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THE EVOLUTION OF ENVIRONMENTAL ECONOMICS: A VIEW FROM THE INSIDE

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This essay provides one economist's perspective on the two-decade evolution of the field of environmental economics, by tracing it through personal reflections on the professional path that has led to my research and writing. Also, the article summarizes the highlights of some of my research and writing during this period.

Keywords: Environmental economics; natural resource economics; energy economics; public policy.

JEL Classification: Q5, Q2, Q3, Q4

1. Professional Path

Over the past two decades, environmental and resource economics has evolved from what was once a relatively obscure application of welfare economics to a prominent field of economics in its own right. The number of articles on the natural environment appearing in mainstream economics periodicals has continued to increase, as has the number of economics journals dedicated exclusively to environmental and resource topics. Likewise, the influence of environmental economics on public policy has increased significantly, particularly as greater use has been made of market-based instruments for environmental protection.

This essay provides one economist's perspective on this 20-year evolution, first by tracing it through personal reflections on the professional path that has led to my research and writing. Then, in Section 2 of the paper, I summarize some highlights of my research from the time I received my Ph.D. degree in 1988 through 1999 in seven topic areas: generic issues in environmental economics; benefits and costs of environmental regulation, and the potential use of efficiency and other criteria for evaluating environmental goals; normative analysis of policy instruments; positive analysis of policy instruments;

environmental technology innovation and diffusion; land-use change; and global climate change policy. In Section 3, I provide a parallel review of my research from 2000 through 2011, again in seven (somewhat different) categories: generic issues in environmental economics; methods of environmental policy analysis; economic analysis of alternative environmental policy instruments; the economics of technological change; natural resource economics; domestic (national and sub-national) climate change policy; and international dimensions of climate change policy. In Section 4, I comment on more recent research, and in Section 5 of the paper, I conclude by describing some common themes that emerge from these two decades of research. I draw, in part, upon chapters in Stavins (2000, 2013).

In retrospect, my professional path may appear somewhat direct, if not altogether linear, but it hardly seemed so as I traveled along it. The path I describe took me back and forth across the United States and to several continents, and it took me from physics to philosophy, to agricultural extension, to international development studies, to agricultural economics, and eventually to environmental economics. During this time, much has changed in the profession.

The early ascendency of the field of environmental economics, during the period from 1970 to 1990, was centered within departments of agricultural and resource economics, mainly at U.S. universities, and at Resources for the Future (RFF), the Washington research institution. Within most economics departments, environmental studies remained a relatively minor area of applied welfare economics. So, when I enrolled in the Ph.D. program in Harvard's Department of Economics in 1983, and when I received my degree five years later, no field of study was offered in the field of environmental or resource economics.

Fortunately, Harvard permitted its graduate students to develop an optional, self-designed field as one of two fields on which they were to be examined orally before proceeding to dissertation research. Without a resident environmental economist in the Department of Economics (Martin Weitzman had yet to move to Harvard from the Massachusetts Institute of Technology), I developed an outline and reading list of the field through correspondence with leading scholars from other institutions, most prominently Kerry Smith, then at North Carolina State University. My proposal to prepare for and be examined in the field of environmental and resource economics (along with my other field, econometrics) was approved by the Department's director of graduate study, Dale Jorgenson. So began my entry into the scholarly literature of the field.

But my interest in environmental economics pre-dated by a considerable number of years my matriculation at Harvard. Like many others before and since, I came to the field because of a personal interest in the natural environment (the origin of which I describe below). This personal interest evolved into a professional one while I was studying for an M.S. degree in agricultural economics at Cornell University in Ithaca, New York, in the late 1970s, where my thesis advisor and mentor was Kenneth Robinson. I had originally gone to Cornell to study for a professional degree in international development, but found agricultural economics more appealing, largely because of the opportunity to examine social questions with quantitative methods within a disciplinary framework.

The faculty at Cornell and the care given to graduate students (including masters students like myself) were outstanding. Kenneth Robinson, my first mentor within the economics profession, became my ongoing role model for intellectual integrity. It was a sad day many years later, in 2010, when Professor Robinson passed away.

A course in linear algebra, brilliantly taught by S. R. Searle, inspired me to pursue quantitative methods of analysis, and I was fortunate to have the opportunity to study econometrics with Timothy Mount. One summer I had the privilege of learning about comparative economic systems in a small workshop setting from George Staller of the Cornell Department of Economics. Working with Bud Stanton, I had my first experience teaching at the university level, and with Olan Forker, I had my first try at serious writing. All of this led to my research and writing of an M.S. thesis, "Forecasting the Size Distribution of Farms: A Methodological Analysis of the Dairy Industry in New York State". The methodology in question was a variable Markov transition probability matrix, the cells of which were estimated econometrically in a multinomial logit framework. Much to my surprise, this work subsequently received the Outstanding Master's Thesis Award in the national competition of the American Agricultural Economics Association.

Armed with my M.S. degree, I moved from Ithaca to Berkeley, California, where I eventually met up with Phillip LeVeen, who had until shortly before that time been a faculty member in the Department of Agricultural and Resource Economics at the University of California, Berkeley. Phil was another superb mentor, and from him I learned the power of using simple models — by which I mean a set of supply and demand curves hastily drawn on a piece of scrap paper — to develop insights into real-world policy problems. He introduced me to a topic that was to occupy me for the next few years — California's perpetual concerns with water allocation. I remember many afternoons spent working with Phil at his dining room table on questions of water supply and demand.

This work with Phil LeVeen led to a consultancy and then a staff position with the Environmental Defense Fund (EDF), the national advocacy group consisting of lawyers, natural scientists, and — then almost unique among environmental advocacy organizations — economists. This marked the beginning of what became an ongoing professional relationship with this rather remarkable organization. At EDF, I was able to experience for the first time the use of economic analysis in pursuit of better environmental policy. With W. R. Zach Willey, EDF's senior economist in California, as a role model, and Thomas Graff, EDF's senior attorney, as my mentor, I thrived in EDF's collegial atmosphere, while thoroughly enjoying life in Berkeley's "gourmet ghetto," as my neighborhood was called. Sadly, Tom Graff — without whose passionate and wise mentorship I would not be where I am today — passed away in 2009 after a heroic battle with cancer.

Although I found the work at EDF rewarding, I worried that I would eventually be constrained — either within the organization or outside it — by my limited education. So, like many others in similar situations, I considered a law degree as the next logical step. In fact, I came very close to enrolling at Stanford Law School, but instead, in 1983, I accepted an offer of admission to the Department of Economics at Harvard, moved back east to Cambridge, Massachusetts, and began what has turned out to be a long-term relationship with the University.

