Banning Chlorofluorocarbons: Epistemic Community Efforts to Protect Stratospheric Ozone

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The protection of the stratospheric ozone layer is a striking instance of international cooperation. Governments adopted regulations for a $100 billion global industry in the Montreal Protocol on Substances That Deplete the Ozone Layer of September 1987. The protocol imposes severe limits on the global use of chlorofluorocarbons (CFCs), which were suspected of decreasing stratospheric ozone, even though scientists and industry representatives agreed that in 1987 "there was not enough data to provide definitive answers about the cause of the decreases."[1] A British journalist puzzled, "Why, when professionals cannot make up their minds even about what is happening in the Antarctic, should the world's diplomats be locked in negotiations?"[2]

The successful coordination of national policies to protect the ozone layer was strongly influenced by the activities of an ecological "epistemic community," a knowledge-based network of specialists who shared beliefs in cause-and-effect relations, validity tests, and underlying principled values and pursued common policy goals.[3] Their orientation is perhaps best expressed in the words

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1. Statement of Mack McFarland, DuPont's principal science adviser for CFC-related issues, in "Ozone Science, Recent Findings," mimeograph, July 1888.
2. John Maddox, "The Great Ozone Controversy," *Nature* 329 (September 1987), p. 101.
3. See Peter M. Haas, "Introduction: Epistemic Communities and International Policy Coordination," in this issue of *IO*.

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of one member, who voiced his willingness to accept the "plausibility of a causal link without certainty."[4]

In the face of foreign policy decision makers' uncertainty about the causes of the problem and the possible consequences of action, the epistemic community was largely responsible for identifying and calling attention to the existence of a threat to the stratospheric ozone layer and for selecting policy choices for its protection. The community channeled discussions toward a strong ozone treaty by spreading information that suggested the need for stringent international CFC controls. Its viewpoint prevailed in policy disputes within the U.S. administration and led the United States to pressure other countries to adopt a stringent treaty. Moreover, by directly influencing the major CFC producer, DuPont, the epistemic community enhanced the prospects of enforcement of the treaty by creating market incentives for smaller actors to gradually eliminate CFCs. The community framed the range of alternatives that actors considered, advocated strong controls within those parameters, and pushed for speedy implementation of controls in the countries in which it had consolidated bureaucratic power. Thus, it directly affected outcomes through the activities of its members within their own governments and organizations, and it indirectly affected outcomes as well by altering the market conditions from which smaller actors formulated their interests and strategies.

A focus on the role of the epistemic community analytically supplements more traditional studies of international leadership that are based on the international distribution of power. Contrary to the more limited expectations of neoliberal institutionalists, who would predict that the extensive uncertainties about costs and time frames would lead to the adoption of an insurance regime,[5] the Montreal protocol is in fact a strong regulatory regime. While the outcomes roughly correlate with the international distribution of power, the ends to which U.S. power was directed elude the systemic explanations offered by structural neorealists.[6] Although the United States played a leadership role throughout the treaty negotiations, dissension within the Reagan administration made it extremely unclear until the very last minute whether the U.S. delegation would be able to uphold its initial commitment to stringent controls. The final choice ran contrary to U.S. domestic particularistic interests, which opposed regulation, and also differed from a contemporary assessment of the aggregate national interest.

4. Interview with Martin Holdgate, Arc-et-Senans, France, 13 September 1989. After serving as chief scientist and head of research in Britain's Department of the Environment, Holdgate became director general of the International Union for the Conservation of Nature and Natural Resources.

5. See, for example, Robert O. Keohane, "The Demand for International Regimes," in Stephen D. Krasner, ed., *International Regimes* (Ithaca, N.Y.: Cornell University Press, 1983), pp. 141–71.

6. For an elaboration of the various strands of neorealism discussed here, see Joseph S. Nye, "Neorealism and Neoliberalism," *World Politics* 40 (January 1988), pp. 235–51; Joseph M. Grieco, "Anarchy and Cooperation," *International Organization* 42 (Summer 1988), pp. 485–507; and Oran R. Young, *International Cooperation: Building Regimes for Natural Resources and the Environment* (Ithaca, N.Y.: Cornell University Press, 1989).

Until late in the negotiations, the U.S. "interest" as perceived by the foreign policy community was not clearly expressed, and the "interest" that was finally identified was seriously at odds with previous U.S. behavior in the area of international environmental politics. As Lynton Caldwell noted, "Three considerations, essentially domestic in origins, appear to have influenced Reagan's environmental policies abroad. [They were the] desire to obtain advantage wherever possible for American economic interests, . . . [the] ideological bias against any increases in U.S. financial contributions to intergovernmental agencies, . . . [and the] preference for reliance upon market forces as a corrective to environmentally harmful practices."[7] Conversely, U.S. behavior in the ozone case was characterized by a willingness to forgo advantages for U.S. producers and by a strong interest in regulation. Although a nominal interest in preserving market rules as a guide to international behavior was preserved, the U.S. position was modified in that market signals would now be used to pursue a new principled objective. As argued below, this new objective was instilled by the ecological epistemic community as its members were consulted by their own national administrations.

Repeated environmental crises precipitated action for controlling CFCs and set the pace for international activities. These crises alerted governments to the urgent need for collective action. They revealed the extent of scientific understanding and uncertainty about the nature of the problem and identified the group of actors to whom governments felt they must turn to explicate the variety of possible policies.

The ecological epistemic community

The ozone negotiations were framed by an ecological epistemic community composed of atmospheric scientists and of policymakers who were sympathetic to the scientists' common set of values, which stressed preserving the quality of the environment, and accepted their causal analysis. The common causal beliefs lay in an acceptance of the 1974 Rowland-Molina hypothesis that the chlorine in CFC emissions upsets the natural ozone balance by reacting with and breaking down ozone molecules and hence depleting the thin layer of stratospheric ozone. Their policy enterprise consisted of preserving this ozone layer, which prevents harmful ultraviolet rays from reaching the earth.

The adherents shared common validity tests based on the scientific method. They were careful to constantly evaluate what they had learned as professionals in what seemed to them to be the most rigorous possible way, and they were reluctant to urge policy actions on problems that had not been fully docu-

7. Lynton Caldwell, "The World Environment: Reversing U.S. Policy Commitments," in Norman J. Vig and Michael E. Kraft, eds., *Environmental Policy in the 1980s* (Washington, D.C.: CQ Press, 1984), p. 320.

mented, even if the actions were consistent with their broader objectives. For instance, in 1985, when scientists reported evidence of a "hole" in the Antarctic ozone, the epistemic community pushed for additional studies. From 1986 on, U.S. scientists not only embarked on expensive annual expeditions to the Antarctic to test for key trace elements that would confirm or falsify their hypothesis but also conducted thorough reappraisals of previous atmospheric data. Consequently, their commitment to professional measures of validity constrained acting fully to extend their policy enterprise.

The epistemic community members all agreed that the accumulation of physical contaminants necessarily has detrimental consequences for the overall environment because it disrupts natural systems. At the same time, however, the members' political motivations and strategies varied. Some saw the ozone problem as part of a broader issue of protecting the stratosphere from pollution. For them, controlling CFCs was only the first step in a broader strategy of either eliminating the levels of various trace gases that could contribute to global warming or of limiting these trace gases to their current emission rates. Others merely hoped to conclude a strong treaty for the isolated issue of ozone. While conservationist members of the community were tolerant of evaluating proposed measures in terms of costs and benefits, preservationist members were unwilling to weigh their objectives with other social objectives, such as economic competitiveness and energy conservation, with which strong regulation of CFCs and other pollutants conflicted.[8] But because all shared an aversion to depleting the ozone layer, they found it easy to tolerate such relatively minor differences in outlook.

The epistemic community was transnational, consisting of officials of the United Nations Environment Programme (UNEP), the U.S. Environmental Protection Agency (EPA), and the U.S. State Department's Bureau of Oceans and International Environmental and Scientific Affairs (OES) as well as atmospheric scientists in the international scientific community. The officials seldom had training in atmospheric science but were eager to accept the scientists' advice because of a shared interest in conserving environmental quality. The scientists were in frequent, informal contact, whereas the government officials interacted less often.

UNEP's two principal representatives in the ozone talks were Mostafa Tolba, an Egyptian microbiologist serving as UNEP's executive director, and Peter Usher, a British meteorologist responsible for UNEP's programs on problems of the atmosphere. With regard to ozone, Usher stated that "UNEP is concerned with limiting the damage. It is probably impossible to avoid the ozone depletion that is likely to occur from the CFCs already emitted to the atmosphere because CFCs have long atmospheric life times—in excess of a

8. For further discussion of the distinction between "preservationist" and "conservationist" environmentalists, see M. J. Peterson, "Whalers, Cetologists, Environmentalists, and the International Management of Whaling," in this issue of *IO*. Regarding the strategies used by proponents of CFC regulation, see Sharon L. Roan, *Ozone Crisis* (New York: Wiley, 1989).

hundred years—and they will continue to deplete ozone for the next century or more. It was UNEP's concern that this damage should be at least contained by reducing the amount of CFCs being emitted into the atmosphere."[9] Tolba was firmly committed to a strong treaty, letting it be known that he would have opposed reductions of only 30 to 40 percent in CFC use "even [at] the expense of not having a protocol."[10]

The epistemic community was strongly represented within the U.S. administration. At the EPA, Administrator Lee Thomas and officials from the offices of air programs and international activities were in the epistemic community. Thomas, who was personally committed to the issue of ozone and took great interest in the formulation and pursuit of a strong treaty from the outset, gave the following testimony before Congress: "Our position is we should not wait until there is scientific certainty and consensus around the world that ozone is depleting. We feel that there is enough evidence that it will be depleted. We think there are examples of where it is depleting to dictate a prudent, stringent course of action around the world."[11] Like Thomas, the officials in the two EPA offices had been associated with strong environmental protection positions well before the ozone issue reached international saliency.

At the OES, Assistant Secretary of State John Negroponte and Deputy Assistant Secretary Richard Benedick were strong supporters of ozone protection. In 1985, Benedick stated that "in a real world of imperfect knowledge and uncertainty, we, as policymakers, nevertheless have the responsibility to take prudent actions for the benefit of generations yet to come. The U.S. Government thus believes that, while cooperation on research . . . is necessary, it is not sufficient in light of the potential risks we all face from ozone layer depletion. . . . The margin of error between complacency and catastrophe is too small for comfort."[12] In 1987, testifying before Congress, he again emphasized the risks: "Even in the face of the scientific uncertainties . . . we nevertheless believe that the nature and extent of the long-term risks require a prudent insurance policy in the form of international controls."[13] And at an international meeting in 1987, Benedick told his fellow delegates that "if we are to err in designing measures to protect the ozone layer, then let us, conscious of our responsibility to future generations, err on the side of caution."[14]

9. Peter Usher, cited in "The Ozone Layer, CFCs, and the Oceans: An Interview with Peter Usher," *The Siren,* no. 35, December 1987, pp. 30–31.

10. Mostafa Tolba, cited by Peter Menyasz in "International Agreement to Protect the Ozone Layer Hailed as Precedent for Global Environmental Solutions," *International Environment Reporter,* 14 October 1987, p. 531.

11. Testimony of Lee Thomas, in U.S. Congress, House Committee on Energy and Commerce, *Ozone Layer Depletion: Hearings Before the Subcommittee on Health and the Environment,* 100th Congress, 1st sess., 1987, p. 135.

12. Richard Benedick, cited in "Protecting the Ozone Layer," Department of State Public Information Series 21, January 1985, p. 1.

13. Testimony of Richard Benedick, in U.S. Congress, *Ozone Layer Depletion: Hearings,* p. 97.

14. Benedick, cited by Henry Kamm in "Thirty Nations Meet on Rules to Protect Ozone Layer," *The New York Times,* 26 February 1987, p. A7.

