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A TWO-WAY STREET BETWEEN ENVIRONMENTAL ECONOMICS AND PUBLIC POLICY

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ABSTRACT

Over the past three decades, the study of environmental and resource economics has evolved from a relatively obscure application of welfare economics to a field of economics in its own right, combining elements from industrial organization, public finance, microeconomic theory, and many other areas of economics. When Edward Elgar Publishing recently invited me to collect some of my papers from the past ten years in an edited volume, it was suggested that I prepare a personal introduction in which I might reflect on the professional path that has led to my research and writing. This paper was prepared as that introduction. In it, I describe the professional and personal path that took me from Northwestern University to the Peace Corps, then to Cornell, to the Environmental Defense Fund, and finally to Harvard. The book consists of 23 articles I selected from the 80 (published and unpublished) papers I produced — frequently with co-authors — from the time I received my Ph.D. in 1988 until the winter of 2000. Selecting the papers and organizing them has allowed me to step back and reflect on the set of research endeavors in which I have been engaged over this decade. This introductory chapter describes the background and major findings of the 23 included papers, and identifies common themes that emerge from this decade of research and writing.

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Over the past three decades, the study of environmental and resource economics has evolved from a relatively obscure application of welfare economics to a field of economics in its own right, combining elements from industrial organization, public finance, microeconomic theory, and many other areas of economics. The number of scholarly articles on the natural environment appearing in mainstream economics periodicals has steadily increased, as has the number of economics journals dedicated exclusively to environmental and resource topics. At the same time, the influence of environmental economics on public policy has increased significantly, as greater use has been made of economic-incentive (or market-based) instruments for environmental protection, particularly tradeable permit systems in the United States. Although more controversial, consideration is increasingly given to the possibility of employing economic criteria to evaluate environmental programs and targets.

When the publisher of this book, Edward Elgar, invited me to collect some of my papers in an edited volume, it was suggested that I prepare a personal introduction in which I might reflect on the professional path that has led to my research and writing. In retrospect, this path may appear direct, if not altogether linear, but it hardly seemed so as I traveled along it. The path I will 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. It culminated in my receipt in 1988 of a Ph.D. degree in economics at Harvard University, where I have since been a faculty member at the John F. Kennedy School of Government. During this time, much has changed in the profession.

The ascendency of the field of environmental economics, at least during the period from 1970 to 1990, was centered within departments of agricultural economics, mainly at U.S. universities, and at Resources for the Future (RFF), the Washington research institution.[1] Within most economics departments, however, environmental studies remained (and largely still remain) 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 there in the area of environmental or resource economics.

[1]I have enjoyed a close working relationship with RFF since 1989, when I accepted an appointment as a University Fellow. Paul Portney, President and Senior Fellow at RFF, and Richard Newell, my former student at Harvard and now a Fellow at RFF, have collaborated with me on several papers, including some that appear in this volume.

But then as now Harvard permitted its graduate students to develop an optional, self-designed field as one of two "special fields" on which they were to be examined 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[2] 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 special field of "environmental and resource economics" (along with econometrics) was approved by the Department's director of graduate study, Dale Jorgenson. So began my entry into the scholarly literature of the field.

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 an intense personal interest in the natural environment, whose origin 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 the late 1970's, 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 lowly masters students like myself) were both outstanding. Ken Robinson, my first mentor within the economics profession, became my ongoing role model for intellectual integrity. A course in linear algebra, brilliantly taught by S. R. Searle, inspired me to pursue quantitative methods of analysis, and I was fortunate to then have the opportunity to study econometrics with Tim Mount. One summer I had the great privilege of learning 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 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 Cornell 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 yield insights on policy problems. He

[2]I have refined and added to that initial reading list over the years in a series of collaborations. The current version contains 950 references and can be downloaded on the Internet (Pfaff and Stavins 1999). Also, two relevant survey articles have appeared during the past decade: on environmental economics (Cropper and Oates 1992); and on the economics of nonrenewable resources (Krautkraemer 1998).

introduced me to a topic that was actually 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 — almost unique among environmental advocacy organizations — economists. 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.