But where did my interest in the natural environment begin? Not at Cornell; it was present long before those days. But it had not yet arisen when I was studying earlier at Northwestern University, from which I received a B.A. degree in philosophy, having departed from my first scholarly interest, astronomy and astrophysics.

Rather, the origins of my affinity for the natural environment and my interest in resource issues are to be found in the four years I spent in a small, remote village in Sierra Leone, West Africa, as a Peace Corps Volunteer, working in agricultural extension (in particular, paddy rice development). It was there that I was first exposed both to the qualities of a pristine natural environment and the trade-offs associated with economic development.

So, I had begun in astrophysics, moved to philosophy (both at Northwestern), then to agricultural extension in a developing country (Sierra Leone), then to international development studies and subsequently to agricultural economics (both at Cornell), then to environmental economics and policy (EDF), and eventually to graduate study in economics at Harvard.

My dissertation research at Harvard was directed by a committee of three faculty members: Joseph Kalt, Zvi Griliches and Adam Jaffe. Joseph Kalt was the first faculty member at the Department of Economics to validate my interest in environmental and resource issues, and he was unfailingly generous to me and many other graduate students in making his office (and personal computer, then a rather scarce resource) available at all hours. Later a colleague at the Kennedy School, Joe provided examples never to be forgotten — that economics could be a meaningful and enjoyable pursuit, and that excellence in teaching was a laudable goal.

Zvi Griliches was not only my advisor and mentor, but my spiritual father as well. Generations of Harvard graduate students would offer similar testimony. My own father had died only a year before I entered Harvard, and Zvi soon filled for me many paternal needs. It is now approaching two decades since Zvi himself passed away. I felt as if I had lost my father a second time.

If Zvi Griliches provided caring and inspiration, Adam Jaffe provided invaluable day-to-day guidance. It was Adam who convinced me not to go on the job market in my fourth year with what would have been a mediocre dissertation, but to put in another year and do it right. That turned out to be some of the best professional advice I have ever received. Our intensive faculty-student relationship from dissertation days subsequently evolved into a very productive professional (and personal) one that continues to this day. The name of Adam Jaffe appears frequently in my curriculum vitae as a co-author; he has been and continues to be much more than that.

Although they were not members of my thesis committee, I should acknowledge two other faculty members at the Harvard Department of Economics who played important roles in my education. I was fortunate to take two courses in economic history (a department requirement) from Jeffrey Williamson, who had recently arrived from the University of Wisconsin. Williamson's class sessions were as close as anything I have seen to being economic research laboratories. In class after class, we would carefully dissect one or more articles — examining hypothesis, theoretical model, data, estimation method, results

and conclusions. If there was any place where I actually learned how to carry out economic research, it was in those classes (Stavins 1988a).

The other name that is important to highlight is that of Lawrence Goulder, then a faculty member at Harvard, and now a professor at Stanford. I say this not simply because he was willing to be my examiner in my chosen field of environmental and resource economics, nor because he subsequently became such a close friend. Rather, what is striking about my professional relationship with Larry is the degree to which he has been an unnamed collaborator on so many projects of mine. Although he and I have co-authored no more than a few articles, his name probably appears more frequently than anyone else's in the acknowledgments of papers I have written. There is no one whose overall judgement in matters of economics I trust more, and no one who has been more helpful.

When I began graduate school at Harvard in 1983, it was my intention to return to EDF as soon as I received my degree. But by my third year in the program, I had decided to pursue an academic career, although one that was heavily flavored with involvement in the real world of public policy. Within the context of this professional objective, it was not a difficult decision to accept the offer I received in February 1988, to become an Assistant Professor at the Kennedy School. Although some of the other offers I received at that time were also very attractive, the choice for me was obvious, and I have never regretted it — not for a moment.

I remain at the Kennedy School today, where I was promoted to Associate Professor in 1992 (an untenured rank at Harvard), and to a tenured position as Professor of Public Policy in 1997. In 1998, I accepted an appointment as the Albert Pratt Professor of Business and Government.

Two years later, I launched the Harvard Environmental Economics Program, which today brings together — from across the University — 32 Faculty Fellows and 27 Pre-Doctoral Fellows, who are graduate students studying for the Ph.D. degree in economics, political economy and government, public policy, or health policy. The Program, which I continue to direct, forms links among faculty and graduate students engaged in research, teaching, and outreach in environmental, natural resource, and energy economics and related public policy, by sponsoring research projects, convening workshops, and supporting graduate (and undergraduate) education.

A key reason why the Program — and its various projects, including the Harvard Project on Climate Agreements — have been so successful is the marvelous administrative leadership and staff support it enjoys. Everyone who has been involved in virtually any way has come away impressed by our Executive Director, Robert Stowe, and Program Manager, Jason Chapman.

At the Kennedy School, I have had an excellent mentor, William Hogan, and a superb advisor and friend, Richard Zeckhauser. Over the years, six successive deans have provided leadership, guidance and support (including abundant time for my research and writing) — Graham Allison, Robert Putnam, Albert Carnesale, Joseph Nye, David Ellwood and Douglas Elmendorf. At Harvard more broadly, I have benefitted from regular interactions with Daniel Schrag, director of the Harvard University Center for the Environment, and Martin Weitzman of the Department of Economics. For two decades, Marty

and I have co-directed a bi-weekly Seminar in Environmental Economics and Policy, which has provided me with frequent opportunities to learn both from seminar speakers and from Marty's questions and comments.

I will also note that Harvard President Drew Faust has provided superb leadership of Harvard's increasing research, teaching and outreach activity on global climate change, and has been exceptionally supportive of my work on climate change policy. I will refrain from naming many others at Harvard and elsewhere from whom I continue to learn — including my many co-authors — only because the list of such valued colleagues and friends is so long. Included have been a most remarkable set of Ph.D. students, many of whom have gone on to productive — indeed illustrious — careers.

Along the way, I have had my share of administrative responsibilities at Harvard, including serving as Director of Graduate Studies for the Doctoral Program in Public Policy and the Doctoral Program in Political Economy and Government and Co-Chair of the Harvard Business School-Harvard Kennedy School Joint Degree Programs. Outside of Harvard, I have had the privilege of being a University Fellow of Resources for the Future, a Research Associate of the National Bureau of Economic Research and the founding Editor and now Co-Editor of the *Review of Environmental Economics and Policy*, as well as a member of the Board of Directors of Resources for the Future, the Scientific Advisory Board of the Fondazione Eni Enrico Mattei and numerous editorial boards. I must also note that I serve as an editor of the *Journal of Wine Economics*. In 2009, I was elected a Fellow of the Association of Environmental and Resource Economists.