In the United States, other members of the epistemic community were atmospheric scientists with a focus on atmospheric chemistry, although not all had graduate training in this specialized area. They composed a hybrid community and relied on one another to understand complementary aspects of atmospheric behavior. Chemists understood atmospheric reactions, whereas physicists studied more general stratospheric dynamics. These individuals worked in universities and government laboratories which were affiliated with the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) and which included NASA's Goddard Space Flight Center, NOAA's Aeronymy Laboratory in Boulder, Colorado, and NOAA's National Center for Atmospheric Research (NCAR) in Boulder. While the scientists shared common views about the way the atmosphere works, many had come to the study of atmospheric chemistry from other disciplines and thus were initially insecure about their scientific standing and felt themselves to be interlopers.[15] The stratosphere had been regarded as a relatively uninteresting piece of the atmosphere, and previous research had concentrated on other areas. Meteorologists, for example, had studied atmospheric dynamics and transport in the lower atmosphere because that is where "the weather occurred." The upper atmosphere had been extensively studied in the 1960s, when the Defense Department supported research associated with missile reentry. Afterwards, interest had turned to the study of atmospheric dynamics on other planets, which would be amply funded by NASA.[16]

Among the group of scientists studying CFCs were Ralph Cicerone, a physicist at the University of Michigan; Sherwood Rowland and Mario Molina, chemists at the University of California at Irvine; Michael McElroy and Steve Wofsy, atmospheric physicists at Harvard University; and Richard Stolarski, a physicist who began his career at the University of Michigan but later joined NASA's Goddard laboratory. They had begun their research on propellant CFCs in the 1970s and had continued their research on CFCs in the upper atmosphere even after CFCs had been banned in aerosols. Concerned that they lacked the "credentials" to get into the fray, they hoped to chart out a small inconspicuous research project to begin with, such as chlorine in the stratosphere, which according to Stolarski "looked like a nice, *quiet* piece of the stratosphere to cut off and maybe get a paper or two while we were learning and nobody would bother us."[17] In the early 1970s, the researchers in this group were not members of the "scientific community concerned with the ozone layer," and "their professional orbits had never overlapped those of atmospheric scientists."[18] As Lydia Dotto and Harold Schiff have pointed out, none

15. See Lydia Dotto and Harold Schiff, *The Ozone War* (Garden City, N.Y.: Doubleday, 1987), p. 19; and Roan, *Ozone Crisis*.
16. Dotto and Schiff, *The Ozone War*, pp. 206–7.
17. Richard Stolarski, cited in ibid., p. 125.
18. Dotto and Schiff, *The Ozone War*, p. 16.

of the early researchers of ozone depletion was "a member of the clique of researchers who had staked out stratospheric chemistry as their special domain. This is one of the most striking features of the ozone controversy—the extent to which 'outsiders' played a crucial role in identifying the threats to the ozone layer."[19] Thus, their institutional status as a small group of scientists who were nonetheless outside the "mainstream" community of atmospheric scientists, in Michael Polanyi's sense,[20] reinforced their collective identity.

U.S. scientists who were part of the epistemic network of universities and laboratories communicated with and visited one another frequently and also had contact with their counterparts in Europe. The transnational contacts within the community were formalized through participation in UNEP's Coordinating Committee on the Ozone Layer, which was established in 1977, and through participation in the project of assessing ozone data, which was begun in 1985, was conducted by NASA and the World Meteorological Organization, and involved over 150 atmospheric scientists from 11 countries. Through their contacts, the scientists shared and diffused information, making it difficult for government agencies to monopolize and control information if they had wanted to do so.

While atmospheric research was predominantly an American activity both in terms of federal support for investigations (NASA's ozone budget was about $100 million per year) and in terms of the number of active researchers, atmospheric scientists conducted vigorous studies in Belgium, Britain, France, Japan, Norway, Sweden, West Germany, and the Soviet Union. Major actors outside the United States included Paul Crutzen, a Dutch meteorologist who had worked at the University of Stockholm and served as an atmospheric modeler first at NCAR and then at the Max Planck Institute for Chemistry in Germany, and Joseph Farman, who was director of the Atmospheric Physics Department of the British Antarctic Survey and was one of the few British scientists crusading against CFCs. Martin Holdgate, the chief scientist and head of research in Britain's Department of the Environment, was in routine contact with scientists and policymakers from other governments and was impressed with the strength of the scientific argument against the use of CFCs, but he felt that the measures being proposed were more powerful than his administration was willing to accept at the time.[21] Ties between the United States and Britain were nonetheless strong and became even stronger when Robert Watson, a British atmospheric scientist, came to work at NASA and pursued his extensive contacts within the international scientific community. Similar ties between U.S. and Soviet scientists were created in 1987, when representatives from the two countries met and agreed to begin collaborative work on the climate and ozone. According to Benedick, the U.S.–Soviet

19. Ibid., p. 11.
20. See Michael Polanyi, "The Republic of Science," *Minerva,* vol. 1, 1962, pp. 54–73.
21. Personal communication from Holdgate, 6 March 1990.

meeting "contributed to a gradual weakening of Soviet opposition to international controls on ozone-depleting compounds."[22]

Nevertheless, the members of the ecological epistemic community continued to face opposition from groups in the United States and elsewhere, who drew different causal conclusions with different policy implications when confronted with the same scientific evidence.[23] Rather than seeing potential ozone depletion as the tip of an ecologically threatening iceberg, as the community members did, the opposing groups considered it only a possibly sui generis ice cube. For instance, in 1986, community members concluded that research on ozone depletion showed a narrowing of the bounds of uncertainty regarding the existence of a real environmental threat and the role of CFCs in the threat. For them, this justified immediate regulation of possible depleters of the ozone layer. Opponents argued that the recent estimates of ozone depletion indicated that the initial scientific findings were wrong and that in any case research was now converging on such low estimates of depletion that immediate management was not urgent. If anything, scientific reports suggested to them that there was ample time for more research before embarking on regulation.[24] The CFC manufacturers in the United States consistently argued through their lobbying organization, the Alliance for a Responsible CFC Policy, that the evidence was incomplete and did not dictate limiting CFC production. At most, they would tolerate a freeze in production levels while additional research was undertaken.[25] Similar positions and calls for more research were echoed by European diplomats and U.S. officials who were not members of the epistemic community.

The ecological epistemic community had a variety of channels to decision making. Through UNEP, it drafted documents and reports, gathered data, organized scientific panels, pressured delegates, and stressed issues that it deemed important. During negotiating meetings, Executive Director Tolba urged delegates to seek consensus and constantly pressed for a strong treaty. He personally chaired meetings and at one point even threatened not to let the delegates go to dinner until they had reached agreement. According to Benedick, head of the U.S. delegation at most of the ozone negotiations, Tolba personally proposed stringent standards in excess of those proposed by most countries, "pressed for deep cuts during internal consultations with heads of key delegations,"[26] and argued that, as an Egyptian, he represented the

22. Richard E. Benedick, *Ozone Diplomacy: New Directions in Safeguarding the Planet* (Cambridge, Mass.: Harvard University Press, 1991), p. 101.

23. In fact, there was great tension between the epistemic community and the opposing groups because of the inability of the latter to grasp the complexities involved in the scientific research and modeling. During an interview conducted on 1 April 1988 with a scientist affiliated with a nongovernmental organization, the scientist referred to members of the opposing groups as "Martians . . . with a different standard of values."

24. See, for example, "Heads in the Ozone," *Wall Street Journal,* 5 March 1984, p. 30.

25. Alliance for a Responsible CFC Policy, "Remarks of Richard Barnett," in *The Montreal Protocol: A Briefing Book* (Rosslyn, Va.: Alliance for a Responsible CFC Policy, December 1987).

26. Richard E. Benedick, "The Ozone Protocol: A New Global Diplomacy," *The Conservation Foundation Letter,* no. 4, 1989, p. 7.

interests of the less developed countries (LDCs) as well as those of UNEP. Under Tolba's leadership, UNEP provided funds for about ten LDCs to send delegates to the ozone negotiations in February 1987.

Within the United States, the ecological epistemic community operated through government agencies. But it did not acquire a serious bureaucratic presence until the mid-1980s, at which time U.S. policy became more supportive of strong regulatory controls on CFCs, largely as a result of changes in government appointments. During the 1970s, the OES had been the sole government agency involved in atmospheric environmental foreign policy. In 1985, Benedick, who had served as coordinator of the OES population studies program, was appointed deputy assistant secretary of state and became responsible for ozone policy. While NASA was charged with coordinating the scientific assessments of ozone depletion and the dissemination of information, EPA officials were called upon to provide policy support and analysis. The EPA itself had undergone numerous changes in the early 1980s. Under Ann Burford Gorsuch, the EPA had opposed most environmental regulation. In fact, the absence of alternatives to CFCs in the early 1980s was due to deliberate decisions by CFC producers to cut back on research for suitable substitutes following strong signs from the EPA that alternatives to CFC use would not be required.[27] When William Ruckleshaus became the EPA administrator in March 1983, he replaced seven of Gorsuch's top eight appointees, including the head of international activities, with stronger supporters of environmental regulation. After Lee Thomas succeeded him in 1984, the EPA became more active in ozone protection issues and its policy became less bound up in antiregulatory rhetoric.[28] The EPA, in tandem with NASA and the OES, was now largely responsible for formulating U.S. foreign environmental policy positions and was staffed by members of the epistemic community.

The atmospheric scientists' influence was applied both through the publicity accorded to their research findings and through testimonies at congressional hearings.[29] Preliminary findings were often circulated at large international coordination conferences and at meetings of the American Geophysical Union. Information on scientific developments was made available to U.S. and other

27. Harry Meier, "Ozone Demise Quickens Despite '78 Ban on Spray Propellant," *Wall Street Journal,* 13 August 1986, p. 25.

28. See J. Clarence Davies, "Environmental Institutions and the Reagan Administration," in Vig and Kraft, *Environmental Policy in the 1980s,* p. 156; and John McCormick, *Reclaiming Paradise* (Bloomington: Indiana University Press, 1989), p. 136.

29. In October 1987, for example, the congressional testimony of Harvard University chemist Michael McElroy was covered by the *Boston Globe*. In his testimony, McElroy made the following statements: "There is no longer reason to doubt that industrial gases containing chlorine are responsible in large measure for a dramatic, large-scale change in the stratosphere observed over Antarctica. . . . There is, in my opinion, a need for immediate additional cuts in the release of industrial chlorinated and brominated hydrocarbons." See testimony of Michael McElroy, in U.S. Congress, Senate Committee on the Environment and Public Works, *Implications of the Expedition to Investigate the Ozone Hole over the Antarctic: Joint Hearings Before the Subcommittees on Environmental Protection and Hazardous Wastes and Toxic Substances,* 100th Congress, 1st sess., 1987, pp. 18–19; and Diane Dumanoski, "Ever Stronger Protection Urged for Ozone Layer," *Boston Globe,* 28 October 1987, p. 3.

delegations through reports and bulletins issued by NASA and by UNEP's Coordinating Committee on the Ozone Layer, and results of new monitoring and modeling exercises were published in scientific journals, notably *Science, Nature,* and *Geophysical Research Letters.* By 1985, the public had become interested in the ozone issue, and congressional testimony by scientists about ozone depletion was often given national and international media coverage.