Although I found the work at EDF exceptionally 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 affection 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 that economic development can bring. 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 computer, then a rather scarce resource) available at all hours. Now 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. As I write this essay, it is only a few

months since Zvi himself passed away, after a heroic battle with cancer. 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 advice I have ever received. Our intensive faculty-student relationship from dissertation days subsequently evolved into a very productive professional one that continues to this day. The name of Adam Jaffe appears frequently in this volume as a co-author; but 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.[3]

The other name it 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. It is true that his name does not appear as a co-author in this book's table of contents, nor — for that matter — in a complete list of my publications. But I suspect that his name does appear more frequently than anyone else's in the acknowledgments of the papers I have written. There is no one who's 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. 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 that same year, I became Faculty Chair of the Environment and Natural Resources Program, and in 1998, I was appointed the Albert Pratt Professor of Business and Government.

[3]These classes also led to a brief, but very interesting venture in cliometric research (Stavins 1988a).

At the Kennedy School, I have had the best possible mentor, William Hogan, and an excellent critic and reviewer, Richard Zeckhauser. Over the years, four successive deans have provided leadership, guidance, and support (including abundant time for my research and writing) — Graham Allison, Robert Putnam, Albert Carnesale, and Joseph Nye. At Harvard more broadly, I have benefitted tremendously from regular interactions with Martin Weitzman of the Department of Economics. For nearly a decade, Marty and I have co-directed a bi-weekly Seminar in Environmental Economics and Policy. This has provided me with frequent opportunities to learn both from the seminar speaker and from Marty's own questions and comments. I will refrain from naming the many others at Harvard from whom I continue to learn only because the list of my valued colleagues and friends within this institution is so long.

What originally attracted me to the Kennedy School was the possibility of combining an academic career with intensive and extensive involvement in the formulation and execution of public policy. I have not been disappointed. Indeed, a theme that emerges from this book 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.

What I have characterized as involvement in policy matters is described at the Kennedy School as faculty outreach efforts, 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 over the past decade fall into five broad categories: advisory work with members of Congress and the White House (for example, Project 88, described below); 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 advocacy groups, most frequently with the Environmental Defense Fund, but also with a number of others; advisory work with state governments; and professional interventions in the international sphere (examples include service as a Lead Author for both the Second and the Third Assessment Reports of the Intergovernmental Panel on Climate Change, professional roles with the World Bank and other international organizations, and advisory work with several foreign governments).

To prepare this book, I selected 23 articles from the 80 (published and unpublished) papers I produced — frequently with co-authors — from the time I received my Ph.D. in 1988 until the winter of 2000. Making this selection was not an easy task, but it was a rewarding one. Selecting the papers and organizing them has forced me to step back and reflect on the set of research endeavors in which I have been engaged over this decade, and thus to think more clearly about future directions.

The book is divided into seven parts. The papers in Part I provide an overview of environmental economics, covering the two components of most environmental policies: a goal or target, and a means of achieving that target. The articles in Part II address the first component, focusing on the benefits and costs of environmental regulation, and the potential use of efficiency and other criteria for evaluating

environmental goals. The articles in Parts III and IV treat the second component — the means of environmental policies. Part III focuses on normative analysis of policy instruments, and Part IV concentrates on positive analysis. The final three parts of the book treat particular areas of policy application. Part V focuses on analysis of environmental technology innovation and diffusion. Part VI includes papers that examine the causes and consequences of land-use changes. And Part VII features economic analysis of global climate policy.

Overview of Environmental Economics

Following this Introduction, Part I continues with two additional papers. The first is a brief essay, originally published in *Nature* and intended for an audience of non-economist academics, that describes "How Economists See the Environment." The motivation for this paper, co-authored with Don Fullerton of the University of Texas, 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. This is not an unusual phenomenon, since many — perhaps most — non-economist academics who study environmental issues seem to hold economics in rather low esteem. But I found that as the evening progressed, 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 wrote a paper in which we respond to a set of myths which non-economists seem to hold about environmental economics (Fullerton and Stavins 1998).

The final paper in Part I was originally prepared for the 1997 edition of the annual workshop of Kennedy School Dean Joseph Nye's project, "Visions of Governance for the Twenty-First Century," held each summer in Bretton Woods, New Hampshire. This brief essay begins with the premise that a fundamental question that needs to be addressed by public policy in the area of environmental protection is, "what is the appropriate role of government?" This question emerges along three fundamental dimensions, which are closely interrelated but conceptually distinct: (1) what is the appropriate *degree* of government activity; (2) what *form* should government activity take; and (3) what *level* of government should be delegated responsibility? I define the questions, suggest criteria that can be used to evaluate responses, and provide outlines of answers. Although a shorter version of the paper was subsequently published (Stavins 1998a), I have included the more complete discussion paper in this volume (Stavins 1997a).

