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企业管理与自然环境

英文版

莱因哈特、维尔特 合著

正版

哈佛商学院案例教程

Business Management and the Natural Environment

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东北财经大学出版社

出 版 者 的 话

当今的世界是一个变革的世界，政治体制在变革，经济结构在变革，管理方式在变革，思想观念在变革……从东方到西方，从中国到世界，一切无不处在变革之中。毫不例外，管理教育也正面临着一场深刻的变革。在以MBA（Master of Business Administration，通常译为“工商管理硕士”）教育为主干的应用型管理教育大行其道的同时，一种以经典案例为主要素材、强调培养实务操作能力、反对一味灌输抽象理论的所谓“案例教学法”（Cases Methods）逐渐取代了传统的管理教学模式，并以惊人的速度风靡全球。

作为世界MBA教育发祥地的美国哈佛大学工商管理研究生院（Graduate School of Business Administration，Harvard University，通常简称Harvard Business School，即“哈佛商学院”），同时也是管理专业案例教学的首创者和积极倡导者。哈佛商学院经过近一个世纪的发展，已经无可争辩地登上了全世界MBA教育的制高点，哈佛商学院MBA已经成为全球企业管理界一块光芒四射的“金字招牌”。个中原因除了素来坚持严格的学员遴选制度之外，主要应归功于独具一格的案例教学方法。

毋庸讳言，我国的管理教育尚处于“初级阶段”，亟待借鉴发达国家的成功经验，包括先进的教学方法、权威的教学素材和科学的教学体系。为此，我们通过多方努力，终于开通了一条通过合法途径引进哈佛商学院案例教程的渠道，并及时推出了首批十余种图书。按照预定计划，我们将在今后两到三年内，陆续推出哈佛商学院MBA其他主干课程案例教程的英文（影印）版和相应的中译版，以满足国内管理教育尤其是MBA、经理培训项目(ETP)师生和其他有关人士的迫切需要，为推动我国管理教育改革和向国际接轨的步伐贡献一份绵薄之力。

对于本套系列教材在选题策划、翻译、编辑、出版以及发行工作中存在的缺点和不足，恳请广大读者不吝指正，我们在此先致谢忱！

东北财经大学出版社

1998年3月

PREFACE

This book is part of the output of an initiative undertaken at Harvard Business School to increase understanding of the relationships between business and the natural environment.

In 1990, Richard Vietor and Harvard Business School Dean John McArthur agreed that the school needed to increase its capability in teaching its students—executives as well as MBAs—about the relationships between business and the natural environment. Accordingly, Vietor agreed to lead an informal "environmental initiative" at the school, with the idea of increasing the attention to environmental questions in the school's curricula, and of developing a research agenda on environmental topics. Forest Reinhardt subsequently joined the faculty in part to assist in this effort.

At Harvard Business School, research and course development in new fields typically proceed on parallel tracks, whether the new field is activity-based costing, business opportunities in the ex-Soviet Bloc, social marketing, or business and the environment. Faculty write cases about a wide variety of situations in the field, with an eye toward understanding the best management practices and some of the common challenges. These cases typically form the basis for elective courses in the subject; many are also included in required curricula, and all can serve as gateways into more traditional scholarly research projects.

The environmental initiative has proceeded along those lines, and this book represents one of its interim products.

Our basic premise in writing these cases has been that business managers cannot afford to neglect the new set of managerial and strategic challenges posed by environmental questions. In our own view, some (although not all) environmental problems present real threats to the continued, sustained well-being of human and natural communities. We feel that these threats will not be effectively addressed without the active participation of the business community, with its management talent, capital resources, and technological capabilities. At the same time, even business managers who are skeptical about the seriousness of environmental problems must acknowledge that these problems can radically alter both the economics and the politics of the managers' industries, affecting corporate constraints and opportunities in tangible, significant ways. Regardless of one's individual feelings about the seriousness of the problems or about the social responsibility of business, then, it seems clear that managers need to understand the problems and to think systematically about the appropriate responses.