Industry representatives also received information through these channels as well as from research funded by their own organization, the Chemical Manufacturers Association. In 1972, nineteen member companies of the association created a fluorocarbon program panel to conduct atmospheric measuring and modeling and to study analytic methods, chemical reactions, and kinetics. From 1972 to 1985, the association spent over $18.9 million on research.[30]

The epistemic community's most potent political resource was its ability to articulate what scientific developments implied for policy, an ability based on its reputation for expertise in atmospheric chemistry. Although the scientific evidence was not clear-cut and did not gain wide consensus until after the ozone treaty was concluded, the scientists were responsible for briefing their political colleagues on where the uncertainties lay and on whether the scientific evidence was approaching closure. As the science improved, the credibility of the epistemic community was enhanced. Benedick acknowledged that CFC regulation "couldn't have occurred without modern science, without atmospheric chemistry, computer models, and projections. It couldn't have happened as recently as 1982."[31]

Origins of concern

CFCs as a class of chemicals were discovered by General Motors in 1931 and soon became widely used for refrigeration, air conditioning, and insulation (see Table 1). Hailed as perfect chemicals because of their inert, nontoxic, noncarcinogenic, and nonflammable properties, CFCs underwent a steady increase in production, with global manufacturing quadrupling in the 1960s alone. During the 1970s and early 1980s, CFCs acquired a new and important application as solvents in the electronics industry. Although CFC use had come into question by the early 1970s, there were few commercial replacements for CFC compounds. American producers had experimented with potential substitutes but abandoned their efforts when the EPA dropped its interest in regulating CFCs in 1981. By 1986, about 2.5 million metric tons of CFC compounds were being produced: 35 percent in the United States, 36 percent

30. Chemical Manufacturers Association, "Fluorocarbon Research Program Revision No. 21," June 1985, p. 4.

31. Benedick, cited by Rochele L. Stanfield in "Global Guardian," *National Journal* 12 (December 1987), p. 3139.

in Western Europe, 8 percent in the Soviet Union and Eastern Europe, 18 percent in Asia and the Pacific, and 3 percent in Latin America.[32] During the same year, the United States consumed about 29 percent of world production (see Table 2).

At the time of the ozone treaty negotiations, CFCs were being produced by only seventeen companies with operations in sixteen countries. Within this oligopolistic market, DuPont was the world leader. With its headquarters in the United States and with subsidiaries and joint ventures in six other countries, DuPont held 50 percent of the U.S. market, was responsible for over 25 percent of global production, and was the only company to produce CFCs for all three major world markets: North America, Europe, and Japan. Given the size of DuPont's market and the fact that the United States was the largest CFC-producing and CFC-consuming country, it is not surprising that the United States became the most powerful actor involved in ozone research and negotiations.

International concern about the depletion of the ozone layer first emerged in the United States in 1970, when scientists on the President's Science Advisory Council voiced fears that supersonic transports could destroy up to 50 percent of the earth's ozone layer.[33] Although this particular concern died along with the demise of widespread supersonic transport use, the problem of ozone depletion continued to be studied. In 1974, Sherwood Rowland and Mario Molina, two chemists at the University of California at Irvine, argued that the chlorine in CFC emissions reacts with and breaks down ozone molecules in the thin layer of stratospheric ozone and thus hinders the ozone layer's ability to prevent harmful ultraviolet rays from reaching the earth. Since CFCs remain in the stratosphere for long periods, the process of ozone depletion is largely irreversible. While possible ozone depletion from chlorine had been suggested earlier, Rowland and Molina were the first to identify the CFC origins of chlorine and directly link them with the depletion process.[34] Their discovery was made possible by the recent invention of sensitive equipment capable of

32. Craig R. Whitney, "Twelve European Nations to Ban Chemicals That Harm Ozone," *The New York Times,* 3 March 1989, p. 1.

33. See Joseph G. Morone and Edward J. Woodhouse, *Averting Catastrophe: Strategies for Regulating Risky Technologies* (Berkeley: University of California Press, 1986), chap. 5.

34. See Mario Molina and Sherwood Rowland, "Stratospheric Sink for Chlorofluoromethanes: Chlorine Atom Catalyses Destruction of Ozone," *Nature* 249 (June 1974), pp. 810–12. See also R. S. Stolarski and R. J. Cicerone, "Stratospheric Chlorine: A Possible Sink for Ozone," *Canadian Journal of Chemistry* 52 (September 1974), pp. 1610–15; and Richard Stolarski, "The Antarctic Ozone Hole," *Scientific American* 258 (January 1988), pp. 30–36. Molina and Rowland's hypothesis did not receive widespread publicity until September 1974, when it was presented at the high-profile national conference of the American Chemical Society. See Arie Rip and Peter Groenewegen, "Les faits scientifiques a l'épreuve de la politique" (The political test of scientific facts), in Michael Callon, ed., *La science et ses réseaux: Genèse et circulation des faits scientifiques* (Science and its networks: The genesis and circulation of scientific facts) (Paris: Council of Europe and United Nations Educational, Scientific, and Cultural Organization, 1988), pp. 149–72.

TABLE 1. *Characteristics and world consumption of CFC compounds, 1985*

Compound	*Application*	*Ozone-depleting potential*[a]	*World consumption in thousand metric tons*
CFC-11 ($CFCl_3$)	Foams, aerosols, and refrigeration	1.0	341.5
CFC-12 (CF_2Cl_2)	Foams, aerosols, refrigeration, and air conditioning	1.0	443.7
CFC-113 ($C_2Cl_3F_3$)	Solvents	0.8	163.2
Halon 1211 (CF_2ClBr)	Fire extinguishers	3.0	10.8
Halon 1301 ($CBrF_3$)	Fire extinguishers	10.0	10.8
Methyl chloroform (CH_3CCl_3)	Solvents	0.1	544.6
Carbon tetrachloride (CCl_4)	Solvents	1.1	1,029.0
Total	—	—	2,543.6

[a]Potential is given relative to a molecule of CFC-11 and is based on scientific consensus.

Sources. James K. Hammitt et al., *Product Uses and Market Trends for Potential Ozone-Depleting Substances, 1985–2000,* RAND Corporation, R-3386-EPA, May 1986; and U.S. Government Accounting Office, *Stratospheric Ozone,* GAO/RCED-89-49, February 1989.

TABLE 2. *Patterns of CFC consumption, 1986*

Consumer	World consumption of CFCs (all compounds)	Industrialized country consumption of specific CFC compounds[a]						
		CFC-11	*CFC-12*	*CFC-113*	*Halon 1211*	*Halon 1301*	*Methyl chloroform*	*Carbon tetrachloride*
Industrialized countries								
United States	29%	22%	30%	45%	25%	50%	50%	27%
Economic Community members, Japan, Canada, and Australia[b]	41%	66%	52%	52%	75%	50%	34%	57%
Soviet Union and other East European countries	14%	12%	18%	3%	0%	0%	16%	16%
Less developed countries (LDCs)								
China and India	2%	—	—	—	—	—	—	—
Other LDCs	14%	—	—	—	—	—	—	—

[a]Data on consumption of specific CFC compounds in 1986 are available only for the group of industrialized countries and are based on company reports to the Chemical Manufacturers Association.

[b]Economic Community members accounted for over 50 percent of the amounts listed in this row.

Sources. James K. Hammit et al., *Product Uses and Market Trends for Potential Ozone-Depleting Substances, 1985–2000,* RAND Corporation, R-3386-EPA, May 1986; and U.S. Government Accounting Office, *Stratospheric Ozone,* GAO/RCED-89-49, February 1989.

monitoring slight amounts of CFC in the stratosphere.[35] Later studies suggested that a 1 percent depletion of the ozone layer would not only adversely affect fishery crops but would also lead to a 1 to 2 percent increase in fatal and nonfatal skin cancers in human populations.[36]

However shocking, this view remained a hypothesis until the late 1980s. No chlorine had actually been observed in the atmosphere; the reactions between CFCs and stratospheric ozone were not clearly understood; and there was not yet any indication of ozone depletion. In fact, global ozone had actually increased during the 1960s—an observation that most scientists could not explain. Thus, scientists lacked confirmation of the Rowland-Molina hypothesis and were unable to predict the rate of ozone depletion that increased CFC production would yield. Nevertheless, the hypothesis led many scientists and members of the public to fear that if the U.S. and other governments waited for actual measurements of depleted ozone, they would be faced with an irreversible degradation of the ozone layer.

As atmospheric modeling became more sophisticated over the decade, it became possible to offer clearer predictions and to create with greater certainty scenarios of how various rates of CFC production would affect the ozone layer at different altitudes and different latitudes.[37] In effect, modelers were responsible for creating the world that they were simulating for decision makers, as no one else had any understanding of the physical area being studied.[38]

Policy responses

Although the Rowland-Molina hypothesis remained unconfirmed and contested after its appearance, it did seize popular attention and gave rise to an

35. The new equipment was designed by James Lovelock. Unlike most modern technological innovations, this one was created by an independent scientist and engineer who consciously isolated himself from the traditional institutions of "big science." When Lovelock found evidence of CFCs in the stratosphere, he did not relate them to a chlorine reaction. Rather, he assumed that CFCs were inert and posed no threat to the environment. For Lovelock, CFCs merely provided a useful indicator for his instrumentation. See Dotto and Schiff, *The Ozone War,* pp. 8–9; and Lawrence E. Joseph, *Gaia: The Growth of an Idea* (New York: St. Martin's Press, 1990), chap. 1.

36. EPA, "Protection of Stratospheric Ozone: Final Rule and Proposed Rule," *Federal Register,* no. 239, December 1987, pp. 47494–95.

37. There are at least 192 chemical reactions and 48 photochemical processes that occur in the stratosphere, although only about 150 or fewer of these parameters are actually used in most models. The models, which are extremely sensitive to the rate of CFC emissions and their reactions with other trace gases, are designed to project ozone concentrations over a span of one hundred years. The concentrations are in turn used to predict the adverse effects on public health. For example, scenarios based on a 2.5 percent annual growth of CFC emissions yielded projections of public health effects that were 90 percent greater than those based on a 1.2 percent annual growth of CFC emissions. See Thomas H. Maugh II, "What Is the Risk from Chlorofluorocarbons?" *Science* 233 (March 1984), pp. 1051–52.

38. Adler offers a similar observation about the role of game theorists in arms control. See Emanuel Adler, "The Emergence of Cooperation: National Epistemic Communities and the International Evolution of the Idea of Nuclear Arms Control," in this issue of *IO*.

initial spasm of international regulation. The governments of nine countries, including the United States, banned the use of CFCs as aerosol propellants,[39] and many others passed voluntary limits on aerosol use. The Economic Community (EC) Council adopted a production cap and a 30 percent consumption reduction from 1976 levels of CFC-11 and CFC-12 used in aerosols.[40] In 1982, it followed with a production capacity freeze on CFC-11 and CFC-12 at the level of 480,000 metric tons.[41] With the existing voluntary limits on aerosols, this cap effectively built in a surplus capacity of 30 percent for European CFC producers.

UNEP was seriously concerned about the risk of ozone depletion. In April 1976, its governing council began preliminary work on plans for coordinated activities to protect the ozone layer. In March 1977, UNEP convened the International Conference on the Ozone Layer. The conference, which was held in Washington and hosted by the U.S. government, released the World Plan of Action on the Ozone Layer, a document calling for a treaty for ozone protection.

UNEP's approach was based on its prior experience with promoting pollution control in the Mediterranean Sea through the development of concurrent environmental assessment and management activities. To consolidate scientific understanding, UNEP established the Coordinating Committee on the Ozone Layer, composed of representatives from international governmental and nongovernmental organizations with active ozone layer research programs. The committee met eight times between 1977 and 1986 and reported its findings in the *Ozone Layer Bulletin.* On the management front, in response to a Scandinavian proposal, UNEP's governing council established the Ad Hoc Working Group of Legal and Technical Experts for the Elaboration of a Global Framework Convention for the Protection of the Ozone Layer. This group met seven times between 1982 and 1985 to draw up a draft convention.[42]

Pressure for a treaty became more acute with an unexpected surge in CFC use. Following the initial spate of legislation, total CFC production had fallen in 1977 and had leveled off until 1983. However, because of the new use of CFC-113 as a solvent for computer chip manufacture, the CFC-113 share of total production had more than doubled from 1975 to 1982.[43] With spectacular leaps in CFC-113 production, the 1984 and 1985 CFC production figures

39. See Thomas B. Stoel, Jr., Alan S. Miller, and Breck Milroy, *Fluorocarbon Regulation: An International Comparison* (Lexington, Mass.: Lexington Books, 1980); and U.S. Congress, *Ozone Layer Depletion: Hearings,* pp. 406–7.