What originally attracted me to the Kennedy School was the possibility of combining an academic career with extensive involvement in the development of public policy. I have not been disappointed. Indeed, a theme that emerges from my professional engagements over the past 25 years is the interplay between scholarly economic research and implementation in real-world political contexts. This is a two-way street. In some cases, my policy involvement has come from expertise I developed through research, following a path well worn by academics. But, in many other cases, my participation in policy matters has stimulated for me entirely new lines of research activity.

What I have characterized as involvement in policy matters is described at the Kennedy School as faculty outreach, recognized to be of great institutional and social value, along with the two other components of our three-legged professional stool — research and teaching. Because they relate to a number of the papers collected in this volume, I should note that my outreach efforts fall into five broad categories: advisory work with members of Congress and the White House (for example, Project 88, a bipartisan effort co-chaired by former Senator Timothy Wirth and the late Senator John Heinz, to develop innovative approaches to environmental and resource problems); service on federal government panels (for example, my role as Chairman of the Environmental Economics Advisory Committee of the U.S. Environmental Protection Agency Science Advisory Board); on-going consulting — often on an informal basis — with environmental NGOs (most frequently, the Environmental Defense Fund) and private firms; advisory work with state governments; and professional interventions in the international sphere, such as service as a Lead Author for the Second and the Third Assessment Reports and a Coordinating Lead

Author for the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, professional roles with the World Bank and other international organizations, and advisory work with foreign governments.

2. Research Highlights from 1988 through 1999

In 1998, my tenth year on the Harvard faculty, I was asked by the British publisher, Edward Elgar Publishing Limited, if I would be willing to assemble my selected papers for a book. I responded with enthusiasm, and selected 23 articles from the 80 (published and unpublished) papers I had produced as of then — frequently with co-authors — from the time I received my Ph.D. in 1988 through 1999. Making the selection was not any easy task, but it was a rewarding one. The resulting volume, *Environmental Economics and Public Policy: Selected Papers of Robert N. Stavins, 1988–1999*, was published in 2000.

For this purpose, I divided my work into seven categories: generic issues in environmental economics; the benefits and costs of environmental regulation, and the potential use of efficiency and other criteria for evaluating environmental goals; normative analysis of policy instruments; positive analysis of policy instruments; environmental technology innovation and diffusion; land-use change; and economics of global climate change policy. In the following sections of this paper, I provide highlights of the highlights, commenting on a small subset of the 23 articles that were in that volume of selected papers.[1]

2.1. *A broad view of environmental economics*

A brief essay, published in *Nature* and intended for an audience of non-economist academics, described "How Economists See the Environment". The motivation for the paper, co-authored with Don Fullerton, occurred during a dinner party in 1996. I was seated across the table from a professor of anthropology, who was skeptical, indeed hostile towards environmental economics. At that time, this was hardly an unusual phenomenon, since many C perhaps most C non-economist academics who studied environmental issues seemed to hold economics in rather low esteem. As the evening progressed, however, my anthropologist dinner companion became less and less hostile toward an economic view of environmental issues as I gradually dispelled a series of misunderstandings about how economists actually think about the environment. With this in mind, Don Fullerton and I responded to a set of myths which non-economists seemed to hold about environmental economics (Fullerton and Stavins, 1998).

[1] That book as well as Sections 2 and 3 of this article focus exclusively on my journal articles, not my books. Therefore, I should note that over the years I have been co-editor with Joseph Aldy of *Post-Kyoto International Climate Policy: Implementing Architectures for Agreement* (Cambridge University Press, 2010), *Post-Kyoto International Climate Policy: Summary for Policymakers* (Cambridge University Press, 2009) and *Architectures for Agreement: Addressing Global Climate Change in the Post-Kyoto World* (Cambridge University Press, 2007); editor of three editions of *Economics of the Environment* (W. W. Norton, 2000, 2005, 2012); co-editor with Bruce Hay and Richard Vietor of *Environmental Protection and the Social Responsibility of Firms: Perspectives from Law, Economics, and Business* (Resources for the Future, 2005); editor of *The Political Economy of Environmental Regulation* (Edward Elgar, 2004), co-editor with Paul Portney of *Public Policies for Environmental Protection* (Resources for the Future, 2000); and author of *Environmental Economics and Public Policy: Selected Papers of Robert N. Stavins, 1988–1999* (Edward Elgar, 2001), and *Economics of Climate Change and Environmental Policy: Selected Papers of Robert N. Stavins, 2000–2011* (Edward Elgar, 2013).

2.2. *Benefits and costs of environmental regulation*

In the fall of 1995, Robert Hahn of the American Enterprise Institute and Paul Portney, then President of Resources for the Future, convened a discussion among a small group of economists with particular interests in environmental issues: The purpose was to develop a sober assessment of the practical potential of benefit-cost analysis for helping to further progressive environmental regulation, at a time when debate in the U.S. Congress on this topic was coming to be dominated by ideological positions from the extremes of the political spectrum. The work led to a paper, which appeared in *Science*, "Is there a Role for Benefit-Cost Analysis in Environmental, Health, and Safety Regulation?" co-authored by Kenneth Arrow, Maureen Cropper, George Eads, Robert Hahn, Lester Lave, Roger Noll, Paul Portney, Milton Russell, Richard Schmalensee, Kerry Smith and myself (Arrow *et al.*, 1996).

There was and still is a heated debate among policy makers regarding the relationship between domestic environmental regulation and international competitiveness. The conventional wisdom is that environmental regulations impose significant costs, slow productivity growth, and thereby hinder the ability of domestic firms to compete in international markets. Under a revisionist view, environmental regulations are not only benign in their impacts on international competitiveness, but may actually be a net *positive* force driving private firms and the economy as a whole to become more competitive in international markets (Porter, 1991).

Adam Jaffe, Steven Peterson, Paul Portney, and I assessed the empirical evidence on these hypothetical linkages between environmental regulation and competitiveness. In our paper, "Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us?" published in the *Journal of Economic Literature*, we argued that there is little empirical evidence to support the view that environmental regulations had a measurably adverse effect on competitiveness (Jaffe *et al.*, 1995). But the picture was even bleaker for the revisionist hypothesis that environmental regulation stimulates innovation and international competitiveness. We found not a single empirical analysis that lent convincing support to this hypothesis, while several studies provided significant evidence to the contrary.

We concluded that international differences in environmental regulatory stringency posed insufficient threats to US industrial competitiveness to justify substantial cutbacks in domestic environmental regulations. At the same time, there was no support for the enactment of stricter domestic environmental regulations to stimulate economic competitiveness. Instead, we argued that policy makers should do what they could to establish environmental priorities and goals that are consistent with the real tradeoffs that are inevitably required by regulatory activities; that is, environmental goals should be based on careful balancing of benefits and costs.

