiency loss due to the imperfect competition in the market. Despite the exercise of market power, PA's gain is only $52.4 million or only a 0.93 percent improvement. Thus, the net loss to all other states as a whole is $95 million, or 1.4 percent of their net costs in Table 3. All permit selling states are slightly worse off than under Scenario 3, and all permit buying states are slightly better off. Of course, all states are better off than had trading not occurred, and all permit sellers are still better off than if Pennsylvania had not joined the agreement.

E. RGGI plus MD Plus EU

The fifth simulation (again not shown in detail) adds the European Union to an expanded RGGI configuration but omits PA. Despite its much larger size in terms of its economy and carbon emissions, the EU is compatible with this arrangement. Its mitigation cost curve is slightly higher than the U.S. average, but slightly lower than the weighted average of the RGGI states (it is lower than ME, MD, and DE, and much lower than PA). Despite having projected CO_2 emissions five times higher than the RGGI group, the EU buys only a modest amount of

35. Pennsylvania's decision to buy fewer permits despite having forced their price down is consistent with behavior in a monopsony market. As in a monopoly market, power is exercised by restricting the market size.

permits (35.7 million tC).[36] Despite having more than ten times the emissions of PA, this means that EU purchases even fewer permits from RGGI than did PA in Case C. The equilibrium permit price for this case is $83.39, or $1.38 less than Case C. Despite all of this, however, the gains from trade to Europe are only about $95 million, or an improvement of only 0.3 percent. Moreover, we have looked at a sub-set of all trading possibilities for Europe. The EU is likely to find other attractive partners in a global trading scheme, and thus its involvement in RGGI would be even smaller, as would its gains from trade.

Comparing this simulation with that of Table 2, all RGGI states, except permit buying states ME, DE, and MD, are better off with the entry of the EU. Of these states, MD suffers the largest absolute loss $48 million, while ME receives the largest percentage decrease (10 percent). All permit sellers are better off with the entry of the EU. The larger absolute gain goes to NY ($220 million) and the largest percentage gain goes to CT (14 percent).

F. RGGI Plus MD, PA and EU

The sixth simulation adds both PA and the EU to the base case. The equilibrium permit price is now $87.43, an increase from Case B of over $18, and a slight increase from Case E of slightly over $4. Accordingly, in comparison to Case E, all permit selling states are projected to be a few percentage points better off in terms of net costs, while all the permit buying entities are projected to be worse off for a few percentage points. The EU is only 0.03 percent worse off.

PA's permit expenditures are $3.271 billion, compared with $3.308 billion in Case C, but the EU's permit purchases, due to a significantly higher permit price in this case, drop to $697 million in Case F from $2.978 billion in Case E. In fact, given other permit opportunities, especially with low cost options in Eastern Europe, it is conceivable that extending an invitation to the EU would be a moot point if PA were also to be part of the trading arrangement.

V. Recent Defections from RGGI

As noted earlier, Massachusetts and Rhode Island recently dropped out of the RGGI coalition, but Maryland is likely to join. We therefore simulated the implications of this modified coalition, though with the original RGGI emission target levels. These levels are assumed to be indicative of future RGGI target adjustments.

The results (not shown in detail) of a simulation including the eight current RGGI states are not much different than those presented in Table 2. The equilibrium permit price rises from $69.13/tC to $69.53/tC

36. The EU cap is approximately equal to its Kyoto commitment of an 8 percent reduction below 1990 levels. We did not have data for the current definition of the EU, so we were forced to use the definition of OECD Europe in its place. This approximation led to using a cap for the EU in our simulations of 7.8 percent, rather than 8 percent, below 1990 levels.

because the defectors, MA and RI, have marginal cost curves below the coalition average. The higher permit prices engender marginally fewer trades. Both MA and RI were permit sellers, and NY, CT, and now VT, take up the slack, though all permit purchasing states buy fewer permits. Changes in net costs for all states are very small, with the largest absolute decrease being $50 million for NY.