40. Document 80/372/EEC, reprinted in *Official Journal of the European Communities,* no. L90/45, 3 April 1980.

41. Document 82/795/EEC, reprinted in *Official Journal of the European Communities,* no. L329/29, 25 November 1982. I am grateful to Nigel Haigh for clarifying my understanding of these decisions.

42. Peter H. Sand, "Protecting the Ozone Layer," *Environment* 27 (June 1985), pp. 18–20 and 40–43.

43. James K. Hammitt et al., *Product Uses and Market Trends for Potential Ozone-Depleting Substances, 1985–2000,* RAND Corporation, R-3386-EPA, May 1986, pp. 4–10.

reported by the Chemical Manufacturers Association precipitated renewed concern about ozone depletion.

In 1985, there was broad consensus that the ozone layer had to be protected, but delegations were soon polarized about what measures should be taken. Governments suggested international efforts consistent with the measures they had already adopted nationally. The United States and Scandinavian countries argued for consumption controls based on different uses, while members of the EC believed only in freezing production capacity for CFCs at current levels. Since the EC firms already had a 30 percent surplus in their manufacturing capacity, such a freeze, combined with voluntary limits on uses in aerosols, would actually permit the European CFC industry to expand output to 1.5 times its present levels. This would allow companies operating in the EC to expand their global markets while others limited theirs.[44] The United States and the "Toronto group" of Canada, Finland, Norway, and Sweden finally advocated a freeze in production, which was to take place immediately, and a 30 percent reduction from the 1976 use levels of CFC-11 and CFC-12, which was to be implemented within two years of the treaty's entry into force.[45]

Despite a two-day negotiating meeting convened by Tolba immediately before the signing ceremony in March 1985, the polarized groups were unable to resolve their differences. On 22 March 1985, a framework agreement called the Vienna Convention for the Protection of the Ozone Layer was signed by twenty countries, but it lacked specific control measures. It merely called for research cooperation and the development of means for controlling activities that might modify the ozone layer.[46] Tolba recommended a cooling off period during which the scientific evidence could be reappraised. He also called for a number of workshops to precede a resumption of negotiations on a detailed protocol stipulating actual control measures, which he hoped could be adopted in April 1987.

Negotiations were galvanized by the unanticipated discovery that a dramatic thinning of the ozone layer over Antarctica occurred every autumn. In 1985, Joseph Farman and his colleagues reported that during the 1977–85 period, they had observed a 40 percent seasonal decrease in the Antarctic ozone layer and had concluded that "possible chemical causes must be considered."[47] Using ground-based instruments, they had first noticed the phenomenon in 1977 but had "hesitated" to report their finding because it had not been predicted by any computer models and had not been confirmed by satellite measurements. Farman's subsequent review of NASA satellite-generated data

44. See "Ozone Agreement Up in the Air," *New Scientist,* 7 February 1985, p. 8. I am grateful to Nigel Haigh for clarifying my understanding of this point.

45. The group was named after an informal negotiating meeting hosted by Canada. Regarding the group's proposal, see UNEP/WG 110/4, Annex IV, 1984.

46. Sand, "Protecting the Ozone Layer."

47. J. C. Farman, B. G. Gardiner, and J. D. Shanklin, "Large Losses of Total Ozone in Antarctica Reveal Seasonal ClO_x/NO_x Interaction," *Nature* 315 (May 1985), pp. 207–10.

revealed that a satellite had indeed been picking up the ozone depletions but that the data had been viewed as an "aberration" and discarded by a computer program.[48]

The Antarctic "hole" was an anomaly. Scientists were unable to explain it in light of their understanding of atmospheric dynamics. They could not identify its cause, nor did they understand the relationship between Antarctic ozone depletion and global ozone depletion. According to Richard Stolarski, the Antarctic phenomenon suggested that "the stratospheric layer of ozone surrounding the globe might be in greater jeopardy than atmospheric models had predicted."[49] Moreover, the steady increase in CFC production suggested that previous scenarios of relatively minor ozone depletion based on stable CFC usage in the early 1980s must be replaced by scenarios reflecting an annual usage increase of 2 to 5 percent by member countries of the Organization for Economic Cooperation and Development (OECD).

The discovery of the ozone hole, combined with the unexpected increases in CFC use, alarmed the public and added a sense of urgency to the international discussions.[50] Concern about ozone depletion became standard fare. Members of the U.S. Congress submitted draft legislation to curb CFC use; UNEP pressed for renewed negotiations following its 1986 data assessment to be completed by the Coordinating Committee on the Ozone Layer; and NASA began to reappraise the state of scientific knowledge about global and Antarctic ozone depletion.

Initial reports about the Antarctic hole were followed in July 1986 by the release of a three-volume report summarizing the state of knowledge about atmospheric ozone and based on a two-year study which was coordinated by NASA and which received financial support from the World Meteorological Organization, UNEP, the EC, the NOAA, the U.S. Federal Aviation Association, and the German Federal Ministry for Research and Technology.[51] With such high-powered institutional support, the report's conclusion that the threat to the ozone was serious and that CFCs were a possible culprit received widespread attention.

During 1986, the EPA convened two symposiums on risk assessment and health effects from ozone depletion, UNEP sponsored two workshops on economic issues related to CFC control, and the organizations jointly sponsored an international conference involving over three hundred participants and focusing on ozone depletion and climate change. The well-attended conference led to a four-volume report which concluded that accelerated rates

48. See Ellen Ruppell Schell, "Solo Flights into the Ozone Hole Reveal Its Causes," *Smithsonian* 18 (February 1988), pp. 142–55.

49. Stolarski, "The Antarctic Ozone Hole," p. 30.

50. See Sand, "Protecting the Ozone Layer," p. 20; and Mark Crawford, "United States Floats Proposal to Prevent Global Ozone Depletion," *Science* 234 (November 1986), p. 927.

51. NASA et al., *Atmospheric Ozone, 1985,* World Meteorological Organization Global Ozone Research and Monitoring Project Report, no. 16, 3 vols. (Geneva: World Meteorological Organization, 1986).

of CFC use posed real threats to the environment and public health. A sophisticated model indicated that a 3 percent annual growth of CFC emissions would lead to a 4 percent thinning of the ozone layer at 30 degrees north latitude, an 8 to 12 percent thinning at 60 degrees north latitude (with the most thinning occurring during the spring), and an average global thinning of 5 percent by the year 2030. EPA-sponsored computer modeling based on projected demand for CFCs estimated that a 5 to 11 percent annual growth of CFC emissions would yield 40 million cases of skin cancer (800,000 of them fatal) in the United States over the next 88 years, above the number that would occur if CFC emissions were held constant at 1986 levels. Models also projected that simply stabilizing the current CFC concentration in the stratosphere would require an immediate 85 percent cut in emissions, based on the atmospheric buildup and persistence of CFC emissions. A freeze in emissions at 1980 levels would still lead to a 2 percent ozone depletion by the year 2025.[52]

The EPA-UNEP atmospheric ozone study served as the scientific basis for the ensuing international negotiations because, as an EPA administrator pointed out, it "established a common understanding of the fundamental scientific issues among all participating nations."[53] However, its implications were immediately interpreted differently in different quarters. The risk-averse ecological epistemic community concluded that immediate cuts in CFC emissions were required. The industry group and the European governments believed that the findings merely counseled a possible freeze at current CFC levels and an increase in research efforts, since even a 2 percent reduction in global ozone would be indistinguishable from naturally occurring depletion and there were still no actual observations of ozone depletion outside Antarctica.[54] As the chairman of the industry group's Alliance for a Responsible CFC Policy stated, "We do not believe the scientific information demonstrates any actual risk from current CFC use or emissions."[55] The industry group also emphasized that if a freeze were to take place, it must be multilateral. Since the United States accounted for less than a third of the global use of CFCs, unilateral control efforts would have little total impact on the ozone layer but would make American companies producing and using CFCs less competitive in the international market.[56]

52. Daniel J. Dudek and Michael Oppenheimer, "The Implications of Health and Environmental Effects for Policy," in U.S. EPA and UNEP, *Effects of Changes in Stratospheric Ozone and Global Climate,* vol. 1 (Washington, D.C.: EPA, August 1986), pp. 357–79.

53. Testimony of A. James Barnes, deputy administrator of the EPA, in U.S. Congress, House Committee on Science, Space, and Technology, *Review of the Results of the Antarctic Ozone Expedition: Hearings Before the Committee on Science, Space, and Technology,* 100th Congress, 1st sess., 1987, pp. 395–401.

54. Alliance for a Responsible CFC Policy, *The Montreal Protocol.*

55. Crawford, "United States Floats Proposal to Prevent Global Ozone Depletion," p. 928.

56. Testimony of Richard Barnett, in U.S. Congress, Senate Committee on the Environment and Public Works, *Ozone Depletion, the Greenhouse Effect, and Climate Change: Joint Hearings Before the Subcommittees on Environmental Protection and Hazardous Wastes and Toxic Substances,* 100th Congress, 1st sess., 1987.

This controversy was abruptly truncated in September 1986, when DuPont issued a statement that undercut much of the industry position. In light of recent findings, DuPont administrators now favored a protocol to "limit" CFC emissions:

> All the models now predict that high sustained CFC growth rates [rates leading to emissions from 3 to 5 times the current levels] would result in significant ozone depletion. . . . The wisdom of permitting continued growth must be weighed against the existing ability of science to specify a safe long-term growth rate. Resolution of this and other key scientific uncertainties about the ozone issue and greenhouse effects could take decades; therefore, we conclude that it now would be prudent to limit worldwide emissions of CFCs while science continues to provide better guidance to policymakers.[57]

DuPont also urged government provision of incentives to develop alternatives to CFCs in order to speed their economic replacement. By announcing acceptance of the need for at least a freeze, DuPont undermined the other companies' argument that the scientific evidence did not justify any action and at the same time bolstered the ecological epistemic community's claim that strong CFC control measures were necessary. The community's position thus gained support and eventually prevailed not because of any improved explanatory power but because the alternative position was undercut.

UNEP called for negotiations to be reconvened in December 1986. U.S. preparations for the new round of negotiations were dominated by members of the OES and the EPA office of international activities and, in particular, by EPA Administrator Lee Thomas. An interagency process had been pursued during the summer, but few other agencies had responded to the OES and EPA invitations for input, either because they did not think the issue was salient at the time or because the memos fell between the bureaucratic cracks. This neglect permitted OES and EPA representatives to write the U.S. position paper. Here, the epistemic community's influence was crucial. Thomas's acceptance of its understanding about the causal mechanisms was obvious in the November 1986 briefing paper presented to the government:

> Based on current scientific understanding, considerable risks may exist to human health and to the environment from continued or expanded global emissions of fully halogenated alkanes. Considerable evidence exists, both in theory and from models, linking these chemicals to depletion of ozone. However, remaining scientific uncertainties prevent a conclusive statement concerning the safe levels of emissions. As a result, we believe that these chemicals should be considered suspect.[58]

57. "DuPont Position Statement on the Chlorofluorocarbon-Ozone-Greenhouse Issues," *Environmental Conservation* 13 (Winter 1986), pp. 363–64.

58. Department of State, "Principles for an International Protocol on Stratospheric Ozone Protection," mimeograph, 3 November 1986, p. 1.