As a glance at the book's table of contents will show, concern about the environment affects firms in a broad variety of industries, and affects them in virtually every functional area: marketing, production, finance, control, and strategy. Accordingly, the cases in this book draw on concepts from throughout the traditional business management curriculum, applying them to this new set of managerial challenges.

The book follows the structure of the thirty-session elective course on business management and the natural environment that Reinhardt teaches to Harvard MBAs. That course uses cases almost exclusively, supplementing them with readings that are also included in this book. The teaching manual contains detailed suggestions for instructors in facilitating case-method discussion of the material.

Instructors teaching shorter business management courses can select cases from each section of the book to give their students a sense of the broad range of environmental problems for business, or they can concentrate on cases from a particular section for courses on particular industries or functional areas.

Instructors can also use the book as a complementary teaching device for a traditional textbook in a course whose primary focus is not business management. For example, the book can be very helpful to teachers and students of such topics as environmental economics, forestry, environment and development, or public policy. Courses in these fields can benefit from the inclusion of practical, hands-on cases that show how the concepts of the course get applied in actual management situations.

For students and teachers unfamiliar with cases, those in this book are likely to present a considerable challenge. The material is inherently complicated and difficult, and it takes time to digest it, to analyze the numerical information in the exhibits, and to come to an understanding of the case protagonist's options. Careful attention to the assignment questions, reproduced in the instructor's manual, can shorten this process; we recommend that instructors distribute the questions to students before the class discussion, or else devise assignment questions of their own. Still, there is no substitute for diligent work. We would recommend that students budget two to three hours to prepare each of these cases for class discussion.

We are confident that the material in this book will repay this kind of careful scrutiny. We think that the problems discussed in the cases are important, both from a business perspective and from a social standpoint. They are also, we think, extremely intriguing from a purely intellectual point of view. We hope that the material in this book increases readers' appetites for a continuously deepening understanding of the natural world and its relation to the human community.

ACKNOWLEDGMENTS

We received a great deal of help from many different people in assembling the cases and notes that make up this book. Our Harvard colleague David Upton contributed his case on McDonald's. Peggy Duxbury, Fiona Murray, Edward Prewitt, and Jackie Prince Roberts worked on many of the cases while employed as Research Associates at Harvard Business School. We are especially grateful to Andrew Matheson and Tom Patterson, MBA graduates in the class of 1993, each of whom took the initiative to write a very fine case with little supervision and no compensation.

More generally, our colleagues at the Harvard Business School created a climate conducive to the kind of work necessary to produce a book of this sort. We are very grateful to them. We would also like to thank the School's Division of Research for providing funds and research support, and the editorial staff at South-Western Publishing.

Elizabeth Elrod, Andrea Walheim, and especially Eilene Zimmerman did an enormous amount of administrative work which we would have been incapable of conducting ourselves and which was indispensable to the production of the book.

We would also like to thank Teresa Heinz for her support of our endeavors.

The time we spent with students in several MBA classes has deepened our understanding of the issues covered in the cases, and has directly improved the suggestions in the instructor's manual that accompanies the book.

Our greatest debts, however, are to the managers in the firms and other organizations that we have studied over the past few years. The company executives, government officials, and environmental leaders with whom we worked taught us a great deal about their own organizations, and more generally about the difficulties and rewards of trying to marry traditional business concerns with the maintenance of a healthy natural environment. Without their generous contributions of time and expertise, we could not have begun to write this book.

C O N T E N T S

Introduction: Business Management and the Natural Environment

On November 18, 1992, a group of 1,500 scientists, including 99 Nobel laureates, issued a three-page "Warning to Humanity." Given the stature of its signatories, this document issued a real and alarming warning that "human beings and the natural world are on a collision course." The scientists identified at least eight areas that they deemed significant threats to the global environment: (1) atmospheric problems, including ozone depletion and acid precipitation, (2) global warming, (3) water resources, including pollution, ground water depletion, coastal zone damage, and fish depletion, (4) solid and hazardous wastes, (5) soil erosion, depletion, and salinization, (6) rainforest destruction, (7) species loss, and (8) human population growth.