The results of the modified coalition, but with the inclusion of PA, are shown in Table 4, and are compared with Table 3. Here the permit price increases from $84.77/tC to $87.45/tC. PA is still the largest permit buyer, though its purchases increase from $3,308 to $3,266. NY is still the largest permit seller, and again its sales increase as it takes up much of the slack from the defectors. Net costs go up for PA and other permit buyers, and go down for all permit sellers relative to Table 3 because of the increased permit price. The maximum absolute value change in mitigation costs is less than two percent (PA). Thus, the defection of MA and RI appears to make little difference, because MA's marginal mitigation cost curve is near the middle of the RGGI pack and because RI is such a small participant.

VI. Other Potential Coalitions

In this section, we explore PA's participation in three other coalitions. The first is with the North Central States of WV, IL, IN, MI, OH, WI, and WV. The assumed advantage for PA is that these states are more similar to the State in terms of economic structure, including energy extraction and fossil fuel electricity generation, and have more consonant marginal costs of mitigation. In fact, the results (not shown in detail for the lack of space) indicate that PA would become a net permit seller, since the State's marginal cost curve is slightly below this coalition's weighted average. This is evidenced by the slight drop in the permit price from $156.97/tC before PA joins to $156.13/tC afterward. The irony, however, is that even though it becomes a permit seller, though of only 1.64 million tons (total revenue of $256 million), PA is still not as well off as if it joined RGGI! The reason is that it loses the opportunity to buy relatively much cheaper permits ($69.13/tC) and must move up its steep marginal cost curve to sell permits. In fact, the gains in terms of net costs from joining the North Central coalition are only estimated to be $3 million per year, in contrast to net cost reductions of $1,301 from joining the original RGGI coalition and $1,193 per year from joining the modified one. Summary results for this coalition and the two following are presented in Table 5.

Another possible coalition option is that of Pennsylvania joining eleven Western States (AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, and WY) in a GHG cap and trade system. As noted earlier, momentum is growing for a regional trading program in the west, and physical proximity is not a prerequisite for a GHG market, especially for "globally-mixed" pollutants like GHGs. Again, here the expectation is that PA might be better off because of low cost abatement options and lower price permits in the west. If we consider all eleven Western States, however, the weighted average of the marginally cost curves are below that of PA, but not below that of the original or modified RGGI coalitions. This is indicated by an equilibrium permit price of $89.06/tC for a Western States coalition without Pennsylvania and $99.87/tC if Pennsylvania joins. For the latter case, PA would buy $2,986 million of permits annually and reduce its net cost by $780 million annually (still less than the $1,193 annual net cost gain of the modified RGGI system). PA would be the largest permit buyer in this arrangement, and California would be the largest seller. The latter's $5,867 million sales make up nearly 75 percent of the market, so there is some possibility of it exercising monopoly power among the other six permit selling states, which has more than 7 percent share of the market. Of course, the gains to PA would increase if some of the high cost Western emitters (e.g., UT, WY) did not join the coalition.

The results of an analysis of a grand coalition of original RGGI plus MD, North Central, and Western States, plus PA, does not improve the situation over the RGGI and Western coalitions individually, though it is better than a North Central state coalition alone. Again, this result emanates from the fact that equilibrium marginal mitigation costs (equivalent to the equilibrium permit price), as always, represent a weighted average of all states involved. Here the permit price is $105.87/tC, and relative cost gains are only $61,12 million for PA.