Thomas had been extensively briefed by two scientists who were members of the epistemic community. He was sympathetic to their environmental concerns and values and found their arguments for strong CFC controls compelling. Thomas's negotiating strategy was to call for a 95 percent cut within ten to fourteen years because this seemed like a sufficiently high percentage to warn manufacturers that they were expected to convert to alternatives as soon as possible. Realistically, he and other EPA members thought that at least a 50 percent cut was necessary to cause sufficient shortages, increase prices, and create a demand for substitutes. But given the European overcapacity, a higher percentage would be needed for an international treaty. Therefore, the 95 percent figure was selected as a baseline from which the United States could appear to make concessions and still wind up with its preferred outcome.

The EPA and OES called for an immediate consumption freeze at 1986 levels for a broad range of substances, including CFCs 11, 12, 113, and 114 as well as the chemically similar halons 1211 and 1301, followed by their full elimination in the future. The two agencies also designed a scheduled phaseout of emissions, which was subject to periodic modification as dictated by changes in scientific understanding.[59]

The U.S. delegation to the December 1986 negotiations in Geneva was led by Benedick of the OES, who was also sympathetic to the epistemic community's goals. During this and subsequent negotiations, the U.S. position was supported by UNEP, which wanted a 20 percent cutback every two years until CFCs were fully eliminated in the year 2000.[60] In addition, the U.S. position was supported by Canada, Denmark, Finland, the Netherlands, New Zealand, Norway, and Sweden.[61] However, the U.S. proposals encountered stiff resistance from others. The EC, led by Britain and France, still hoped for only a production cap, which would minimize the costs to European CFC producers.[62] Because the consumption freeze proposed by the United States would constrain European exports as well, the EC pushed for a treaty that would regulate production rather than consumption. The LDCs were slow to take a position, but they also resisted U.S. proposals. With little domestic production capacity, the LDCs did not want to retard their economic growth or face impeded access to air conditioning and refrigeration as they industrialized and their populations' demand grew. Argentina, Brazil, Egypt, Kenya, Mexico, and Venezuela became the major articulators of the LDC position. A treaty had to

59. See ibid.; and Department of State, "U.S. Position Paper, UNEP Ozone Layer Protocol Negotiations, Second Session: February 23–27, 1987, Vienna, Austria," mimeograph, 19 February 1987. Consumption was to be calculated according to the following formula: production − exports + imports − amounts destroyed.

60. See "Nations Move Closer to Global Consensus on Protection of Stratospheric Ozone Layer," *International Environment Reporter,* 13 May 1987, p. 195.

61. See John D. Negroponte, "Protecting the Ozone Layer," *Department of State Bulletin,* no. 2123, June 1987, p. 59.

62. Richard E. Benedick, "The Ozone Treaty: Acting Before the Disaster," *Washington Post,* 4 January 1988, p. A13.

be designed in a manner that would satisfy LDC demands for exemptions yet prevent the LDCs from undermining the treaty's effects by attracting CFC producers to their countries. South Korea and India did not attend the talks, and many observers are still concerned that they will encourage an influx of CFC manufacturers.[63]

Controlling CFCs proved extremely contentious. Although UNEP had convened another negotiating session in Vienna in February 1987 and had hoped to conclude negotiations in Geneva in April 1987, even more sessions were needed. The negotiators met again in Brussels in June 1987 and scheduled the Conference of Plenipotentiaries for September 1987. At the latter conference in Montreal, it was still not clear whether a treaty would be successfully concluded. While Benedick had headed the U.S. delegation at the previous talks, Thomas took the lead in the Montreal meeting. Ultimately, the differences among the contending groups were resolved through a combination of U.S. leverage and diplomatic compromise, supported by newly strengthened scientific consensus.

Some of the issues were not fully resolved until the last day of the Montreal meeting, when Thomas and the head of the EC delegation horse-traded through the early hours of the morning. However, even where American leadership or leverage led to international cooperation, as the conventional power-based explanations have it, the choice of form of cooperation was determined by the epistemic community, which first directed American leverage toward extremely strong CFC controls and then established the parameters within which the political negotiations occurred.

Initially, the industry group and the EC seemed to prefer no action to a global treaty, but they were afraid of any possible U.S. unilateral action that would limit access of products containing CFC to the U.S. market. Their preference ordering (no action > global treaty > unilateral action) contrasted sharply with that of the United States (global treaty > no action). By exercising political muscle at the meetings, the United States was able to ensure that a treaty would be negotiated. Its leverage was provided by two U.S. senators, John Chafee (a Republican from Rhode Island) and Max Baucus (a Democrat from Montana), who sponsored bills to freeze production of CFCs at current levels within one year, to eliminate 95 percent of the production of CFCs and the two ozone-depleting halons within six to eight years, and to bar the import of products made with or containing CFCs.[64] In the absence of real evidence that significant alternatives to CFCs were available in the short run and in light of the serious problems inherent in monitoring imports of products made with CFCs or containing only small amounts of them, the threat of such strong measures had its intended effect of fortifying the U.S. position. Dissatisfied with the meager movement at the December 1986 meeting, Chafee hoped to

63. Ibid.
64. U.S. Congress, Senate bills 570 and 571, 100th Congress, 1st sess., 1987.

accelerate the pace of international talks by alerting both U.S. and foreign CFC manufacturers of his commitment to pursue strong unilateral action if multilateral action was not forthcoming.[65] Subsequently, the Senate passed a resolution encouraging the U.S. delegation to stick to its position favoring an immediate freeze in production at 1986 levels and a "prompt automatic reduction of not less than 50 per centum in the production of such chemicals and, as set forth in the United States' original position, the virtual elimination of such chemicals."[66]

With this strong domestic support, Benedick was able to argue that if a stringent multilateral treaty was not concluded, the United States would push for more onerous controls domestically. At the February 1987 meeting, he artfully posed this ploy, indicating that it was no bluff and that his own position was being determined by forces beyond his control at home.[67] Since the Europeans and the industry group wanted to avoid U.S. unilateral action, they were forced to retreat to their second preference of a global treaty.

Between the December 1986 and the February 1987 sessions, the U.S. delegation had continued to promote its position worldwide through visits and discussions with foreign ministry, embassy, and trade officials and through scientific exchanges. A team from NASA, NOAA, and the EPA, consisting of scientists and diplomats who believed in the need for an immediate strong treaty, had traveled to Moscow. Benedick and a scientist from NASA had discussed the issue with experts, policymakers, and journalists in ten European capitals via a U.S. Information Agency "Worldnet" interactive satellite transmission in order "to amplify [their] persuasive voice."[68]

Following U.S. threats of unilateral action, serious discussions about the protocol's terms resumed. Negotiations focused on a number of differences involving scope (which substances should be covered); stringency, type, and timing of control mechanisms; form of controls (production or consumption); type of scientific review mechanism; treatment of LDCs; and prevention of free riding in the form of attracting CFC producers to nonsignatory countries. Subsequent scientific consensus about modeling reinforced the U.S. position on scope, stringency, timing, and LDC treatment. Conflicts over the form of controls, as well as some issues related to the treatment of LDCs, were resolved by political compromise, which led to awkward phrasing in the protocol.

On scope, the United States wanted to control the five CFCs and two halons that were thought to have the greatest ozone-depleting potential. The EC only wished to control CFC-11 and CFC-12, on which it had already set production

65. *Congressional Record,* Senate proceedings, 8 October 1986, p. S15679. At a congressional hearing in May 1987, Chafee asked Benedick if his bills helped in the negotiations for a strong treaty, and Benedick responded affirmatively.

66. U.S. Congress, Senate resolution 226, 100th Congress, 1st sess., 1987.

67. Richard E. Benedick, "International Efforts to Protect the Stratospheric Ozone Layer," *U.S. Department of State Current Policy,* no. 931, 1987.

68. See "The Environmental Agenda and Foreign Policy," *U.S. Department of State Current Policy,* no. 943, 1987; and Negroponte, "Protecting the Ozone Layer," p. 59.

capacity limits. Japan concurred with the EC, since controlling CFC-113 would impede Japanese production of computer chips. The Soviet Union also supported the EC view. Everyone agreed that it would be much easier to regulate the use of bulk chemicals rather than getting involved in the technicalities of dealing with products containing or made with CFCs.

The United States and the EC disagreed about the form of controls. The former still hoped for consumption controls, while the latter advocated production controls. The United States wanted deep cuts, while the EC thought only in terms of a production capacity freeze and the Soviet Union and Japan opposed any cuts. Moreover, the United States wanted a freeze within one year, a 20 percent cut two years later, and another 30 percent cut after six to eight years.[69] U.S. negotiators thought that this schedule would give producers sufficient time to develop substitutes, although European producers argued disingenuously that they lagged ten to fifteen years behind U.S. companies in research on substitutes.[70] With an interest only in a freeze, the EC preferred a three-year wait for the freeze to come into force, with no subsequent cuts.[71]

The United States and the EC disagreed about the role for science in the institutional structure that they were designing. Both approved holding regular meetings of scientists every four years to assess evidence and propose any new controls deemed necessary, but they disagreed on a related issue of mandating cuts. The United States thought that the cuts should be automatic unless subsequent scientific evidence demonstrated that they were unnecessary (a "negative trigger"). In contrast, the EC thought that subsequent reductions should occur only when justified by scientific evidence at the time (a "positive trigger"), which would require voting anew on any scheduled future cuts. A slightly modified "negative trigger" approach allowing cuts to be overruled by countries responsible for two-thirds of world CFC consumption prevailed during the negotiations, although scientific research subsequently reinforced the call for more stringent action.[72]

Ensuring compliance was a particularly thorny subject, since the LDCs demanded exemptions from all controls so that they could satisfy their economies' growing demands. A concurrent working group of trade specialists fashioned a "carrot and stick" approach to discourage the LDCs from building their own CFC production plants.[73] LDCs abiding by the treaty would be offered a grace period of exclusion from consumption controls, would receive information and advice on the best technologies for recycling and conserving CFCs, would be given some technical assistance on developing substitutes for

69. Sand, "Protecting the Ozone Layer," p. 41.
70. Paul Lewis, "Borderline Protection," *The New York Times,* 12 April 1987, p. E26.
71. See UNEP/WG 167/2, 1987.
72. See UNEP/WG 172/2, 1987.
73. Mark Crawford, "Landmark Ozone Treaty Negotiated," *Science* 237 (September 1987), p. 1557.

CFCs, and would be expected to limit CFC use to a specified amount following the grace period. Those not abiding by the treaty would face an embargo on all CFCs. Imports of CFCs from nonsignatory states would be banned one year after the treaty entered into force, and exports of controlled CFCs to nonsignatory states would be banned after 1993.

On the one hand, LDCs with virtually no domestic production capacity—such as Algeria, Argentina, Brazil, China, India, Mexico, South Korea, Taiwan, and Venezuela—stood to benefit from the treaty's exclusionary provisions.[74] But on the other hand, the treatment of LDCs still left a large loophole for those capable of manufacturing and exporting products containing CFCs, such as air conditioners and refrigerators, since embargoes would only apply to the chemicals themselves.

As negotiations proceeded, the stringency and form of controls remained a focus of U.S. concern. Eventually, however, the obdurate EC opposition to U.S. proposals showed signs of weakening, partly as the result of changes in the chairmanship of the EC Council of Ministers and in the attitude of the West German government. Britain, which was hostile to CFC controls, chaired the council until January 1987. Belgium, which had long been more sympathetic to strong CFC controls, subsequently assumed the chairmanship. In March 1987, the EC Council of Ministers approved a modified position that called for freezing production of CFC-11 and CFC-12 at the 1986 levels and for phasing down production by 20 percent within five to seven years, subject to scientific verification that this was necessary.[75] In West Germany, the Greens had made a strong showing in the early 1987 federal elections and were successful in pressuring the government to endorse a ban on aerosols and the eventual elimination of CFCs.[76] The section head of the Federal Ministry of the Environment in West Germany now took the position that "the EC position [was] too low" and called for a 40 to 50 percent reduction, which was closer to the U.S. position.[77] France and Britain nevertheless continued to oppose compromises. In March 1987, France's environmental minister denied any definitive link between CFCs and ozone depletion.[78] Similarly, Britain stuck to its earlier view that ozone depletion was very slight, a view based on a controversial scientific study using pre-1985 data.