The world's population, already about 45% urban, generates an immense volume of air pollutants—suspended particulates, lead, carbon monoxide, nitrogen oxide, ozone, and sulfur dioxide—all of which have been proven dangerous to human health. In a recent study of the world's twenty largest cities, most had problems with particulates; most had moderate to heavy particulate and nitrogen pollution; more than half a dozen each had problems with carbon monoxide, lead, and/or ozone. Five cities—Beijing, Shanghai, Mexico City, Rio, and Seoul—suffered from sulfur dioxide emissions.[1] This, of course, was just the tip of an iceberg, representing problems of hundreds of other urban areas.

A related, more systemic global problem is ozone depletion, precipitated by production and release of chlorofluorocarbons (CFCs). Since 1988, scientists have had convincing evidence that the release of these gases, through aerosols, solvents, foam blowing, and refrigeration, depletes stratospheric ozone. Doing so allows more ultraviolet radiation to penetrate the troposphere, substantially increasing the threat of skin cancer.[2] Although developing countries have moved to stop production of CFCs by the end of 1995, developed countries continue to increase production and will not phase them out for several decades. Even then, existing CFCs will continue to be released to the atmosphere for years to come.

1 World Health Organization and United Nations Environment Programme, *Urban Air Pollution in Megacities of the World* (Oxford, U.K.: Blackwell Reference, 1992), p. 39; cited in World Resources Institute and The United Nations Environment Programme, *World Resources, 1994-95* (New York: Oxford University Press, 1994), p. 199.

2 National Aeronautics and Space Administration, *Ozone Trends Panel Report: Executive Summary* (Washington, D.C.: March 1988).

A less certain, longer-term problem, but with potentially more severe consequences, is global climate change. The loading of carbon dioxide, nitrogen oxides, methane, and CFCs into the atmosphere is thought by most scientists to cause atmospheric warming via the "greenhouse effect." These gases trap infrared radiation, or heat. According to the Intergovernmental Panel on Climate Change (IPCC), sponsored jointly by the United Nations and the World Meteorological Organization, global average temperatures have risen 0.3 to 0.6 degrees centigrade over the last 130 years. Over the next 50 to 100 years, the IPCC predicts further increases of about 0.3 degrees centigrade every decade. If this occurs, the IPCC believes that sea levels would probably rise some 65 centimeters and cause extensive flooding to low-lying cities and countrysides throughout the world. Furthermore, the hotter temperatures would shift agriculture patterns throughout the world, push forest growth north, and cause warmer temperatures in presently temperate, populated zones.[3]

Although the CFC aspect of this problem is more or less under control, due to the Montreal Protocol, the volume of carbon emissions continues to grow steadily. While some European countries and Japan have promised to limit their emissions to 1990 levels, the volume of emissions in the United States, which currently represents 19% of total emissions, continues to grow. More significantly, in China, India, and other rapidly growing countries, the amount of carbon emissions is increasing dramatically. China, for example, has grown from a 1% to a 10% share of the growing world total in just two decades. Short of gains in energy efficiency, these trends are likely to continue. Meanwhile, in Brazil, Malaysia, Indonesia, and other countries with significant rain forests, cutting continues to reduce the forests' ability to convert carbon dioxide to oxygen.

Water too is under pressure from the world's vast population, from agriculture, municipal sewage, and industry. Only about 0.008 percent of the world's water is in usable form—unfrozen and fresh, in lakes and rivers. Of the total annual river flows—about 47,000 cubic kilometers, unevenly distributed across the continents—about 3,000 is currently withdrawn for use.[4] In some areas, such as the Nile Basin, southwest Asia, and the Middle East, the amount of water available is inadequate and politically contentious. In developing areas, most water is untreated. The U.S. Agency for International Development estimates that provision of safe water could save 2 million annual deaths from diarrhea, and hundreds of millions of cases of roundworm, schistosomiasis, and guinea worm.[5] Added to this is the runoff of pesticides and fertilizer in agricultural areas, and the severe drawdown of water tables in many urbanized areas.[6]