2.3. *Normative analysis of environmental policy instruments*

My Harvard Kennedy School appointment began to shape my career path even before that appointment commenced. In early June of 1988, several days before graduation from the

Ph.D. program in the Department of Economics, I answered the phone in my Littauer Center office to hear a voice say, "This is Senator Tim Wirth, and I would like to talk with you about a project that Senator John Heinz and I would like to sponsor". Wirth had called me on the recommendation of Graham Allison, then Dean of the Kennedy School.

My phone conversation with Tim Wirth led to a trip to Washington the following week, just a few days after graduation. I met the two Senators C Timothy Wirth, Democrat of Colorado, and John Heinz, Republican of Pennsylvania, for the first time, and after a half-day of discussions, I agreed to direct for them an endeavor they called Project 88, the stated purpose of which was to inject innovative ideas for environmental protection into the two Presidential campaigns: George H. W. Bush (Republican) versus Michael Dukakis (Democrat). I poured myself into the project nearly on a full-time basis in the summer and fall of 1988. What began as a broad venture to promote innovative approaches to environmental protection became a highly focused effort to identify a comprehensive set of market-based instruments for environmental protection.

Beginning in July 1988, I assembled a team of 50 persons from academia, government, private industry and the environmental community to help with the effort. We prepared a report, "Harnessing Market Forces to Protect Our Environment: Initiatives for the New President" (Stavins, 1988b), which presented 36 policy recommendations for 13 major environmental and resource problems. The report was very well received by central policy figures in Washington. Through meetings with high-ranking officials in the White House, EPA, the Office of Management and Budget, and elsewhere, the Project had a significant influence on the development of the Bush Administration's environmental policies, a fact which the President confirmed in his speech announcing his Clean Air Act proposals in June of 1989. The cap-and-trade system for acid-rain reduction, articulated in Project 88, was included in the Clear Air Act amendments signed into law by President Bush in 1990.[2]

It is typically assumed at least within academic circles that the relationship between research and outreach in the policy community is a one-way street, where academics spread the gospel to practitioners in the field, drawing upon the results of their own and other scholarly research. My experience with Project 88 was precisely the opposite. At the time of my work on the project, I had never carried out scholarly research on market-based instruments. But after producing the reports and arguing in policy circles on behalf of these innovative approaches, a related research agenda began to emerge. As a direct consequence of my work on Project 88, I authored or co-authored more than a dozen articles over the succeeding five years that had as their common theme the potential of market-based instruments for addressing environmental problems.[3]

[2] In the summer of 1990, Senators Wirth and Heinz initiated Round II of Project 88, focused on the design and implementation of effective and practical incentive-based policy mechanisms for three problem areas: global climate change; solid and hazardous waste issues; and natural resource management. I again served as project director. The final report, "Incentives for Action: Designing Market-Based Environmental Strategies," was released in 1991, one month after the tragic death of Senator Heinz. The report received an even more favorable reception than the first volume, with 10,000 copies eventually distributed (Stavins, 1991).

[3] Another benefit from my work on Project 88 was my getting to know a number of experts on market-based instruments, including Robert Hahn, who was then a Senior Staff Economist at the Council of Economic Advisers, and deeply involved in the development of the Clean Air Act Amendments of 1990, and who became a frequent research collaborator.

One example is "Transaction Costs and Tradeable Permits," published in the *Journal of Environmental Economics and Management*, where I found that although trading systems could offer significant advantages over conventional approaches to pollution control, claims made for their relative cost-effectiveness may have been exaggerated (Stavins, 1995). Transaction costs reduce trading levels and thus increase abatement costs, both directly and indirectly. Most important, for certain types of transaction cost functions, equilibrium permit allocations and hence aggregate control costs are sensitive to initial permit distributions, providing an efficiency justification for politicians' typical focus on initial allocations. This stands in contrast to the frequently invoked — and very important — finding of Montgomery (1972) that the equilibrium allocation and hence the aggregate costs of control are independent of the initial allocation of permits among sources. The general message for public policy that arose from this work was that the "devil is likely to be in the details".

There are two major dimensions along which market-based and conventional environmental policies are thought to differ. First, market-based policies can lead in the short run to cost-minimizing allocations among firms of the burden of achieving given levels of environmental protection, in contrast with conventional standards, which typically do not lead to such cost-effective allocations. Second, market-based systems can provide dynamic incentives for adoption of environmentally superior technologies, since under such systems it is always in the interests of firms to clean up more if sufficiently inexpensive clean-up technologies can be found.

In an article that appeared in the *Journal of Environmental Economics and Management*, Adam Jaffe and I developed a framework for comparing empirically the effects of alternative environmental policy instruments on the diffusion of new technology (Jaffe and Stavins, 1995). We examined empirically the likely effects of Pigouvian taxes, technology adoption subsidies and technology standards as instruments to reduce emissions of greenhouse gases. In particular, we employed state-level data on the diffusion of thermal insulation in new home construction, comparing the effects of energy prices, insulation cost and building codes.

In his classic 1974 article on "Prices vs. Quantities", Martin Weitzman established that benefit uncertainty on its own has no effect on the identity of the optimal (efficient) control instrument, but that cost uncertainty can have significant effects, depending upon the relative slopes of the marginal benefit and marginal cost functions (Weitzman, 1974). But in the real world, we rarely encounter situations in which there is exclusively either benefit uncertainty *or* cost uncertainty. On the contrary, in the environmental arena, we typically find that the two are present simultaneously. In "Correlated Uncertainty and Policy Instrument Choice," published in the *Journal of Environmental Economics and Management*, I drew upon an element of Weitzman's original analysis that had been neglected by environmental economists over the intervening 20 years (Stavins, 1996), and demonstrated that with correlated benefit and cost uncertainty and plausible values of relevant parameters, the conventional identification of a price or quantity instrument could be reversed.

2.4. *Positive analysis of environmental policy instruments*

Positive analysis of environmental policy instrument choice asks why and how specific instruments are chosen in real-world political settings. Together with Nathaniel Keohane, then a Ph.D. student in Political Economy and Government at Harvard, and Richard Revesz, a faculty member at New York University School of Law (then visiting at Harvard Law School), I sought to explain why in the realm of environmental policy instrument choice, there was tremendous divergence between the recommendations of normative economic theory and positive political reality. Four gaps, in particular, stood out for us. First, despite the advantages of market-based policy instruments, they had been used to a minor degree, compared with conventional, command-and-control instruments. Second, pollution-control standards were typically much more stringent for new than for existing sources, despite the inefficiency of this approach. Third, in the few instances in which market-based instruments were adopted, they were nearly always in the form of grandfathered tradable allowances, rather than auctioned permits or pollution taxes, despite the advantages in some situations of these other instruments. Fourth, the political attention given to market-based environmental policy instruments had increased dramatically over time.