VII. Further Analysis of Results

All of the simulations reveal the overall efficiency gains from trading with a system of flexible state-by-state quotas or caps. These gains are, however, modest—less than 15 percent reduction in cost in all configurations, owing to the relatively narrow range of mitigation cost curves. This is reminiscent of other intra-state trading experiences, such as the U.S. Sulfur Emissions Allowance Program,[37] in sharp contrast to the much higher gains of a world-wide GHG permit trading system, which is projected to lower costs by more than 75 percent.[38]

Still, despite the overall efficiency gains, several anomalies arise with respect to how individual states are affected within a given geographic configuration and with respect to increased flexibility, in our simulations, that of broadening the geographic coverage ("where" flexibility). Some of these outcomes relate to idiosyncrasies of individual state characteristics (primarily mitigation cost curves and

37. A. DENNY ELLERMAN, ET. AL., MARKET FOR CLEAN AIR: THE U.S. ACID RAIN PROGRAM (2000).

38. ZhongXiang Zhang, *Greenhouse Gas Emissions Trading and the World Trading Systems*, 32 J. WORLD TRADE 219 (1998); Adam Rose & Brandt Stevens, *An Economic Analysis of Flexible Permit Trading in the Kyoto Protocol*, 1 INT'L ENVTL. AGREEMENTS: POL., L. & ECON. 219 (2001). Note that the estimates of the gains from trade in this paper are lower bounds on the potential, because they implicitly call for trading by state entities. If trading is allowed by individual emitters, costs are not averaged within a state, and more gains can be obtained by taking advantage of greater differentials between high cost and low cost trading partners.

baselines), including the ability to wield market power. Others stem from the nature of any market, permit or otherwise, especially with regard to the important role of relative prices. A major manifestation of these features is some unusual distributions of gains from entering a GHG mitigation agreement, some of which may be considered to be inequities.[39]

A summary of permit trading results affecting PA are presented in Table 5. Some of the anomalies presented there, or as an implication of these results, stem from the fact that new entrants into a geographic configuration may raise the permit price, may undercut existing states' permit sales, and may be able to exercise market power. Some specific anomalies and surprises include:

• The New England states' net costs of achieving their GHG emission target are virtually the same if they were to proceed alone or if they join in the expanded RGGI system.

• DE, MD, ME (all permit buyers) are worse off with the entry of Pennsylvania, because its entrance raises the equilibrium permit price.

• PA would dominate an expanded RGGI market, with 91 percent of all permit purchases, at a trading volume of over $3.3 billion.

• PA monopsony power makes little difference to its own net costs or to other RGGI participants.

• EU involvement in an expanded RGGI system is likely to be small and may be nil if PA enters, because of the increase in the permit price stemming from PA's relatively high mitigation cost.

• PA is worse off joining a coalition of North Central States rather than joining RGGI, even though it becomes a permit seller, because the former coalition provides relatively fewer low cost mitigation options.

• PA is also worse off joining a coalition of all twelve Western States rather than joining RGGI, though the situation could change if the former coalition did not include some states with relatively high GHG mitigation costs.

Overall, many of these anomalies can be explained by the relative position of any given state in relation to others in a coalition. More gains are to be achieved for the group as a whole, the broader the distribution of mitigation cost curves (i.e., the more dissimilar the states and their

39. The problem is compounded by the lack of a consensus definition of the concept. *See* Adam Rose, et. al., *International Equity and Differentiation in Global Warming Policy*, 12 ENVTL. & RESOURCE ECON. 25 (1998); Adam Rose & ZhongXiang Zhang, *Interregional Burden-Sharing of Greenhouse Gas Mitigation in the United States*, 9 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 477 (2004).

ability to mitigation and sequester GHGs). States with relatively high costs are better off joining a coalition with low abatement cost states, even if it means having to be a permit buyer rather than a seller. States with relatively low abatement cost curves are better off if they attract high cost states into their coalition. Finally, not all states are better off by moving to national trading arrangement versus various regional ones, though, of course, the nation is better off as a whole in terms of addressing GHG mitigation at the lowest possible cost.