Even ocean resources, the fish that feed more than 1 billion people, are being polluted and overharvested. It is estimated that 20% of the fish species worldwide, and as much as 42% in the European area, have been seriously depleted, or are threatened with extinction. Peruvian anchovies, Atlantic bluefin tuna, and New England groundfish are just the most visible of the fisheries under pressure in the mid-1990s.[7]

A third set of problems is that of wastes. Hazardous wastes are produced in chemicals, metals, petroleum, rubber, plastics, and other industries. This waste, and even solid waste, is especially a problem of developed countries, where the waste volume is huge and disposal

3 Intergovernmental Panel on Climate Change, *Climate Change: The IPCC Scientific Assessment*, J.T. Houghton, G.J. Jenkins, and J.J. Ephraums, eds. (Cambridge, U.K.: Cambridge University Press, 1990).

4 Igor A. Shiklomanov, "World Fresh Water Resources," in Peter H. Gleick, ed., *Water in Crisis* (New York: Oxford University Press, 1993), pp. 13-20.

5 Esrey, Steven A., et al., "Health Benefits from Improvements in Water Supply and Sanitation: Survey and Analysis of the Literature of Selected Diseases," U.S. Agency for International Development, Water and Sanitation for Health, Technical Report 66, Washington, D.C.; cited in World Bank, *Development and the Environment* (New York: Oxford University Press, 1992), p.47.

6 World Bank, *Development and the Environment*, pp. 45-50.

7 "The Tragedy of the Oceans," *Economist*, March 19, 1994, pp. 21-24.

space limited. Wastes are usually dumped or burned in incinerators and cement kilns. In the United States, a prolifically wasteful country, trash amounted to 4.3 pounds, and hazardous wastes, between 6 and 13 pounds per person, per day.[8] But waste generation is growing rapidly in developing countries, where it threatens to become a significant contributor to both air and water pollution.

The abuse of agricultural lands, through the use of pesticides, erosion, and salinization, is another severe problem that threatens many areas of the world—particularly in the face of immense increases in population over the next 40 years. These problems are most severe in Africa, but are not insignificant in parts of China, India, South America and South Asia. Desertification has seized an ever larger part of Africa, claiming as much as 200 latitudinal kilometers across the Sahel during the 1980s. Overall, some 3 billion acres—nearly 11 percent of the earth's vegetated surface—have suffered significant degradation of soil quality during the last 45 years. Soil erosion has damaged yields throughout the world, reducing them by as much as 3–10 percent in the United States, and significantly in Mexico, China, and other regions. And salinization threatens as much as 24 percent of irrigated lands, in China, India, Mexico, and the western United States.[9]

Deforestation, especially in tropical rain forests which constitute much the world's biomass and house the majority of species, has become an increasingly serious problem. In the last decade alone (1981–90), the U.N. Food and Agriculture Organization estimates that 15.8 million hectares of forest (0.8 percent) were lost annually due to burning and cutting. Of this, Indonesia and Brazil accounted for 22% each. Malaysia, Zaire, and Columbia contributed 8%, 8%, and 5% respectively, and all other countries, 34%.[10] Evidence from Brazil and Africa indicates that degradation (removal of plants important to the life cycle of other species) and fragmentation may have an even more severe impact on the forest than outright deforestation. Global loss of biomass is estimated at 2.5 gigatons per year, reducing the potential by 20 percent in Africa and as much as 70 percent in continental Asia.