When negotiations resumed in April 1987 in Geneva, the EC delegation indicated its willingness to adopt a freeze and move toward 20 percent cuts in

74. U.S. Office of Technology Assessment, "An Analysis of the Montreal Protocol on Substances That Deplete the Ozone Layer," 1 February 1988, p. 36.

75. Kathy Johnston, "Europe Agrees to Act for Protection of the Ozone Layer," *Nature* 326 (March 1987), p. 321.

76. See David Doniger, "Politics of the Ozone Layer," *Issues in Science and Technology* 4 (Spring 1988), p. 90; and Steven Dickman, "West Germany Strives Toward CFC Elimination by 2000," *Nature* 327 (May 1987), p. 93.

77. Paula M. Block, "UN Focuses on Ozone Levels," *Chemical Week,* 13 May 1987, p. 8.

78. See "Nations Move Closer to Global Consensus on Protection of Stratospheric Ozone Layer," p. 198.

production of CFC-11 and CFC-12 by 1993 or 1994, although it remained unwilling to extend coverage beyond these two chemicals.[79] In May, after the environmental ministry of West Germany argued that the April negotiating session did not go far enough toward eliminating emissions and production of CFCs, the EC once again reconsidered its stand.[80] In July, the EC environmental ministers finally supported a second 30 percent cut during their meeting. By this time, Britain had rotated out of the committee of delegates coordinating the EC ozone position.[81] Formulated by delegates from Belgium, Denmark, and West Germany, the EC position was now sufficiently close to the U.S. position to enable a compromise that was acceptable to American and European delegates.

The biggest push toward compromise came from the epistemic community. In an effort to reduce scientific disagreements, Tolba, on his own authority, organized a multinational meeting of atmospheric scientists to compare their models and assessments of ozone depletion. The meeting, which included members of the epistemic community, was convened in April 1987 in Würzburg, West Germany. By agreeing on common scenarios—the effects of no change, an immediate freeze, and a midpoint of 50 percent cuts—the atmospheric modelers bounded the range of policies to be considered at subsequent government negotiations. They compared their assumptions and standardized model runs and concluded that a 50 percent reduction in CFC emissions would still lead to a 5 to 20 percent depletion of ozone.[82] They also concluded that CFCs 11, 12, and 113 and halons 1211 and 1301 significantly contributed to ozone depletion.[83] Moreover, they approved a standard set of values for determining the "ozone-depleting potential" of compounds that contain chloride. On the basis of this standard, scientists unambiguously concluded that seven substances—CFCs 11, 12, 113, 114, and 115 and halons 1211 and 1301—should be covered in the protocol. Methyl chloroform and carbon tetrachloride were found to have less ozone-depleting potential and were therefore omitted from immediate plans for coverage.

Tolba promptly transmitted this information to the political negotiators. Since "consensus among the scientific community has been confirmed by the major ozone modelers," he argued, "it was . . . no longer possible to oppose action to regulate CFC releases on the grounds of scientific dissent."[84] The

79. Ibid, pp. 195–96.

80. See "Council Discusses Global Efforts to Protect the Stratospheric Ozone Layer," *International Environment Reporter,* 10 June 1987, p. 276.

81. See Benedick, *Ozone Diplomacy,* p. 36. EC positions were initially formulated in a committee composed of the past, present, and future chairs of the EC Committee of Environmental Ministers, all of whom serve six-month terms. With Britain's absence, this committee could support more stringent controls; however, Britain could still block votes in the full committee, which operated by consensus.

82. UNEP, "Ad Hoc Scientific Meeting to Compare Model-Generated Assessments of Ozone Layer Change for Various Strategies for CFC Control," UNEP/WG 167/INF 1, 1987.

83. Ibid.

84. Tolba, cited in UNEP/WG 172/2, 1987, p. 2.

effect of the consensus was that a number of the arguments made by the EC and Japan on the basis of objections to the accuracy of the models were now logically impossible to sustain. The U.S. delegation and UNEP promptly applied this fresh ammunition to support their arguments for broader scope, deeper cuts, and more rapid entry of the protocol into force.

The Würzburg scientific consensus also justified taking a concessionary approach to the LDCs. Earlier, Norway and the United States had considered offering the LDCs a five-year grace period of exemption from controls, after which time they would be expected to limit CFC consumption to 0.2 kilograms per capita. However, the Würzburg findings indicated that a ten-year grace period for small-scale CFC consumers would make little difference in long-term ozone depletion and that the subsequent cap for them could be raised to 0.3 kilograms per capita with little harm to the environment.[85] This plan would mollify outspoken countries such as Venezuela and Yugoslavia, which would benefit from the expanded cap.

In September 1987, the Montreal Protocol on Substances That Deplete the Ozone Layer was finally adopted and bore the epistemic community's imprint. The protocol covered the five CFCs and two halons identified at Würzburg and called for two staggered cuts in consumption that would lead to a 50 percent total reduction from 1986 levels. The first cut of 20 percent was to take effect in 1993, while the second cut of 30 percent would follow in 1998. The protocol also reflected a number of compromises, many of which were worded awkwardly during the negotiations and were not submitted to the UNEP legal office for editing lest the subtle compromises be upset before the protocol could be signed.

Included in the protocol were side-payments to encourage compliance from various parties. To ensure future supplies of the chemicals for LDCs, production was reduced by only 40 percent. Rather than dictating that production and consumption of each of the chemicals be reduced by specific amounts, the protocol merely specified the total percentage of cuts, thereby allowing Japan to concentrate on using CFC-113 for computer chip manufacture while reducing the use of the other chemicals. The Soviet Union was granted permission to include in its 1986 baseline the capacity of two plants that were currently under construction. The EC "rationalization" plans were accommodated by a special provision indicating that once all twelve EC states ratified the treaty, the EC would be treated as a single entity. This would allow companies to redistribute production among plants in different countries to achieve the most efficient production.

In the media coverage of the agreement, one reporter noted that "the actual numbers included in the protocol specifying percentages are recognized as politically rather than scientifically based."[86] While it is true that the actual

85. Interview with an official at the U.S. Department of State, Washington, D.C., 23 March 1988.
86. Kathy Johnston, "First Steps in Ozone Protection Agreed," *Nature* 329 (September 1987), p. 189.

controls, which still allow for a 2 percent long-term depletion in ozone, were reached by political compromise and U.S. leverage, it is important to emphasize that the ecological epistemic community was responsible for determining the range of chemicals that were covered, the stringency of controls, and the time frame for implementing reductions. In essence, the epistemic community was in the position of satisfying competing claims to the pie by saying "I cut; you choose." By specifying the parameters of choice and using the Würzburg consensus to bolster their efforts, members of this community were able to move negotiations in the direction of strong international CFC controls.

Environmental bandwagoning

The terms of the Montreal protocol were accepted in September 1987, and the protocol was subsequently ratified by thirty-one countries, including the United States, the members of the EC, the Soviet Union, Japan, Egypt, and Nigeria. By the time the protocol went into force, on 1 January 1989, many of the participating governments had decided that it did not go far enough and were calling for accelerated implementation and an expansion of the list of substances covered.

In 1987, ozone depletion reached an historic high. In March 1988, a report by a multinational group called the Ozone Trends Panel was released by NASA and presented irrefutable evidence that chlorine gas in the stratosphere was present during periods of high ozone depletion over Antarctica and that CFC emissions were related to Antarctic and global ozone depletion.[87] Within a week of the news, DuPont responded that it would discontinue CFC production by the end of the century. In September 1988, EPA Administrator Lee Thomas called for a freeze on the use of methyl chloroform, a substance that was not regulated under the current protocol, and for a time table to eliminate all CFC production.[88] And two months later, Britain began to call for 85 percent cuts in CFCs. By the time the protocol entered into force, more and more countries had become alarmed about the environmental threat of CFCs.

In early 1989, evidence from the most recent Antarctic expedition demonstrated that the ozone layer was being depleted more rapidly than originally predicted.[89] The EC states and 123 other countries were now advocating full elimination of CFCs by the end of the century.[90] In May 1989, during the first government review meeting of the Montreal protocol, 81 countries adopted a

87. R. T. Watson, M. J. Prather, and M. J. Kurylo, *Present State of Knowledge of the Upper Atmosphere, 1988: An Assessment Report* (Washington, D.C.: NASA, 1988).

88. See "EPA Chief Asks for a Total Ban on Ozone-Harming Chemicals," *The New York Times,* 27 September 1988, p. A20; and Pamela Zurer, "EPA Calls for a Total Ban on Chlorofluorocarbons," *Chemical and Engineering News,* 3 October 1988, p. 8.

89. Richard A. Kerr, "Arctic Ozone Is Poised for a Fall," *Science* 243 (February 1989), p. 1007.

90. David Dickson and Elliot Marshall, "Europe Recognizes the Ozone Threat," *Science* 243 (March 1989), p. 1279.

resolution to phase out all production and consumption of CFCs by the year 2000. They also agreed to establish a fund of unspecified size to ameliorate the costs of adjustments for LDCs, which complained that they were being asked to give up CFCs without being ensured of access to suitable substitutes. In the following month, 93 countries approved several modifications to the protocol: an expansion of controls to include products made with CFCs; a phaseout of production and consumption of the two halons already on the list of substances covered; and the addition of two substances, carbon tetrachloride and methyl chloroform, to the list, with the production of the first one to be reduced 85 percent by the year 1995 and eliminated by the end of the century and with the production of the second one to be reduced 70 percent by the end of the century and eliminated by the year 2005. In addition, funding to facilitate the transfer of CFC substitutes to the LDCs was set at $160 million, with the agreement to expand funding to $240 million following ratification of the modified protocol by India and China. The United States agreed to contribute $40 million to $60 million to the fund, thereby reversing its original opposition to creating new multilateral financial institutions.[91]

National policies and practices also rapidly changed as a result of the international furor. Many countries, including such initially apathetic ones as Brazil, adopted domestic measures that were even more stringent than those in the Montreal protocol.[92] In Western Europe and the United States, a number of industry groups announced their intention to stop using materials containing CFCs. Manufacturers of CFCs actively began searching for alternatives and embarked on joint programs to test the toxicity of the possible alternatives.[93] In 1988 alone, DuPont spent more than $30 million for process development, market research, applications testing, and small-lot production of CFC substitutes.[94]

Factors influencing responses to the environmental threat

While the overall speed with which CFCs were regulated internationally was quite dramatic, individual countries responded to the ozone threat at different

91. See "Ninety-Three Countries Agree to Ban Chemicals That Harm Ozone," *The New York Times,* 30 June 1990, p. 1.

92. See "London Conference on the Ozone Layer," *Financial Times,* 7 March 1989, p. 14. The Federation of European Aerosol Manufacturers concluded a voluntary agreement for a 90 percent reduction in the use of CFCs in aerosols used in 1990. See "April in the EEC," *Economist,* 29 April 1989, p. 148; "More Companies to Phase Out Peril to Ozone," *The New York Times,* 11 October 1989, p. A27; and Roan, *Ozone Crisis,* pp. 242–43. Various U.S. municipalities banned the use of foam plastic food containers made with CFCs. See "EPA Plan May Allow Delays in Clean Air Rule," *The New York Times,* 24 September 1987, p. 14.

93. L. E. Manzer, "The CFC-Ozone Issue: Progress on the Development of Alternatives to CFCs," *Science* 249 (July 1990), pp. 31–35.