One implication of the strategy of picking the best permit trading partner is to consider looking beyond U.S. borders, especially to the west and south. Developing countries are considered to have lower GHG mitigation costs than industrialized ones, due primarily to less efficient energy utilization of the former. The Western States might consider including Mexico into their coalition, as well as other countries throughout the Pacific Rim. Even Pennsylvania might consider this option or to become involved in the bi-lateral offset arrangement called the Clean Development Mechanism (CDM), which enables an industrialized country (or firm within it) to sponsor a GHG reducing action in a developing country and to receive emission reduction credits for it. Finally, we note that the results here should be viewed as illustrative of a higher level of mitigation effort than actually agreed to by the RGGI states, as well as being preliminary because of the rough nature of mitigation cost and future emission estimates. In terms of the latter, our estimates are likely to be at the upper range, thereby biasing costs and permit price results toward the high side. The results across states, however, are less sensitive to these tenuous underlying considerations. Moreover, indications are that they would not qualitatively change the results. For example, a recent forecast of NY having lower emissions in 2010 than in 1990, and PA having significantly higher ones, simply reinforce NY's likely role as the major permit seller and PA's role as the major buyer.[40] PA would have a larger gap between its baseline emissions and its cap, and NY would essentially be able to sell emissions already likely to occur without the agreement (an anomaly referred to as "hot air").

VI. Conclusions

Several simulations have been presented of possible configurations of permit trading coalitions confronting Pennsylvania, with one of them even incorporating possible trading with the EU. The results indicate the clear advantages of permit trading in general over a system of fixed emission caps. Moreover, they indicate the overall gains from expanding

40. Note that we have not addressed the issue of carbon leakage within and across trading regions. This refers to the shift of firms, as well as associated emissions, out of a geographic area because an environmental policy has increased the costs of doing business there, or to an increase in imports. This is a major possibility in the Northeast, especially with respect to competitive electricity markets. It is a major motivation for expanding the geographic coverage of the trading area.

the geographic coverage of the program. At the same time, several anomalies are revealed for the permit market as a whole and for individual states. It should be noted that only one of these anomalies, market power, detracts from the efficiency of the system. Several of them, however, are likely to lead to a perception of inequity. Fortunately, several studies have shown that the distributional outcome of permit trading can be adjusted by modification of permit allocations, baselines, or caps, and without undercutting overall efficiency.[41] At the same time, focusing on the equity issue makes the policy design all the more political. A fair and open stakeholder process, however, can go a long way to resolving the ensuing tension.

Finally, we note that our focus on permit policy design has been on the geographic dimension, or "where" flexibility. Discussions in RGGI included limited use of offsets to expand the system in other dimensions. These include: "what" flexibility (emitters other than electric utilities and the inclusion of other GHGs), "when" flexibility (inclusion of borrowing and banking), and "how" flexibility (inclusion of options such as soil sequestration). Our modeling approach is capable of identifying implications of these enhancements as well, in order to aid stakeholders and policymakers in their decisions.

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41. *See* Adam Rose, et al., *International Equity and Differentiation in Global Warming Policy*, 12 ENVTL. & RESOURCE ECON. 25 (1998); Adam Rose & ZhongXiang Zhang, *Interregional Burden-Sharing of Greenhouse Gas Mitigation in the United States*, 9 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 477 (2004).

TABLE 1. COST OF ACHIEVING 1990 CARBON EMISSIONS CAPS IN YEAR 2010: NEW ENGLAND STATES ONLY (million $2004)

State	Before Trading	After Trading		
	Mitigation Cost	Mitigation Cost	Trading Cost	Net Cost
CT	396	535	-150	385
MA	968	972	-4	968
ME	385	136	183	319
NH	176	165	11	176
RI	81	117	-40	77
VT	62	62	-0	62
Total	2,072	1,988	0	1,988

Permit Price = $68.02 per ton carbon (tC)

TABLE 2. COST OF ACHIEVING 1990 CARBON EMISSIONS CAPS IN YEAR 2010: RGGI STATES (million $2004)