This destruction of forested lands not only limits wood production, worsens erosion, and exacerbates global warming, but it is especially damaging to biodiversity. Biodiversity is the genetic diversity of species—both plants and animals—in terms of variations between individuals and populations, within a species, among communities (or ecosystems), and the functional differences of various organisms. Destruction of tropical forests particularly threatens species extinction because two-thirds to three-fourths of all species live in tropical forests.[11]

Estimates of the total number of species vary widely, from 10 to 100 million. Only about 1.4 million have been identified. E.O. Wilson, a Harvard entomologist, is among the most prominent of those scientists warning of an imminent disaster of species destruction.[12] With an estimated background rate of extinction of 1 mammal species and 2 bird species per 400 years, the extinction rate has recently increased to 58 mammals and 115 birds in the past 400 years. About 12 percent of mammals and 11 percent of birds were classified as threatened in 1990, and various projections estimate that 5% or more of all species will be destroyed per decade during the next 50 years.[13]

The final problem, and one which obviously underlies the others, is population growth. Over the next 30 years, population is expected to grow by nearly two-thirds, from 5.5 billion to

8 Office of Technology Assessment, Congress of the United States, *Facing America's Trash, What Next for Municipal Solid Waste?* (Washington, D.C., 1989); and Leading Edge Reports, "Hazardous Waste Generation," December 1990.

9 World Bank, *Development and the Environment*, pp. 55-57, 134-141.

10 Food and Agriculture Organization of the United Nations, *Forest Resources Assessment, 1990: Tropical Countries* FAO Forestry Paper 112 (Rome: FAO, 1993), tables 8a, 8b, and p. 25; cited in *World Resources, 1994-95*, p. 131.

11 Theodore Panayotou and Peter Ashton, *Not by Timber Alone* (Washington, D.C.: Island Press, 1992).

12 E. O. Wilson, *The Diversity of Life* (Cambridge: Harvard University Press, 1992).

13 Paul Ehrlich and E.O. Wilson, "Biodiversity Studies: Science and Policy," *Science* 253: 758 ff (16 August, 1991).

8.5 billion—an annual rate of 1.68%. Of all these people, approximately 7.1 billion will live in developing countries.[14] Growth in Africa leads at about 2.9%. Asian growth is about 1.8%, South America, 1.7%, and most of the developed world, below 1%. In the longer term, population is estimated to grow to more than 20 billion by the year 2150, assuming that the earth can absorb it.

We don't believe that populations can continue to grow, with present environmental trends, much longer. Food production, water use, and renewable fuels will fall short long before that time. Economic "throughput" is increasingly stretching the capacity of some finite natural resources. Effluents and wastes, moreover, are becoming unmanageable. The carrying capacity of the environment—its ability to handle wastes—is being exceeded in a number of respects. Ecosystems begin to break down. We are seeing this with soil systems, forest ecologies and their diverse species, clean air and water systems, ozone, and the global climate.

* * *

Our scientific knowledge is sufficiently advanced to provide many of the necessary solutions to this crisis. Thus, we think there is a pressing need for effective environmental management—not just by firms in developed countries, although they should certainly take the lead—but by economic enterprises throughout the world. This textbook examines the challenges—managerial and economic as well as technical and scientific—that modern management faces in using natural resources and reducing effluents.

The United States and other industrial nations already spend a significant fraction of their wealth on environmental protection. Although this spending is responsible for the considerable progress made so far in reducing pollution flows and preserving natural amenities, it is obviously free neither in an economic nor in a political sense. Current proposals for regulatory reform in Washington D.C., reflect widespread frustration with the institutional mechanisms of environmental protection. The challenge for managers, both in the private sector and in the government, is to set priorities among the environmental problems that society confronts, and to design institutions and management systems that will address the important problems effectively and equitably.

These problems are especially acute for managers in companies, on which most of the cases in this book are focused. Companies have been among the principal agents of technological and social change throughout modern history. We believe that they can continue to play leading roles in managing environmental assets responsibly, maintaining public goods while satisfying their traditional obligations to shareholders and others. These roles are discussed in depth in Module 3, and elucidated in readings throughout the book.