In an article that appeared in the *Harvard Environmental Law Review*, "The Choice of Regulatory Instruments in Environmental Policy," we searched for explanations for these four anomalies by drawing upon intellectual traditions from economics, political science and law (Keohane *et al.*, 1998). We found that all fit quite well within an equilibrium framework, based upon the metaphor of a political market. In general, explanations from economics tended to refer to the demand for environmental policy instruments, while explanations from political science referred to the supply side. Overall, we found that there were compelling theoretical explanations for all four apparent anomalies.

As of the late 1990s, the most ambitious application ever attempted of a market-based instrument for environmental protection was the sulfur dioxide (SO_2) allowance trading program for the control of acid rain, established by the Clean Air Act amendments of 1990, and intended to cut US electric utility emissions by 50%. In "What Can We Learn from the Grand Policy Experiment? Lessons from SO_2 Allowance Trading," in the *Journal of Economic Perspectives* (Stavins, 1998), I identified a substantial set of both normative and positive lessons from this experiment in economically oriented environmental policy.

2.5. *Environmental technology innovation and diffusion*

In the long run, the development and use of new technologies can greatly ameliorate what, in the short run, appear to be overwhelming conflicts between economic well-being and environmental quality. In order for technology to improve, three steps are required: invention, innovation and diffusion (Schumpeter, 1939). *Invention* is the solving of technical problems to construct a prototype new product or process that achieves technical performance that is superior to what was previously possible; *innovation* is the conversion of that technical prototype into a commercially available product; and *diffusion* is the gradual replacement in use of older equipment by equipment that embodies the new technology.

Working with Adam Jaffe and later with Richard Newell, one of my first Ph.D. students (and later a Professor at Duke University, and now President of Resources for the Future), I became engaged in a series of research projects which sought to understand economic, regulatory and other factors affecting these three stages of the process of technological change.

We developed a framework for thinking about the "paradox" of very gradual diffusion of apparently cost-effective energy-conservation technologies. In "The Energy Paradox and the Diffusion of Conservation Technology," published in *Resource and Energy Economics*, Adam Jaffe and I sought to provide some keys to understanding why this technology-diffusion process is gradual, and focus attention on the factors that cause this to be the case, including those associated with potential market failures — information problems, principal/agent slippage and unobserved costs — and those explanations that do not represent market failures — private information costs, high discount rates and heterogeneity among potential adopters (Jaffe and Stavins, 1994c). Likewise, in a paper published in *Energy Policy,* "The Energy Efficiency Gap: What Does It Mean?" we sought to disentangle some confusing strands of argument regarding this question (Jaffe and Stavins, 1994a), and in so doing, we identified five distinct notions of "optimality": the economists' economic potential, the technologists' economic potential, hypothetical potential, the narrow social optimum and the true social optimum. Each of these had associated with it a corresponding definition of the energy efficiency gap.

A natural extension of this work was carried out with Jaffe and Richard Newell. Our motivation was the fact that for a long-term policy problem such as global climate change, the rate and direction of innovation of new technologies is presumably more important than short-term changes brought about by the diffusion of existing technologies. In, "The Induced Innovation Hypothesis and Energy-Saving Technological Change," published in the *Quarterly Journal of Economics* (Newell *et al.*, 1999), we developed an econometric methodology for testing Hicks induced innovation hypothesis by estimating a product-characteristics model of energy-using consumer durables, augmenting the hypothesis to allow for the influence of government regulations. For the products we explored, we found that: (i) the *rate* of overall innovation was independent of energy prices and regulations, (ii) the *direction* of innovation was responsive to energy price changes for some products but not for others, (iii) energy price changes induced changes in the subset of technically feasible models that were offered for sale, (iv) this responsiveness increased substantially during the period after energy-efficiency product labeling was required and (v) nonetheless, a sizeable portion of efficiency improvements were autonomous.

2.6. *Causes and consequences of land-use changes*

By many accounts, one of the most critical environmental problems faced by the United States in the 20th century was the depletion of wetlands, areas which have very important benefits in terms of water-quality protection, natural flood and erosion control and wildlife habitat. My Harvard Ph.D. dissertation research resulted in two articles. The first, "Unintended Impacts of Public Investments on Private Decisions: The Depletion of Forested

Wetlands", published in the *American Economic Review*, and co-authored with Adam Jaffe, described a methodology for investigating a broad class of problems in economics — situations in which our theoretical models describe the behavior of individual agents, whether producing firms or consuming individuals, but the available data are in an aggregated form, such as county-level information (Stavins and Jaffe, 1990). We developed a method to econometrically estimate the parameters of such models, by simultaneously estimating both the parameters of the individual behavioral relationship and a relationship which describes the unobserved, underlying heterogeneity which characterizes the distribution of individuals in the aggregate. In the other paper, "Alternative Renewable Resource Strategies: A Simulation of Optimal Use", I developed a methodology for identifying socially optimal natural resource exploitation paths in the presence of negative environmental consequences (Stavins, 1990).

In the late 1980s, when I was carrying out my dissertation research at Harvard, the economics profession had yet to focus much attention on global climate change.[4] It turned out, however, that the methodology that Jaffe and I had developed in the 1980s for analyzing the causes of land-use changes could be extended to investigate the costs of an important strategy for mitigating climate change: biological carbon sequestration through increased forestation and retarded deforestation. In an article in the *American Economic Review*, "The Costs of Carbon Sequestration: A Revealed-Preference Approach," I asked whether this approach to carbon management would be as inexpensive as previous studies had claimed (Stavins, 1999). I found that the marginal costs of carbon sequestration were highly non-linear and that those marginal costs were much greater than previous studies had found. I concluded that sequestration ought to be part of the short-term portfolio of US greenhouse strategies, but play a declining role over time.

2.7. *Global climate change policy*

One paper in this realm grew out of my work from 1993 to 1995 as a Lead Author on Working Group III (Socioeconomics) of the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), where I had the opportunity to work closely with a talented group that included Scott Barrett, Peter Bohm, Brian Fisher and others.[5] Later, in "Policy Instruments for Climate Change: How Can National Governments Address a Global Problem?" (Stavins, 1997), I observed that the theoretical advantages of market-based instruments, such as carbon taxes and systems of tradable carbon rights, were striking in the context of global climate change. I argued that in the US domestic context, grandfathered cap-and-trade would probably be the preferred approach (if any) in the short run, although revenue-neutral carbon taxes would hold greater promise in the long run.