Benefits and Costs of Environmental Regulation

The common theme in Part II is analysis of the goals of environmental policy, where economic efficiency and other criteria are considered, and benefit-cost analysis and other analytical methods are used to operationalize these criteria. Three papers are included.

In the fall of 1995, Robert Hahn of the American Enterprise Institute and Paul Portney 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. This assessment was carried out at a time when debate in the U.S. Congress on this topic was 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 (1996).

Although it is unquestionably true that the benefits of environmental policies (damages of environmental problems) are vastly more difficult to estimate in economic terms than the costs of such policies, the latter is by no means a trivial matter.[4] The second paper in Part II focuses on the cost side of the analytical ledger. There is a heated debate among policy makers regarding the relationship between domestic environmental regulation and international competitiveness. The conventional wisdom among economists 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 (then at the Economics Resource Group), 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 have had a measurably adverse effect on competitiveness (Jaffe, Peterson, Portney, and Stavins 1995). But the picture is bleaker still for the revisionist hypothesis that environmental regulation stimulates innovation and improved 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 pose insufficient threats to U.S. industrial competitiveness to justify substantial cutbacks in domestic environmental regulations. At the same time, there is no support for the enactment of stricter domestic environmental regulations to stimulate economic competitiveness. Instead, policy makers should do what they can to establish environmental priorities and goals that are consistent with the real tradeoffs that are inevitably required by regulatory activities; that is, our environmental goals should be based on careful balancing of benefits and costs.

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[4]A substantial fraction of scholarly research in environmental economics is associated with alternative methods of environmental valuation, that is, environmental policy benefit estimation. The reader may note an absence of such papers in this volume. I have made only one modest foray into that research world, and that work, continually pushed to the back-burner of my research schedule, is still in progress (Stavins 1997c).

The final paper in Part II steps back from the efficiency criterion and examines so-called "health-health analysis," which posits a seemingly unassailable criterion for regulatory assessment: policies intended to protect human health ought to exhibit positive health benefits (even after taking into account the potentially negative health consequences of a policy's economic costs). Despite the apparent logic of this criterion, my co-author, Paul Portney, and I felt it was important to ask whether it would really aid in the quest for better public policies. In an article published in the *Journal of Risk and Uncertainty*, "Regulatory Review of Environmental Policy: The Potential Role of Health-Health Analysis," we found that in most applications the health impacts of regulatory compliance costs are unlikely to be significant (Portney and Stavins 1994). Our conclusion was that conventional benefit-cost analysis ought to remain the principal tool of economic assessment of environmental laws and regulations.

Environmental Policy Instruments: Normative Analysis

In Parts III and IV, the book turns to the means of environmental policy, focusing on normative analysis and positive analysis, respectively, of environmental policy instruments. Much of the focus is on so-called economic-incentive or market-based approaches to environmental protection. This focus illustrates the fact that my Kennedy School appointment began to shape my career path even before that appointment commenced. In early June of 1988, several days before graduation, I answered the phone in my Littauer Center office to hear a voice say, "This is Senator Tim Wirth, and I'd 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 — 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," whose stated purpose was to inject "innovative ideas for environmental protection" into the two Presidential campaigns. I poured myself into the project virtually on a full-time basis in the summer and fall of 1988. What began as a general venture of promoting on a bipartisan basis some innovative approaches to environmental protection, became a highly focused effort to identify and describe a comprehensive set of market-based instruments for environmental protection.

Beginning in July 1988, I assembled a team of fifty persons from academia, government, private industry, and the environmental community to help with this effort. We prepared a 100-page report, "Harnessing Market Forces to Protect Our Environment: Initiatives for the New President" (Stavins 1988b), which presented thirty-six policy recommendations for thirteen major environmental and resource problems. The Project 88 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 tradeable permit 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.