94. See Joseph P. Glas, "Protecting the Ozone Layer: A Perspective from Industry," in Jesse H. Ausubel and Hedy E. Sladovich, eds., *Technology and Environment* (Washington, D.C.: National Academy Press, 1989), p. 150; Roan, *Ozone Crisis,* pp. 242–43; Jacques Theys, Sylvie Faucheux, and Jean-Francois Noel, "La guerre de l'ozone" (The ozone war), *Futuribles,* October 1988, pp. 67–73; and U.S. EPA Office of Air and Radiation and Office of Program Development, "How Industry Is Reducing Dependence on Ozone-Depleting Chemicals," June 1988.

rates. The pacing of national responses can be explained largely in terms of the extent of the epistemic community's influence on various governments and its ability to help them interpret the emerging scientific consensus and articulate appropriate policies.

The first countries to actively encourage global controls were those in which the epistemic community and the tradition of proenvironmental sentiment were the strongest: the United States, Canada, Finland, Norway, and Sweden. In general, the EC and other countries followed suit once channels had been established between individual epistemic community members and their own national administrations. One exception was West Germany, where the 1985 Rhine chemical spill precipitated the creation of a new environmental ministry. While other European countries were still reluctant to control CFCs, West Germany became an outspoken supporter of CFC controls in 1985 and introduced strong domestic measures soon after.

The time lag between European and American responses may also be attributable to differences in political, cultural, and social relations between the scientific community and the governments on the two continents. In the United States, the highly fragmented nature of government and society and the more confrontational atmosphere facilitate the entry of strongly motivated technical experts into the decision-making process. Groups of specialists tend to be large, and given the prestige and demand for scientists in both private and state-supported institutions, their mobility is not restricted. In Europe, with less acrimonious relations between scientists and government officials, a less autonomous role for "public science," a lower status accorded to scientists working in private institutions, and more bureaucratically secure policymakers, it takes much longer for nongovernmental actors to gain access to the decision-making process.[95]

While the differences in domestic structure meant that epistemic community members were forced to operate through different loci of decision making in the various countries, cultural factors as well as the level of training of individuals whom they attempted to influence also dictated that they pursue different styles in the conduct of their dialogue. For example, as Sheila Jasanoff pointed out in her analysis of political culture and risk management, regulators in the United States have tended to show "a preference for rigorous quantitative analysis" and to respond to the stringent methodological approach

95. For comparative studies of science policy and for discussions of patterns of technical advice to policymakers, see Ronald Brickman, Sheila Jasanoff, and Thomas Ilgen, *Controlling Chemicals* (Ithaca, N.Y.: Cornell University Press, 1985); David Vogel, *National Styles of Regulation* (Ithaca, N.Y.: Cornell University Press, 1986), p. 181; Sheila Jasanoff, *Risk Management and Political Culture* (New York: Russell Sage Foundation, 1986); and George Hoberg, Jr., "Risk, Science and Politics: Alachlor Regulation in Canada and the United States," *Canadian Journal of Political Science* 23 (June 1990), pp. 257–77. For studies of the United States, see Thomas M. Dietz and Robert Rycroft, *The Risk Professionals* (New York: Russell Sage Foundation, 1987); and Samuel P. Hays, *Beauty, Health, and Permanence: Environmental Politics in the United States, 1955–1985* (Cambridge: Cambridge University Press, 1987).

with which many scientists are comfortable.[96] In the case of ozone depletion, professionals with technical training who were familiar with politically tinged and technical policy dialogue (such as administrators trained at the Kennedy School) tended to respond readily to this approach, while political appointees and lawyers were influenced by other methods. In countries in which a more moderate mode of negotiated solutions is generally followed and the language of the epistemic community was less compatible with existing norms, community members operated much more frequently and effectively by usurping or monopolizing channels of advice.

The delay in accepting the international scientific consensus on the ozone issue was most observable in Britain, one of the last countries to support the Montreal protocol. Prime Minister Margaret Thatcher, choosing to rely on the opinions of British scientists whom she respected, appointed her own commission, the Stratospheric Ozone Review Group (SORG), to investigate the role of CFCs in ozone depletion. In its first report in August 1987, SORG downplayed both the extent of the ozone threat and the role of CFCs.[97] When the Ozone Trends Panel report was released in March 1988 and contradicted the SORG findings, Thatcher suspected that it was biased toward U.S. interests because of NASA's strong role in its formulation, and she therefore turned again to SORG for advice. By and large the SORG membership was independent of U.S. links, although it included Joseph Farman, a member of the ecological epistemic community who had "discovered" the Antarctic ozone hole in 1985 and had publicly dismissed the earlier SORG findings, arguing that they were based on out-of-date scientific evidence.[98]

In June 1988, SORG published its executive summary, which supported the findings of the Ozone Trends Panel.[99] One month later, the House of Lords Select Committee on the European Communities announced its acceptance of the view that CFCs were responsible for ozone depletion and recommended an extension of the Montreal protocol to cut CFC use by 85 percent.[100] But the real turnaround came at the end of September 1988, when Thatcher indicated in a speech to the Royal Society that "protecting the balance of nature [was] one of the great challenges of the late twentieth century" and called for immediate action to safeguard the ozone layer, fight acid rain, and delay global warming.[101] Shortly thereafter, she invited countries to attend an ozone conference to be held in London. During the March 1989 conference, she not only called for an

96. Jasanoff, *Risk Management and Political Culture,* p. 30.

97. SORG, *Stratospheric Ozone: First Report* (London: Her Majesty's Stationery Office, 1987).

98. See Geoffrey Lean, "Cancer-Causing Hole in the Sky Is Man-Made," *The Observer,* 6 September 1987, p. 3.

99. SORG, *Stratospheric Ozone, 1988* (London: Her Majesty's Stationery Office, 1988).

100. House of Lords Select Committee on the European Communities, *The Ozone Layer: Implementing the Montreal Protocol,* H.L. Paper 94, 17th Report, 1987–88 session (London: Her Majesty's Stationery Office, 1988).

101. Margaret Thatcher, cited by Geoffrey Lean in "Tories Plan 'Green Bill,' " *The Observer,* 2 October 1988, p. 1.

85 percent cut in CFC use but also announced several changes in British funding policies. In addition to doubling its annual UNEP commitment to £3 million, Britain would restore and slightly increase its funding to the British Antarctic Survey.[102]

The sudden British shift in attitude toward CFC controls was the result of multiple convergent factors. Domestic advice to Thatcher from British scientists whom she trusted was important. The timing was also certainly suggestive. Before the new SORG findings were released, the British position had been essentially driven by the Department of Trade and Industry, which was oriented toward protecting Britain's sole CFC producer, Imperial Chemical Industries. Yet additional political factors obtained. Environmental issues had become an important focus of domestic concerns in the summer of 1988, with the unexplained but widely publicized death of North Sea seals and with the refusal of British authorities to allow the cargo ship *Karin B* to enter Britain with its load of toxic waste. The summer of 1988 had also been unusually hot, and since CFCs contributed to the global warming effect, the control of ozone-depleting substances was increasingly viewed as a politically popular and relatively inexpensive action. Just before Thatcher delivered her speech to the Royal Society in September 1988, she had received papers warning of global warming from Crispin Tickell, the British ambassador to the United Nations who was a long-standing confidant of Thatcher and was interested in issues concerning the climate.[103] And the speech had come only a week before the Labor party congress. At the time, public opinion polls revealed mounting proenvironmental sentiments and support of the Green party. In fact, the Green party subsequently received 15 percent of Britain's votes in the 1989 elections for the European Parliament.[104]

Countries in which the ecological epistemic community did not consolidate its influence have tended to be less directly supportive of CFC controls other than those which were in effect determined by altered market conditions. France, for example, has remained fairly inactive in the ozone sphere. Domestic scientists conducted little ozone research,[105] and French officials of the Environment Ministry and Industry Ministry paid little attention to domestic findings in any case. The Industry Ministry, which had an innate bias toward the interests of the French CFC producer, ATOCHEM, successfully dominated the policymaking process. The Soviet Union has not only refused to pursue any CFC reductions beyond the Montreal protocol but has remained one of the few countries to continue to deny the sufficiency of scientific

102. John Hunt, "Conference Urges Faster Action on CFCs," *Financial Times,* 8 March 1989.

103. See "The Greening of Margaret Thatcher," *Economist,* 11 March 1989, pp. 55–56; and Geoffrey Lean, "Ozone: UN Acts to Tighten Controls," *The Observer,* 5 March 1989, p. 2.

104. See Tom Burke, "The Year of the Greens," *Environment* 31 (November 1989), p. 20; and "The Greening of British Politics," *Economist,* 3 March 1990, p. 49.

105. For a list of French research, see Secretariat d'Etat a l'Environnement, "La protection de la couche d'ozone" (The protection of the ozone layer), Paris, 1989.

consensus.[106] Japan, without much epistemic community influence in policymaking, was only finally swayed to support the ozone protocol by permission to continue using certain CFC compounds while reducing the use of others.

In general, public sentiment and the activities of nongovernmental organizations such as Friends of the Earth had little direct impact on the adoption of CFC controls. Instead, they tended to merely reinforce government regulations that had already been introduced. For example, in the two countries with the most active and developed consumer movements, the United States and Britain, public movements for CFC regulation did not really get going until after the Montreal protocol was signed.[107]

Decision making within the United States

The goal of strong CFC controls encountered significant challenges within the Reagan administration. Yet the epistemic community based in the EPA and OES prevailed over other groups seeking to articulate the U.S. position and thus managed to keep the United States committed to a highly restrictionist policy. Ironically, EPA and OES officials were in effect implementing U.S. policy at the 1987 international meetings while it was still being reviewed at home.

In February 1987, the Alliance for a Responsible CFC Policy became alarmed about the American bargaining position at the international negotiations and voiced its concern to the secretaries of a number of U.S. departments. The alliance found a sympathetic ear in several departments whose own missions would be influenced by the ozone protocol. Although these departments had been approached by the EPA and OES during the earlier process of preparing the U.S. position, higher-level officials contended that they had not been fully apprised of the planning sessions and were not aware of what had been decided. Shocked by the strong measures advocated by the American delegation, they demanded a review of the U.S. policy.

Particularly sharp opposition came from the Departments of the Interior, Energy, and Commerce. The first of these departments was heavily influenced by President Reagan's minimalist regulation policy and opposed any type of government CFC control. In May 1987, the secretary of the Department of the Interior, Donald Hodel, reportedly suggested instead a "personal protection campaign" encouraging Americans to wear sunglasses, long-sleeved shirts, and sunscreen.[108] This proposal was met with immediate ridicule, indicating the

106. See "London Conference on the Ozone Layer," p. 14.

107. James Ehrlichman, "Stores Drop Ozone Carriers," *Guardian,* 28 July 1988, p. 3.

108. See Cass Peterson, "Administration Ozone Policy May Favor Sunglasses, Hats," *Washington Post,* 29 May 1977, pp. 1 and 26; and Mark Crawford, "Ozone Plan: Tough Bargaining Ahead," *Science* 237 (September 1987), p. 1099. I have, however, been assured that the statement about personal protection was incorrectly attributed to Hodel and was actually made by someone from another department at an Office of Management and Budget briefing.

extent to which the epistemic community's assessment of the seriousness of the ozone threat had been accepted in most quarters. The Department of Energy opposed government regulation on the grounds that alternatives to CFCs were less energy-efficient and would thus interfere with energy conservation goals. And the Department of Commerce was worried that regulation would affect the international competitiveness of American CFC manufacturers.

Other departments voiced concern as well. The Department of Defense indicated that it could accept a freeze but was afraid that a cut in halon use would impede its own use of halons in fire-fighting procedures. The President's science adviser, William Graham, also argued that the available scientific data did not yet justify the strong actions supported by the EPA and OES. He and the heads of dissatisfied departments thus instigated a policy review.