A different paper investigated a central issue in debates regarding the Kyoto Protocol: the likely performance of international greenhouse gas trading mechanisms. This paper, co-

[4] But one of the first economists to examine global climate issues rigorously was William Nordhaus (1982).
[5] See Fisher *et al.* (1996).

authored with Robert Hahn, was published as a monograph by AEI Press (Hahn and Stavins, 1999). We began by noting that virtually all design studies and many projections of the costs of meeting the Kyoto targets had assumed that nations can establish an international trading program that minimizes the costs of meeting overall goals. But one important issue had received little, if any, attention: the interaction between an international trading regime and a heterogeneous set of domestic policy instruments. This was (and is) an important issue, because the Kyoto Protocol explicitly provided for domestic sovereignty regarding instrument choice, and because it was unlikely that most countries would choose tradable permits as their primary domestic vehicle.

3. Research Highlights from 2000 through 2011

In 2001, 10 years after the publication of my first set of selected papers (1988–1999), Edward Elgar Publishing Limited suggested a second volume. This led to the publication in 2013 of *Economics of Climate Change and Environmental Policy: Selected Papers of Robert N. Stavins, 2000–2011*. I selected 26 articles from many more (published and unpublished) papers I wrote over the decade. Here I describe a small subset of the articles.

I again divided my work into seven categories: generic issues in environmental economics; methods of environmental policy analysis; economic analysis of alternative environmental policy instruments; the economics of technological change; natural resource economics; domestic (national and sub-national) climate change policy and international dimensions of climate change policy. Below, I briefly summarize a few articles in each of these seven categories.

3.1. *A broad view of environmental economics*

Here I treated several key topics, including economic views of: the problem of the commons (Stavins, 2011); the history of US environmental regulation (Hahn *et al.*, 2003) and corporate social responsibility (Reinhardt *et al.*, 2008).

In "The Problem of the Commons: Still Unsettled after 100 Years" (Stavins, 2011), I argued that the application of economic principles to environmental policy over the past century had greatly enhanced human understanding of some of the most serious challenges facing the planet. Problems associated with the commons had not diminished, and the lag between understanding and action could be long. While some commons problems have been addressed successfully, others continued to emerge. Some — such as the threat of global climate change — are both more important and more difficult than problems of the past. In particular, I recognized that within the realm of natural resources, there are special challenges associated with renewable resources, which are frequently characterized by open-access. An important example is the degradation of open access fisheries. In the article, I traced the evolution of environmental policy over the previous 100 years, and concluded that modern-day economic theory and related policy instruments may hold the key to overcoming the "ultimate commons problem" of the 21st century — global climate change.

In "Corporate Social Responsibility through an Economic Lens" (Reinhardt *et al.*, 2008), Forest Reinhardt, Richard Vietor and I took as our starting point the reality that business leaders, government officials, and academics were continuing to talk about corporate social responsibility (CSR). Because of this, we addressed four key questions. May firms sacrifice profits in the social interest within the scope of their fiduciary responsibilities to their shareholders? Can they do so on a sustainable basis, or will the forces of a competitive marketplace render such efforts and their impacts transient at best? Do firms, in fact, frequently or at least sometimes behave this way, reducing their earnings by voluntarily engaging in environmental stewardship? And finally, should firms carry out such profit-sacrificing activities? In other words, is this an efficient use of social resources?

3.2. *Methods of environmental policy analysis*

Articles in this category focused, respectively, on: interpreting sustainability in economic terms (Stavins *et al.*, 2003); the use of discounting in net present value analysis (Goulder and Stavins, 2002); the development of a newly revealed-preference method for inferring environmental benefits (Bennear *et al.*, 2005); and the value of formal assessment of uncertainty (Monte Carlo analysis) in regulatory impact analysis (Jaffe and Stavins, 2007).

In "An Eye on the Future: How Economists' Controversial Practice of Discounting Really Affects the Evaluation of Environmental Policies" (Goulder and Stavins, 2002), Lawrence Goulder and I noted that as economists, we often encounter skepticism about discounting, especially from non-economists. Some of the skepticism seemed quite valid, yet some reflected misconceptions about the nature and purposes of discounting. In this article, we sought to clarify the concept and the practice. Much skepticism about discounting and, more broadly, the use of benefit-cost analysis, is connected to uncertainties in estimating future impacts. We found that the uncertainties are substantial and unavoidable, but they do not invalidate the use of discounting (or benefit-cost analysis). They do oblige analysts, however, to assess and acknowledge those uncertainties in their policy assessments.

In "Using Revealed Preferences to Infer Environmental Benefits: Evidence from Recreational Fishing Licenses" (Bennear *et al.*, 2005), Lori Bennear, Alex Wagner, both former Ph.D. students, and I developed and applied a new method for estimating the economic benefits of an environmental amenity. The method was based upon the notion of estimating the derived demand for a privately traded option to utilize an open-access public good. In particular, we used the demand for state fishing licenses to infer the benefits of recreational fishing. Using panel data on state fishing license sales and prices for the continental United States over a 15-year period, combined with data on substitute prices and demographic variables, we estimated a license demand function with instrumental variable procedures to allow for the potential endogeneity of administered prices. The econometric results led to estimates of the benefits of a fishing license, and subsequently to the expected benefits of a recreational fishing day. In contrast with previous studies, which utilized travel cost or stated-preference methods, our approach provided estimates that are directly comparable across geographic areas. Our findings showed

substantial variation in the value of a recreational fishing day across geographic areas in the United States, suggesting that the previous practice of using benefit estimates from one part of the country in national or regional analyses might lead to substantial bias in benefits estimates.

3.3. *Economic analysis of alternative environmental policy instruments*

Work in this third category included examinations of: vintage-differentiated environmental regulation (Stavins, 2006); cost heterogeneity and the potential savings from employing market-based environmental policies (Newell and Stavins, 2003); the effects of allowance allocations on the performance of cap-and-trade systems (Hahn and Stavins, 2011); and second-best theory and the use of multiple policy instruments (Bennear and Stavins, 2007).

In "Vintage-Differentiated Environmental Regulation" (Stavins, 2006), I recognized that a common feature of many environmental policies in the United States — and other countries — is vintage-differentiated regulation (VDR), under which standards for regulated units are fixed in terms of the units' respective dates of entry, with later vintages facing more stringent regulation. I examined why an economic perspective suggests that VDRs are likely to retard turnover in the capital stock, and thereby reduce the cost-effectiveness of regulation in the long-term, compared with equivalent undifferentiated regulations. Further, under some conditions the result can be higher levels of pollutant emissions than would occur in the absence of regulation. Thus, age-discriminatory environmental regulations retard investment, drive up the cost of environmental protection, and may even retard pollution abatement.