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 report of this second project consisted of detailed analyses of specific incentive-based policies for the three problem areas, emphasizing practical design and implementation.[5] The report drew on papers and ideas contributed by prominent authorities in their fields, and reviews from 100 leaders from private industry, the environmental community, government, and academia. 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).

It is typically assumed — at least within academic circles — that the relationship between research and outreach work 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's 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 two reports and arguing in policy circles on behalf of these innovative approaches, a related research agenda began to emerge. 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 was later to become a frequent research collaborator.

My research on normative aspects of environmental policy instrument choice and design has included seven projects over the past ten years or so: (1) potential applications of market-based environmental instruments; (2) the importance of integrating theory and practice; (3) the effect of transaction costs on the performance of tradeable permit markets; (4) empirical analysis of the dynamic efficiency of alternative types of instruments; (5) the effect of correlated uncertainty on the choice between price and quantity instruments; (6) the effect of cost heterogeneity on the relative performance of market-based instruments; and (7) environmental policy instruments for transition economies. The first five are represented by the five papers that make up Part III of this book.[6]

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. The one I have chosen for inclusion in this volume

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[5]To achieve rapid and effective development and dissemination of these policy ideas, this project contained six distinct components: preparation and dissemination of a second public-policy report; a series of seminars at the Kennedy School; a policy forum, held at the School; a set of four policy workshops — one at the Kennedy School and three in Washington, D.C. — bringing together academics, practitioners, and policy-makers to discuss the report and the results of the seminar series; preparation and distribution of the published proceedings of the workshops; and a set of student internships in Washington, D.C. and elsewhere.

[6]The interim results of the sixth and seventh projects, respectively, are described by: Newell and Stavins 1999; and Zylicz and Stavins 1995.

appeared in *Policy Review*, "Clean Profits: Using Economic Incentives to Protect the Environment" (Stavins 1989). I selected this because it is the earliest article I wrote on this subject and because it includes an interesting exchange with Fred Smith of the Competitive Enterprise Institute.

The next paper in Part III — "Economic Incentives for Environmental Protection: Integrating Theory and Practice" — appeared in the *American Economic Review Papers and Proceedings*, and was written in response to the observation that the preference economists had shown for incentive-based instruments over command-and-control approaches seemed to be based largely on those instruments' theoretical efficiency advantages in highly stylized situations. This was my first collaboration with Bob Hahn. In the paper, Hahn and I noted that in nearly all comparisons of conventional standards with market-based systems, potential gains from trade or efficiency gains are simulated, an approach that tends to exhibit two major problems. First, it assumes that all gains from trade will be achieved, an unlikely occurrence in markets characterized by transaction costs or regulatory distortions. Second, actual command-and-control performance has typically been contrasted with the performance of a hypothetical incentive-based instrument. A more realistic and appropriate comparison, we argued, would be between actual command-and-control policies and either actual market-based programs or a reasonably constrained market-based system (Hahn and Stavins 1992).

As a natural extension, the next paper in this part of the book investigates the potential effects of transaction costs on the performance of tradeable permit markets. In "Transaction Costs and Tradeable Permits," published in the *Journal of Environmental Economics and Management*, I found that although trading systems can 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 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 arises from this work is that the "devil is likely to be in the details."

The next paper in Part III moves from the world of static analysis to dynamic analysis. 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. There have been few empirical analyses of the actual, relative cost-effectiveness of alternative instruments, and virtually *no* empirical analyses of their relative dynamic efficiency attributes.

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 posited that market-based and command-and-control approaches can be quantitatively compared by estimating the economic penalty that firms face if they violate pollution standards. We developed a method of estimating this perceived penalty from the behavior of firms. With this technique, we empirically examined the likely effects of Pigouvian taxes, technology adoption subsidies, and technology standards as instruments to reduce emissions of greenhouse gases in order to address concerns about climate change. 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.