The Office of Management and Budget (OMB), under the auspices of the Domestic Policy Council, convened a series of technical briefings from February through May 1987, concurrent with the international negotiations. Most of the scientific summaries were presented by epistemic community members who had briefed Thomas, the EPA administrator, a year earlier. The OMB economists were swayed by the cost-benefit analysis presented by the President's Council of Economic Advisers (CEA), an analysis that was based on conservative economic estimates of human health effects from ozone depletion, was drawn from the EPA's extensive 1986 risk assessment study, and concluded that stringent regulations to prevent depletion of the ozone layer would be highly cost-effective.[109] In preparing their analysis, the CEA members had included none of the ethical and ecological considerations that had encouraged the epistemic community to support stringent controls. Nevertheless, their findings based on economic considerations supported the community's position. In any case, the CEA members had been impressed and persuaded by the thoroughness of the epidemiological presentations during the policy review, and their reputation for economic professionalism helped overcome the Reagan administration's aversion to regulation.

The OMB drafted an options paper for the Domestic Policy Council's consideration. The paper offered a list of possible positions that could be pursued by the United States and in essence represented the same array of policy formulations being negotiated internationally. Ultimately, the decision on the U.S. position was made by Reagan. After a meeting of the Domestic Policy Council in June 1987, he supported the same EPA and OES proposals that had been initially influenced by the epistemic community: 50 percent cuts over eight years, with negative triggers for all the CFCs and halons in bulk form. Although strong CFC controls had won the backing of the President, they were not yet a fait accompli. At the international level, Benedick and Thomas still had to convince the EC members to abandon their recommendation for smaller cuts. And at the domestic level, the task of writing CFC regulations was

109. See Benedick, *Ozone Diplomacy,* p. 22.

assumed by mid-level EPA officials who were members of the epistemic community.

Decision making within the CFC industry

The ecological epistemic community played a switchboard role, communicating with policymakers and CFC manufacturers alike, accelerating their endorsement of the ozone research findings, and encouraging corporate decision makers to hasten their search for new products that would enable the Montreal protocol cuts to be achieved. Among CFC manufacturers, DuPont assumed the leadership role, both in its 1986 acceptance of the need for CFC controls and in its 1988 announcement of its intention to phase out the production of CFCs.

While each of DuPont's key decisions was made by higher-level executives for diverse corporate reasons, the epistemic community was responsible for rapidly introducing new policy ideas to the company through the research wing of the Freon products division. The senior scientist, the principal ozone policy analyst, and the head of this division were all chemists whose evaluations of CFCs were continually modified in keeping with advances in the scientific understanding of the role of chlorine in the atmosphere. In light of NASA's 1985 ozone report and in follow up to the 1986 UNEP and EPA workshops, the corporate scientists began to reevaluate the potential problems associated with CFC emissions, making use of an in-house state-of-the-art atmospheric computer model that DuPont had developed in 1979. In September 1986, when they reported to the DuPont executives that the level of stratospheric chlorine would rise with increased CFC use, the executives concluded that this problem could be averted by instituting a freeze on CFC production.[110] At the time, the DuPont executives did not support cutbacks in production.

Shortly after the Ozone Trends Panel report was released in March 1988, however, DuPont announced that the company would completely phase out the production of CFCs and would assist its customers in converting to chemical substitutes. The timing of this decision was striking. Only two weeks before the panel report had been made public, the chairman of DuPont's board had written to three senators, indicating that because the threat to the atmosphere remained unproven, DuPont was not willing to reduce CFC production.[111] Although DuPont's scientific coordinator had been a participant in the Ozone Trends Panel, he had been sworn to secrecy about his work and had not discussed it with his company before the panel report was released.[112] After the DuPont executives received and read the executive summary of the panel report and were briefed by their scientific coordinator, they became

110. Interviews with DuPont executives, Wilmington, Del., 21 July 1988.

111. William Glaberson, "Science at Center Stage in DuPont Ozone Shift," *The New York Times,* 26 March 1988, pp. 41 and 43.

112. Ibid.

convinced by the scientific evidence that CFC emissions were linked with global and Antarctic ozone depletion.

The decision to eliminate CFC production by the end of the century entailed real costs and losses in opportunity for DuPont. It essentially meant that DuPont would be able to enjoy only three years' worth of windfall profits from selling CFCs made scarce by the Montreal protocol, whereas its competitors would continue to reap profits by selling CFCs to old and new customers.

While DuPont's affinity with the epistemic community increased its propensity for acquiring scientifically qualified input, its decision to act on this input was also a consequence of its experience and position. DuPont was one of the first companies in the United States to organize its divisions with science in mind, to rely on innovation and the development of new products, and to foster a corporate culture in which technically trained people could rise to high positions and participate in the corporate decision-making process.[113] While DuPont already enjoyed a good relationship with environmental groups, its decision in 1988 represented an easy way to maintain its reputation and further differentiate itself from other chemical producers. Moreover, as the dominant company in the CFC market, with CFC sales in 1987 totaling $600 million and representing about 2 percent of the company's revenues,[114] DuPont could afford to take a longer-term view than its competitors, who tended to focus their concern on maximizing short-term profits. As it turned out, however, DuPont's decision to phase out CFCs and develop substitutes changed the market conditions and forced other CFC manufacturers to follow suit.

Conclusions and alternative explanations

Suspecting a possible link between CFC emissions and the depletion of the stratospheric ozone layer, the ecological epistemic community played a primary role in gathering information, forming a consensus regarding the available scientific evidence, disseminating information to government and corporate decision makers, and helping them formulate policies regarding CFC consumption and production. Community members were effective in persuading the two major actors of the need for strong CFC controls: the United States, which was the largest CFC-producing and CFC-consuming nation, and DuPont, which was the world leader in CFC production. The United States in turn compelled other nations to accept its view, while DuPont's eventual decision to phase out

113. See David A. Hounsell and John Kenly Smith, Jr., *Science and Corporate Strategy: DuPont R&D, 1902–1980* (New York: Cambridge University Press, 1988); and Alfred D. Chandler, Jr., *Strategy and Structure: Chapters in the History of the American Industrial Enterprise* (Cambridge, Mass.: MIT Press, 1962).

114. See Cynthia Pollock Shea, "Why DuPont Gave Up $600 Million," *The New York Times,* 10 April 1988, section 3, p. 2. CFCs may actually have accounted for slightly more of DuPont's profits, since its CFC plants were well established and required little maintenance.

CFC production changed the international market and compelled its competitors to follow.

Without the epistemic community, international controls would have been weaker and taken much longer to adopt and implement, and domestic controls would have been more disparate. In this regard, we can consider two counterfactuals. In the absence of a group of professionals with the ability to interpret the technical and scientific evidence, there would have been little incentive for the United States or other countries to try to move beyond the weak 1985 Vienna convention. Without U.S. leadership, traditional interest-based negotiations among equals would have yielded at most an international protocol reflecting the lowest common denominator. By helping U.S. negotiators formulate their position and by framing the broader context in which international negotiations occurred, the epistemic community added focus to the negotiations and moved them in the direction of strong CFC controls. Similarly, in the absence of a transnationally active epistemic community, national policy choices would have been influenced almost entirely by domestic politics: countries without CFC producers or with highly influential environmental groups would have been more likely to enact strong domestic controls, while countries with large and influential CFC producers would have adopted weak controls. In the United States, for example, Hodel's 1987 skeptical comments about ozone protection might have received much more public credence if the epistemic community had not succeeded in convincing people that the environmental threat was serious and required stringent government regulation.

The epistemic community operated differently at various levels of international relations. With its grounding in international secretariats, it played a major role in agenda setting. By capturing DuPont, it set market signals for other firms. And by capturing the hegemon, it not only guided the tempo of international negotiations but also helped alter the circumstances to which smaller countries responded. While Britain, the LDCs, and other countries were politically suspicious of the arguments of foreign scientists, they eventually changed their policies following the introduction of local epistemic community members into their domestic administrations. In the case of the LDCs, side-payments were also instrumental in changing attitudes and behavior.

The epistemic community's influence was thus exercised in part through usurpation of decision-making channels and in part through persuasion. Scientists with training and experience in using computer models became much more supportive of a stronger treaty after the Würzburg meeting, where the range of uncertainties underlying the atmospheric models was discussed and the modelers' efforts to surmount them were described.[115] In the United States,

115. Interviews with officials at the OMB and the Department of the Interior, Washington, D.C., 23 March 1988.

technical arguments were accepted by officials more familiar with computer modeling. While others who were ideologically opposed to the idea of regulation dismissed all predictions based on models, arguing that such predictions were entirely dependent on the assumptions made by the modelers, they were eventually forced to acknowledge accumulating scientific evidence that ozone depletion was occurring in Antarctica and elsewhere and that speedy and stringent actions were required.

Dramatic reports of environmental crises such as the ozone hole had two effects on political leaders. The news of atmospheric degradation provoked political challenges from domestic environmental voters, leading government heads such as Thatcher and Reagan to search for new policies to appease the new demands. Coupled with this political effect was a functional effect: leaders were now truly responsible for environmental protection. The epistemic community was the only competent scientific group at hand which could interpret the uncertainty surrounding policymaking about ozone-depleting substances, and news of the environmental crises not only publicized the community's opinions but also reinforced the value of its policymaking input.

The fact that the epistemic community was able to gain and exercise influence at both the national and international levels explains the rapid adoption of convergent policies to control CFCs. While the United States exercised hegemonic leadership, a deductive, structural focus on the distribution of power alone does not provide an accurate specification of U.S. interests or resources in the case of ozone protection. "National interests" remained unclear and disputed throughout much of the negotiations. Any exercise of U.S. cultural hegemony over atmospheric research was offset by indigenous European capabilities. For countries without extensive indigenous scientific resources, fears of such cultural hegemony were dispelled by UNEP and Tolba's independent scientific assessments.

According to Benedick, the successful control of CFCs was a consequence of deft diplomacy responding to unfolding scientific understanding.[116] He argues that subject to the identification of interests revealed by successive scientific reports, diplomats were able to create subtle compromises that satisfied the interests of all the major parties. While his account is not fundamentally at odds with the epistemic community argument, it underplays the extent to which the epistemic community circumscribed the array of policies that diplomats considered.

While policy in Europe as well as in the United States was in part driven by electoral concerns and a substantial change in public environmental sentiment, domestic politics alone does not fully explain the similar form and timing of national CFC regulations. Many regulations were adopted in Europe before the emergence of widespread environmental concerns in the 1980s. In any case, the Greens and other environmental groups in Europe have tended to be

116. Benedick, *Ozone Diplomacy*.

poorly organized and ineffectual in their efforts to convert public consciousness into political change.[117] As argued above, if domestic politics were the only force at work, there would be wide variation in national policies, depending on the domestic weighting of political power.

Consensual knowledge alone does not tell the full story either. Broad scientific consensus regarding the issue of CFCs and ozone depletion emerged in March 1988 after the Ozone Trends Panel released its report. The Montreal protocol, however, had already been concluded in September 1987. In articulating the implications of the available scientific evidence, the epistemic community had acted during the negotiation period in a manner consistent with its own norms of validity, which would tolerate some degree of uncertainty. While consensus among the broader scientific community emerged only after the real decisions had been made, it did help speed the process of developing national CFC regulations.

In summary, members of the epistemic community contributed to the timing and stringency of CFC regulations through a combination of strategies ranging from the persuasion of individuals and groups to the capture of various decision-making channels. Most important, by capturing the United States and DuPont and by limiting the range of alternatives that decision makers considered, the epistemic community changed the external environment in which policies were made by other governments and firms.

117. See Michael Renner, "A Green Tide Sweeps Europe," *Worldwatch* 3 (January–February 1990), pp. 23–27; Sara Parkin, *Green Parties: An International Guide* (London: Heretic Books, 1989); and "The Greening of British Politics," pp. 49–50.