In "The Effect of Allowance Allocations on Cap-and-Trade System Performance" (Hahn and Stavins, 2011), Robert Hahn and I focused on an idea that is closely related to the Coase Theorem, namely, that the market equilibrium in a cap-and-trade system will be cost-effective and independent of the initial allocation of tradable rights. That is, the overall cost of achieving a given emission reduction will be minimized, and the final allocation of permits will be independent of the initial allocation, under certain conditions. This independence property is politically important because it allows equity and efficiency concerns to be separated. We therefore examined the conditions under which it is more or less likely to hold — both in theory and in practice. In short, we found that in theory, a number of factors can lead to the independence property being violated. These are particular types of transaction costs in cap-and-trade markets; significant market power in the allowance market; uncertainty regarding the future price of allowances; conditional allowance allocations, such as output-based updating-allocation mechanisms; non-cost-minimizing behavior by firms; and specific kinds of regulatory treatment of participants in a cap-and-trade market. In our empirical analysis of the independence property in past and current cap-and-trade systems, we found that the property appears to be broadly validated.

3.4. *The economics of technological change*

This is a topic on which I continued to carry out much work, including: a survey of the literature on environmental policy and technological change (Jaffe *et al.*, 2002); an analysis

of the interaction of environmental and technological market failures (Jaffe *et al.*, 2005); an empirical assessment of the effect of environmental regulation on technology diffusion in the case of chlorine manufacturing (Miller *et al.*, 2003); and the effects of economic and policy incentives on carbon mitigation technologies (Jaffe *et al.*, 2006).

In "The Effects of Environmental Regulation on Technology Diffusion: The Case of Chlorine Manufacturing" (Miller *et al.*, 2003), Nolan Miller, Lori Snyder (Bennear) and I examined the effects of regulation on technological change in chlorine manufacturing by focusing on the diffusion of membrane-cell technology, widely viewed as environmentally superior to both mercury-cell and diaphragm-cell technologies. Our results were both interesting and surprising. In an econometric analysis, we analyzed the effects of economic and regulatory factors on adoption and exit decisions by chlorine manufacturing plants from 1976 to 2001. We found that environmental regulation did affect technological change, but not in the way many people might assume. It did so not by encouraging the adoption of some technology by existing facilities, but by reducing the demand for a product and hence encouraging the shutdown of facilities using environmentally inferior and more costly options. This is a legitimate way for policies to operate, although it is the one most politicians would probably prefer not to recognize.

3.5. *Natural resource economics*

Three articles stood out in the area of natural resource economics — focusing on land and water resources: an analysis of the factors driving land-use change in the United States (Lubowski *et al.*, 2008); an econometric examination of the significance of *terroir*, the notion that wine quality is primarily determined by location (Cross *et al.*, 2011); and an assessment of urban water demand under alternative pricing structures (Olmstead *et al.*, 2007).

Sheila (Cavanagh) Olmstead came to the Harvard Ph.D. program in public policy with a strong background and keen interests in water resources and water policy. I brought on board Michael Hanemann, then a Professor at the University of California at Berkeley, as a collaborator, and together we obtained a grant from the National Science Foundation that supported Sheila's dissertation research on econometrically estimating demand for municipal water in the presence of block-rate pricing schedules. That led to an article that appeared in the *Journal of Environmental Economics and Management* in 2007, "Water Demand Under Alternative Price Structures", where we estimated the price elasticity of water demand with household-level data, structurally modeling the piecewise-linear budget constraints imposed by increasing-block pricing. We developed a mathematical expression for the unconditional price elasticity of demand under increasing-block prices, and compared conditional and unconditional elasticities analytically and empirically. Further, we tested the hypothesis that price elasticity may depend on price structure, beyond technical differences in elasticities. We found that due to the possibility of endogenous utility price structure choice, observed differences in elasticity across price structures may be due either to behavioral response to price structure, or to underlying heterogeneity among water utility service areas.

In "The Value of Terroir: Hedonic Estimation of Vineyard Sale Prices" (Cross *et al.*, 2011), co-authored with Robin Cross and Andrew Plantinga, a merger occurred for the first time of my profession and my avocation — environmental economics and oenonomy (the study — as well as the enjoyment — of fine wine). The topic also turns out to be quite relevant to concerns about global climate change. We examined a concept that is central to the thinking of wine geeks around the world — terroir, which refers to the special characteristics of a place that impart unique qualities to the wine produced. We asked what is the value of terroir in the American context? Does the "reality of terroir" — the location-specific geology and geography — predominate in determining the quality of wine? Does the "concept of terroir" — the location within an officially named appellation — impart additional value to grapes and wine? Does location within such an appellation impart additional value to vineyards? With detailed and plentiful data, we were able to carry out a hedonic analysis of vineyard sales in Oregon's Willamette Valley to address these questions. We found that vineyard sale prices are strongly determined by location within specific, designated appellations, but not by site attributes, raising questions about whether the designations have a fundamental connection with terroir. On the other hand, our results made clear that the concept of terroir matters economically, both to consumers and to wine producers, with buyers and sellers of vineyard parcels attaching a significant premium to designated origins. These results indicated to us that the concept — if not the reality — of terroir matters economically.

3.6. *National and sub-national climate change policy*

In this category, four articles stood out on domestic (national and sub-national) climate change policy, beginning with a description and assessment of a comprehensive US cap-and-trade system for carbon dioxide and other greenhouse gas emissions (Stavins, 2008), and followed by: an examination of the interactions of national and sub-national climate policies (Goulder and Stavins, 2011); an econometric study of the carbon-sequestration supply function (Lubowski *et al.*, 2006); and an assessment of the factors that affect the costs of biological carbon sequestration (Newell and Stavins, 2000). See also Stavins (2010).

In a paper of mine that appeared in the *Oxford Review of Economic Policy* in 2008, "Addressing Climate Change with a Comprehensive U.S. Cap-and-Trade System," I proposed and analyzed a scientifically sound, economically rational and politically feasible approach for the United States to reduce its contributions to increases in atmospheric concentrations of greenhouse gases, in particular, an up-stream, economy-wide CO_2 cap-and-trade system, implementing a gradual trajectory of emissions reductions over time, with mechanisms to reduce cost uncertainty. The analysis found impacts on GDP ranging from one-half of 1% per year to 1% per year depending upon policy ambition. The bottom line appeared to be that getting serious about greenhouse gas emissions would not be cheap and nor would it be easy, but that a serious and sensible approach was technically (if not politically) feasible.