The fifth and final paper in Part III — "Correlated Uncertainty and Policy Instrument Choice" — introduces uncertainty into normative questions of policy instrument choice. My thinking on this subject had its origins in comments I made as a discussant in Cambridge in 1994 at the Congress of the International Institute of Public Finance, which prompted me to read again a classic paper by my colleague, Marty Weitzman (1974). The dual tasks of choosing environmental goals and selecting policy instruments to achieve those goals must be carried out in the presence of the significant uncertainty that affects the benefits and the costs of environmental protection. Since Weitzman's paper on "Prices vs. Quantities," it has been generally acknowledged 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. Environmental economists have made frequent use of these results.[7]

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. What can be said about optimal policy instruments under these conditions? In "Correlated Uncertainty and Policy Instrument Choice," published in the *Journal of Environmental Economics and Management*, I addressed this question by drawing upon an element of Weitzman's original analysis that had been neglected by environmental economists over the intervening twenty years (Stavins 1996). I demonstrated that with plausible values of relevant parameters, the conventional identification of a price instrument will be reversed, to favor instead a quantity instrument. I also found that the opposite reversal — from the choice of a quantity instrument to a price instrument — is less likely to occur. Although the analysis was carried out within the context of environmental policy, the findings are of potential significance to other areas where the choice between price and quantity instruments is made in the presence of benefit and cost uncertainty.

[7] Indeed, Weitzman's 1974 article won the "Publication of Enduring Quality Award" from the Association of Environmental and Resource Economists in 1996.

Environmental Policy Instruments: Positive Analysis

Part IV continues the focus on environmental policy instrument choice, but shifts from normative to positive analysis with three papers. Positive analysis of environmental policy instrument choice asks why and how specific instruments have been chosen in real-world political settings. My first work in this area investigated factors affecting the political acceptability of alternative environmental policy proposals. This led to an article, co-authored with Robert Hahn, which appeared in *Ecology Law Quarterly*, and which is the first paper in Part IV. In that article, "Incentive-Based Environmental Regulation: A New Era From An Old Idea?," Hahn and I noted the increased attention given by political leaders to market-based environmental instruments, and examined the forces that had affected the introduction and acceptance of market-based approaches in political debate (Hahn and Stavins 1991).

Six years later I began working on a more formal approach to similar questions with Nathaniel Keohane, 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). Our analysis was motivated by recognition that 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 tradeable permits, 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, Revesz, and Stavins 1998).[8] 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 the four apparent anomalies, although the theories had not been empirically verified.

The final paper in Part IV focuses on what has been by far the most ambitious application ever attempted of a market-based instrument for environmental protection — the sulfur dioxide (SO_2) allowance trading program for the control of acid rain, established under Title IV of the Clean Air Act amendments of 1990, and intended to cut nationwide electric utility emissions by 50 percent by the year

[8]Also emerging from the same research effort was a paper that appeared in a *festschrift* in honor of Wallace Oates (Keohane, Revesz, and Stavins 1999).

2000. The essay included here, "What Can We Learn from the Grand Policy Experiment? Lessons from SO_2 Allowance Trading," appeared in the *Journal of Economic Perspectives* (Stavins 1998b). The essay identifies lessons that can be learned from this experiment in economically oriented environmental policy, beginning with positive political economy lessons, drawing upon my earlier work with Keohane and Revesz. Three questions are addressed: Why were conventional, command-and-control instruments the dominant form of environmental regulation, at least until 1990? Why was allowance trading adopted for acid-rain control in 1990, and why did the system take its particular form?[9]

Environmental Technology Innovation and Diffusion

The three papers that constitute Part V are based upon the premise that 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 Richard Newell, I have been engaged in a series of research projects which have sought to understand economic, regulatory, and other factors affecting these three stages of the process of technological change.[10]

The role played by the development and use of more energy-efficient technologies is a crucial factor to be considered in any assessment of global climate change and public policies that may be adopted to address it. For this and other reasons, our efforts in this area have focused on energy-efficiency technologies. In the first selection in this part of the book, Jaffe and I develop 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*, we seek 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).[11]

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[9]The essay on SO_2 allowance trading also includes normative lessons that can be learned from the program's design and performance. These are organized into four categories: lessons for environmental policy; for design and implementation of tradeable permit systems; for analysis of prospective and adopted systems; and for identifying new applications.

[10]The first project, with Adam Jaffe, focused on the diffusion stage; the second project, with Jaffe and Richard Newell, focused on innovation; and a current project seeks to integrate analyses of invention, innovation, and diffusion.