State	Before Trading	After Trading		
	Mitigation Cost	Mitigation Cost	Trading Cost	Net Cost
CT	396	550	-169	381
MA	968	1,001	-33	968
ME	385	139	180	319
NH	176	169	7	176
RI	81	121	-44	77
VT	62	62	-4	62
NY	2,211	2,758	-579	2,178
NJ	1,434	1,283	147	1,430
DE	323	143	143	286
MD	1,085	686	348	1,034
Total	7,125	6,916	0	6,916

Permit Price = $69.13/tC

TABLE 3. COST OF ACHIEVING 1990 CARBON EMISSIONS CAPS IN YEAR 2010: RGGI STATES PLUS PENNSYLVANIA (million $2004)

State	Before Trading Mitigation Cost	After Trading Mitigation Cost	After Trading Trading Cost	After Trading Net Cost
CT	396	785	-466	319
MA	968	1,434	-517	917
ME	385	205	150	356
NH	176	242	-70	172
RI	81	172	-110	62
VT	62	92	-33	59
NY	2,211	3,935	-2,006	1,925
NJ	1,434	1,848	-444	1,404
DE	323	209	103	312
MD	1,085	997	88	1,082
PA	6,945	2,336	3,308	5,644
Total	14,074	12,251	0	12,251

Permit Price = $84.77/tC

TABLE 4. COST OF ACHIEVING 1990 CARBON EMISSIONS CAPS IN YEAR 2010: RGGI STATES MINUS MA & RI AND PLUS PA (million $2004)

	Before Trading	After Trading		
State	Mitigation Cost	Mitigation Cost	Trading Cost	Net Cost
CT	396	829	-525	304
ME	386	218	142	360
NH	178	257	-88	169
VT	62	97	-39	58
NY	2,211	4,161	-2,305	1,856
NJ	1,433	1,957	-570	1,387
DE	324	221	93	312
MD	1,085	1,057	27	1,085
PA	6,945	2,486	3,266	5,752
Total	13,021	11,283	0	11,283

Permit Price = $87.45/tC

TABLE 5. SUMMARY OF PERMIT TRADING RESULTS

Case	Permit Price ($/tC)	Largest Seller ($ million)	Largest Buyer ($ million)	Largest Gainer[a] ($ million)	PA Gain[a] (%)
RGGI + PA	84.77	NY 2,006	PA 3,308	PA 1,301	PA 19
RGGI + PA (MP)	82.09	NY 1,734	PA 2,673	PA 1,353	PA 19
RGGI + EU + PA	87.43	NY 2,285	PA 3,271	PA 1,199	PA 17
RGGI - MA/RI + PA	87.45	NY 2,305	PA 3,266	PA 1,193	PA 17
N. Central + PA	156.13	IL 5,155	WV 4,331	WV 6,013	PA 0[b]
Western + PA	99.87	CA 5,867	PA 2,986	WY 5,248	PA 11
NC + W + PA	105.87	CA 7,144	IN 4,375	WV 7,496	PA 9

[a]Refers to difference between Net Cost Before Trading and Net Cost After Trading.
[b]Less than 0.5 percent.

APPENDIX TABLE A. BASIC DATA FOR RGGI STATES

State	Emissions in 1990 (million tC)	Emissions in 2010 (million tC)	Autarkic Marginal Mitigation Cost ($2004 per tC)	Gross State Product in 2000 ($2004 million)
CT	10.63	14.60	57.39	175,268
MA	21.98	30.19	67.89	306,390
ME	4.98	6.82	119.71	39,264
NH	3.86	5.29	71.04	51,288
RI	2.28	3.13	55.20	39,059
VT	1.41	1.94	67.96	19,617
NY	55.80	76.65	61.11	864,149
NJ	30.06	41.29	73.52	386,898
DE	4.61	6.34	108.28	40,315
MD	18.81	25.84	88.89	200,292
PA	69.94	96.07	153.06	432,396