In an article co-authored with Ruben Lubowski and Andrew Plantinga, which appeared in 2006 in the *Journal of Environmental Economics and Management*, "Land-Use Change

and Carbon Sinks: Econometric Estimation of the Carbon Sequestration Supply Function", my co-authors and I investigated the cost of supplying domestic forest-based carbon sequestration, using an econometric model of the revealed preferences of landowners who can use their land for alternative purposes. We modeled six major land uses, employed detailed micro-data of land use and land quality that were comprehensive of the contiguous United States, and treated key commodity prices as endogenous in simulations of the carbon-sequestration supply function. We compared our estimates of the marginal costs of carbon sequestration with estimates of costs from energy-based carbon abatement analyses, and found that the estimated carbon sequestration supply function was roughly similar to the central tendency of the carbon abatement supply functions from leading studies. This indicated that, at a minimum, forest-based carbon sequestration merited consideration as part of a cost-effective portfolio of domestic US climate change strategies.

3.7. *International climate change policy*

Four articles stood out in this topic area: a comparison of alternative global climate change policy architectures (Aldy *et al.*, 2003); an assessment of the Kyoto Protocol (Hahn and Stavins, 2009); an examination of a promising post-Kyoto international climate regime (Olmstead and Stavins, 2006); and a detailed examination of a key element of emerging international climate policy architecture, namely the linkage of regional, national and sub-national tradable permit systems (Ranson *et al.*, 2010).

In 2003, Joseph Aldy, Scott Barrett and I critically examined the Kyoto Protocol and 13 possible alternative international policy architectures in an article which appeared in *Climate Policy*, "Thirteen Plus One: A Comparison of Global Climate Policy Architectures". We employed six criteria to evaluate the policy proposals: environmental outcome, dynamic efficiency, cost-effectiveness, equity, flexibility in the presence of new information, and incentives for participation and compliance. We found that the Kyoto Protocol did not fare well on a number of criteria, but none of the alternative proposals fared well along all six dimensions. In the process, we were able to identify several major themes among the alternative proposals: Kyoto is "too little, too fast"; developing countries (DCs) should play a more substantial role and receive incentives to participate; implementation should focus on market-based approaches, especially those with price mechanisms; and participation and compliance incentives are inadequately addressed by most proposals. Our investigation revealed tensions among several of the evaluative criteria, such as between environmental outcome and efficiency, and between cost-effectiveness and incentives for participation and compliance.

In 2010, Matthew Ranson, Judson Jaffe and I turned our attention to "Linking Tradable Permit Systems: A Key Element of Emerging International Climate Policy Architecture" (*Ecology Law Quarterly*). We began from the premise that by broadening markets for allowances, linking cap-and-trade systems increases the liquidity and improves the functioning of markets, and can reduce the costs of the linked systems by making it possible to shift emission reductions across jurisdictions. Just as allowance trading within a system allows higher cost emission reductions to be replaced by lower cost reductions, trading

across systems allows higher cost reductions in one system to be replaced by lower cost reductions in another system. In this paper, one of many we have written on this general topic, we examined both the merits and the concerns of international linkage, and described the roles it could potentially play in international climate change policy.

4. More Recent Research: 2012–2016

In the two previous sections, I described some highlights of my published research during two periods since receiving my Ph.D. degree: 1988–1999 and 2000–2011. I chose those two periods because my work was summarized respectively in two such volumes of selected papers published by Edward Elgar Limited. I have not been idle in the years since 2011, with some 80 additional journal articles, book chapters and policy papers having been published in the interim (plus an additional 50 essays at my blog, *An Economic View of the Environment*). But it is much too soon to try identify highlights (and lowlights) from this more recent body of work, so I postpone to the future any summary of my work over the past five years.

5. Common Themes

Preparing this brief professional autobiography has caused me to review a number of the several hundred articles, book chapters and essays I have written. This has allowed me to identify some common themes that emerge from these two-decades-plus of research and writing. First, there is the value — or at least, the potential value — of economic analysis of environmental policy. The cause of virtually all environmental problems in a market economy is economic behavior (that is, imperfect markets affected by externalities), and so economics offers a powerful lens through which to view environmental problems, and therefore a potentially effective set of analytical tools for designing and evaluating environmental policies.

A second message, connected with the first, is the specific value of benefit-cost analysis for helping to promote efficient policies. Economic efficiency ought to be one of the key criteria for evaluating proposed and existing environmental policies. Despite its limitations, benefit-cost analysis can be useful for consistently assimilating the disparate information that is pertinent to sound decision making. If properly done, it can be of considerable help to public officials when they seek to establish or assess environmental policies.

Third, the means governments use to achieve environmental objectives matter greatly, because different policy instruments have very different implications along a number of dimensions, including abatement costs in both the short and the long term. Market-based instruments are particularly attractive in this regard.

Fourth, an economic perspective is also of value when reflecting on the use of natural resources, whether land, water, fisheries or forests. Excessive rates of depletion are frequently due to the nature of the respective property-rights regimes, in particular, common property and open-access. Economic instruments — such as ITQ systems in the case of

fisheries — can and have been employed to bring harvesting rates down to socially efficient levels.

Fifth and finally, policies for addressing global climate change — linked with emissions of carbon dioxide and other greenhouse gases — can benefit greatly from the application of economic thinking. On the one hand, the long time-horizon of climate change, the profound uncertainty in links between emissions and actual damages, and the possibility of catastrophic climate change present significant challenges to conventional economic analysis. But, at the same time, the ubiquity of energy generation and use in modern economies means that only market-based policies — essentially carbon pricing regimes — are feasible instruments for achieving truly meaningful emissions reductions. Hence, despite the challenges, an economic perspective on this grandest of environmental threats is essential.

6. Final Words

On a personal level, the professional path I have taken offers confirmation that research can influence public policy, and that involvement in public policy can stimulate new research. The quest — both professional and personal — that took me from Evanston, Illinois, to Sierra Leone, West Africa, to Ithaca, New York, to Berkeley, California, and finally to Cambridge, Massachusetts suggests some consistency of purpose and even function. I find myself doing similar things, but in different contexts. It is fair to say that my professional life has taken me along a path that has brought me home. The words of T. S. Eliot (1943) ring true:

> *We shall not cease from exploration*
> *And the end of all our exploring*
> *Will be to arrive where we started*
> *And know the place for the first time.*

Writing this essay has forced me to reflect on the past, and think more clearly about the future. The 22 articles that comprised the first book of my selected papers (Stavins, 2000) and the 26 essays that comprised the second volume (Stavins, 2013) were the product of 23 years on the Harvard faculty. I continue to learn about environmental economics and related public policy from colleagues, collaborators, students, friends and inhabitants of the "real world" of public policy, individuals from government, private industry, advocacy groups and the press. I hope and trust that the learning will continue.

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