[11]We later extended this work to examine its policy implications (Jaffe and Stavins 1994b). That analysis indicated how specific policy instruments -- both economic incentives and direct regulations — can hasten the diffusion of energy-conserving technologies. Additionally, Jaffe and I carried out an empirical analysis focusing on the incorporation of energy-conserving technologies in new residential structures. That analysis examined both the "energy paradox" and

Our work on technology diffusion provided an opportunity to develop some insights into the discussion among policy makers of an "energy efficiency gap" between actual and optimal energy use. In a paper published in *Energy Policy* and included here, "The Energy Efficiency Gap: What Does It Mean?", we sought to disentangle some confusing strands of argument that are frequently brought to bear on this question, by identifying the major conceptual issues that determine the set of feasible answers (Jaffe and Stavins 1994a). We identified five separate and 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 has associated with it a corresponding definition of the energy efficiency gap.

A natural extension of the above work was carried out in a subsequent project with Jaffe and Richard Newell, while the latter was a Ph.D. student in Public Policy at Harvard. Our motivation for this work 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. The third paper in Part V, "The Induced Innovation Hypothesis and Energy-Saving Technological Change," was published in the *Quarterly Journal of Economics* (Newell, Jaffe, and Stavins 1999).

In that paper, we develop an econometric methodology for testing Hick's 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, the evidence suggests: (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.

Causes and Consequences of Land-Use Changes

Part VI includes two of my earliest published papers (both based upon my dissertation research) and one of my most recent papers, which builds upon that original foundation, albeit for different analytical purposes in a very different policy context.

By many accounts, one of the most critical environmental problems facing the United States over the past several decades has been 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 dissertation research on wetland depletion resulted in two articles which are included here — one from the *American Economic Review* and the other from the *Journal of Environmental Economics and Management*.

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the relative effectiveness of alternative policy instruments in fostering more rapid diffusion of energy-conserving technologies. That work is included in Part III of the present volume (Jaffe and Stavins 1995).

The first paper, "Unintended Impacts of Public Investments on Private Decisions: The Depletion of Forested Wetlands," 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). The paper developed and applied 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. The particular application was (and is) of substantial policy importance — the conversion of forested wetlands to agricultural cropland. The paper investigated the principal factors causing such wetland conversion to occur, including the unintended but significant role played by Federal flood-control and drainage projects.

The second paper in Part VI, "Alternative Renewable Resource Strategies: A Simulation of Optimal Use," developed a methodology for identifying socially optimal natural resource exploitation paths in the presence of negative environmental consequences (Stavins 1990). The empirical application was again in the context of forested wetland depletion. The question addressed is the following: if the Federal government is indeed (partly) responsible for wetland depletion, ought we condemn it or thank it for this service? A welfare analysis of the optimal use of wetlands for forestry and agriculture was carried out.

In the late 1980's, when I was carrying out my dissertation research at Harvard, the economics profession had yet to focus much attention on global climate change.[12] It turned out, however, that the methodology that Jaffe and I had developed in the 1980's for analyzing the causes of land-use changes can be extended to investigate the costs of one important strategy for mitigating climate change: carbon sequestration through increased forestation and retarded deforestation. In fact, the possibility of encouraging the growth of forests as a means of sequestering carbon dioxide has received considerable attention because of concerns about the threat of global climate change. This approach is an explicit element of both U.S. and international climate policies.

In a paper published 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). Most previous analyses had relied on engineering-costing methods or least-cost simulations to estimate the relevant marginal cost functions. This paper develops an alternative method for developing estimates of the costs of carbon sequestration on the basis of econometric evidence of landowners' actual behavior. The analytical framework incorporates silvicultural modeling of the intertemporal linkages between deforestation and carbon emissions, and between forestation and carbon sequestration.

I found that the marginal costs of carbon sequestration are highly non-linear and that those marginal costs are much greater than previous studies had found, particularly at higher levels of sequestration. I

[12]One of the first economists to examine global climate issues rigorously was William Nordhaus (1982).

estimated that U.S. marginal carbon sequestration costs will be greater than marginal carbon abatement costs (through changes in fuels used and reductions in energy demand) at low levels of control, but that the difference between the two will become dramatic as targets increase. Thus, I concluded that sequestration ought to be part of the short-term portfolio of U.S. greenhouse strategies, but it should play a declining role over time.[13] In a more recent paper, forthcoming in the *Journal of Environmental Economics and Management*, Richard Newell and I examine the sensitivity of carbon sequestration costs to changes in critical factors, including the nature of management and deforestation regimes, silvicultural species, relative prices, and discount rates (Newell and Stavins 2000).

Global Climate Policy

The final part of the book, Part VII, examines what may prove to be the most significant of all environmental problems — global climate change; significant both in terms of its possible damages and in terms of its potential mitigation costs. Three papers on this topic are included.[14]

The first paper 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.[15] The paper included here, "Policy Instruments for Climate Change: How Can National Governments Address a Global Problem?," was prepared for a conference at the University of Chicago Law School and published in *The University of Chicago Legal Forum* (Stavins 1997b). In this paper, I observed that the theoretical advantages of market-based instruments, such as carbon taxes and systems of tradeable carbon rights, are striking in the context of global climate change. I argued that in the U.S. domestic context, grandfathered tradeable permits 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. In the international context, I found that a system of international tradeable permits could provide important advantages over alternative approaches, but noted that it was difficult to imagine an existing international institution that could administer such a system.

The second paper in Part VII investigates a central issue in the climate change debate associated with the Kyoto Protocol: the likely performance of international greenhouse gas trading mechanisms. This paper, co-authored with Robert Hahn, was published as a monograph by AEI Press (Hahn and Stavins

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[13]This work was mainly of methodological significance, since the data set employed for the application was itself very limited. In a new project, we are developing a more comprehensive model of multiple categories of land use, and carrying out an econometric analysis with data for the 48 contiguous states from the Natural Resources Inventory. This new work features a new collaboration — with Andrew Plantinga of the University of Maine — and includes the dissertation research of Ruben Lubowski, a Harvard Ph.D. student in Political Economy and Government.

[14]Several papers included in other parts of this volume also relate directly to global climate policy issues, including the set of papers in Part V on technological change in energy efficiency (Jaffe and Stavins 1994a, 1994b, 1994c, 1995), and the final paper in Part VI on the costs of carbon sequestration (Stavins 1999).

[15]See: Fisher, Barrett, Bohm, Kuroda, Mubazi, Shah, and Stavins 1996.

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 greenhouse policy instruments. This was (and is) an important issue because the Kyoto Protocol explicitly provides for domestic sovereignty regarding instrument choice and because it is unlikely that most countries will choose tradable permits as their primary domestic vehicle.

Nations can minimize costs if all countries use domestic tradable permit systems to meet their national targets (allocate permits to private parties) and allow for international trades. But when some countries use non-trading approaches such as greenhouse gas taxes or fixed-quantity standards — which seems likely in light of previous experience — cost minimization is not ensured. In those cases, achieving the potential cost savings of international trading will require some form of project-by-project credit program, such as joint implementation. But theory and experience with such credit programs suggest that they are less likely to facilitate major cost savings. Thus, individual nations' choices of domestic policy instruments to meet the Kyoto targets can substantially limit the cost-saving potential of an international trading program. An important trade-off exists between the degree of domestic sovereignty and the degree of cost-effectiveness. International permit trading remains an attractive approach to achieving global greenhouse targets. We concluded that this suggests the need for policymakers to analyze the likely cost-savings from feasible, as opposed to idealized, international policy approaches to reducing emissions of greenhouse gases.

In the final paper in this volume, published as a *Climate Issue Brief* by Resources for the Future, Adam Jaffe, Richard Newell, and I examine "Energy-Efficient Technologies and Climate Change Policies: Issues and Evidence" (Jaffe, Newell, and Stavins 1999). Enhanced energy efficiency occupies a central role in evaluating the efficacy and cost of climate change policies. Since total greenhouse gas (GHG) emissions are the product of population, economic activity per capita, energy use per unit of economic activity, and the carbon intensity of energy used. Although greenhouse gas emissions can be limited by reducing economic activity, this option obviously has little appeal even to rich countries, let alone poor ones. Much attention has therefore been placed on the role that technological improvements can play in reducing carbon emissions and in lowering the cost of those reductions.

Although there is little debate over the importance of energy efficiency in limiting GHG emissions, there is intense debate about its cost-effectiveness and about the government policies that should be pursued to enhance energy efficiency. At the risk of excessive simplification, we characterize "technologists" as believing that there are plentiful opportunities for low-cost, or even "negative-cost" improvements in energy efficiency. Technologists recognize that realizing these opportunities will require active intervention in markets for energy-using equipment to help overcome barriers to the use of more efficient technologies. Most economists, on the other hand, acknowledge that there are "market barriers" to the penetration of various technologies that enhance energy efficiency, but maintain that only some of these barriers represent real "market failures" that reduce economic efficiency.

In this closing essay, my co-authors and I examine what lies behind this dichotomy in perspectives. Ultimately, the veracity of different perspectives is an empirical question and reliable empirical evidence is surprisingly limited. We review the evidence that is available, finding that although energy and technology markets certainly are not perfect, the balance of evidence supports the view that there is less of a "free lunch" in energy efficiency than some would suggest. On the other hand, a case can be made for the existence of specific inefficiencies in energy technology markets, thus raising the possibility of some inexpensive GHG control through energy-efficiency enhancement.

Final Words

Selecting the essays for this volume has permitted me to identify some common themes that have emerged from this decade of research and writing. First of all, there is a message about the value of economic analysis in the realm of environmental policy. Because the cause of virtually all environmental problems in a market economy is economic behavior (i.e. the operation of imperfect markets tainted by externalities), economics offers an exceptionally valuable perspective (albeit only one of many) for viewing environmental problems, and a powerful set of analytical tools for designing and evaluating environmental policy.

A second message is the value of benefit-cost analysis for helping to promote efficient policies. Economic efficiency ought to be one of the fundamental criteria for evaluating proposed and existing environmental policies and programs, although — as these essays indicate — it is only one among a set of relevant criteria. Despite its well known limitations, benefit-cost analysis can be a key method for consistently assimilating the disparate information that is pertinent to sound decision making. If properly done, it can be of great help to public officials as they seek to identify environmental targets and goals.

The means governments use to achieve their environmental goals can also matter greatly, since different policy instruments have very different implications along a number of important dimensions, including the costs of abatement in both the short and the long term. Market-based instruments are attractive along these dimensions, although they have only recently become acceptable in the real world of environmental politics and policy.

There are sound reasons why the political world has been slow to embrace the use of market-based instruments for environmental protection, including the ways economists have packaged and promoted their ideas in the past: failing to separate means (cost-effective instruments) from ends (efficiency); and treating environmental problems as little more than "externalities calling for corrective taxes." Much of the resistance has also been due to the very nature of the political process and the incentives it provides to both politicians and interest groups to favor command-and-control methods instead of market-based approaches.

But, despite this history, market-based instruments have moved center stage, and policy debates look very different from the time when these ideas were characterized as "licenses to pollute" or dismissed as completely impractical. Of course, no single policy instrument — whether market-based or conventional

— will be appropriate for all environmental problems. Which instrument is best in any given situation depends upon characteristics of the specific environmental problem, and the social, political, and economic context in which the instrument is to be implemented. There is no policy panacea.

On a more personal level, the professional path I have taken offers some confirmation that research (or at least researchers) can influence public policy, but it also illustrates that involvement in public policy can stimulate new lines of 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 a strange consistency of purpose and even of function. I find myself doing similar things, but in quite different contexts. From origins with my first family — my parents and brother — to life with my second family — my wife and children, my personal and professional search has taken me along a marvelous path that has brought me home:

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.[16]

Selecting the papers for this volume has forced me to step back to reflect on the past and to think more clearly about the future. Looking today at the stacks of materials in my office, I find that my current research efforts and writing projects fall quite consistently within the broad areas that have interested me over the past decade, with one exception. Simmering on the back burner is a promise I have made to myself to try another merger of profession and avocation: a hedonic analysis of premium wine pricing may be the venue for a combined study of economy and oenonomy. In the meantime, I will stick to environmental economics and policy.

The twenty-three essays that comprise this book are the product of twelve wonderful years on the faculty of Harvard's John F. Kennedy School of Government. During this time, I have learned more about environmental economics and public policy than I previously thought possible. I have learned from colleagues, collaborators, students, friends, and — perhaps most strikingly — from daily interactions with the inhabitants of the "real world" of public policy, individuals from government, private industry, advocacy groups, and the press. The learning continues. And so I look forward to another decade of more of the same, and a decade after that, and then who knows.

[16]Eliot 1943.

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