* * *

The book is organized into five modules, with 31 readings. Module 1 frames the general problems of the environment for corporate management. It contains several important essays which articulate the intellectual elements of environmentalism, and a general strategy case on Du Pont. Module 2 focuses on market failures and the pressures of government regulation on firms. Ten readings in this section examine issues of public goods in resource-based companies, and issues of externalities related to air pollution and hazardous wastes. In Module 3, the centerpiece of the book, we examine market opportunities and competitive pressures created by environmental issues. Here, nine readings examine energy efficiency and costs, market

14 World Resources Institute, *World Resources, 1994–95*, pp. 27–41, 268–69.

differentiation, and strategies oriented towards sustainability. In Module 4, we examine various international issues, including trade, climate change, forestry in Malaysia, and energy policy in China. And Module 5 focuses on environmental values by examining three environmental, nongovernmental organizations.

We start the book with a case on Du Pont Freon® Products, and the problems of ozone depletion associated with the manufacture of chlorofluorocarbons. This was the first case that we prepared, in 1989, and it remains one of our best studies of science, public pressure, managerial values, and corporate strategy. Du Pont, at the time of the case, manufactured one-fourth of the world's chlorofluorocarbons—chemicals developed in the 1930s for use in aerosol sprays, foam blowing, as an electronic solvent, and most importantly, as a refrigerant. Du Pont had four other competitors in the United States, and equal numbers in Europe and Japan.

In October 1987, most governments of the world had signed the Montreal Protocol, agreeing to phase down CFC production 50% by the year 2000. This decision was based on scientific concern that CFCs destroyed atmospheric ozone, allowing ultraviolet radiation to penetrate the atmosphere, raising the incidence of skin cancer. In March 1988, the National Aeronautics and Space Administration published a key report in which scientists identified chlorofluorocarbons as the culprit.

Du Pont management had to decide, that very day, what to do about their $600 million business. No case that we've ever done has a sharper decision point. As with all the cases and readings in this book, effective analysis must consider how these developments are likely to affect the political arena, and how they'll change the marketplace, particularly the firm's competitive position. There are any number of criteria against which a decision must be evaluated. The outcome chosen by the company, moreover, is not necessarily the best answer.

Next are excerpts from a pair of historical readings: Gifford Pinchot, *The Fight for Conservation*, and Aldo Leopold, *A Sand Country Almanac* (with essays on conservation from *Round River*). Pinchot, a graduate of Yale in 1889, was the first professional American forester. After doing postgraduate studies in France, he became chief of the Federal Forestry Division in 1898. He was a personal friend of Theodore Roosevelt, a master publicist, and eventually, the driving force behind the Progressive conservation movement, the establishment of national forests, and the organization of the Forest Service. He went on to develop a career in state politics.

In *The Fight for Conservation*, Pinchot developed his ideas about efficient resource utilization. Conservation, he believed, was neither preservation of natural resources, nor ecology. Rather, it was the use and careful husbanding of natural resources—coal, minerals, soil, forests, and water—that would eventually be depleted if not managed efficiently. Pinchot praised the immense natural wealth of the United States and warned that inefficient use would lead to "exhaustion and decay." Despite this strong commitment to the environment, Pinchot had his eye firmly on economic development. He went so far as to warn that "conservation . . . stands for development . . . the right of the present generation to the fullest necessary use of all the resources . . . ." This, we shall see, is a precursor to the term "sustainability" as the Brundtland Commission uses it: "meeting the needs of the present without compromising the welfare of future generations." It remains an important intellectual thread of present-day environmental thinking.

Leopold took Pinchot's thinking a considerable step further. Born in Iowa in 1887, Leopold also graduated from Yale and joined the newly founded U.S. Forest Service in 1909. His observations of ecological change, particularly in the southwestern United States, made him a passionate advocate of wilderness preservation. He later held posts at the Forest Service's Forest Products Laboratory in Wisconsin, and at the University of Wisconsin. He died in 1948, fighting a brush fire on a neighbor's farm. *A Sand County Almanac* and *Round River*, both published posthumously, were collections of essays on ecology and on humans' relationship to the earth. There is no need to paraphrase Leopold's arguments here, as they are direct, lucid, and forcefully expressed.

Next we present in an essay the conceptual framework around which this textbook is organized. The essay first describes the broad context in which business is affected by environmental issues—either directly by the environmental impact, through a variety of secondary social institutions, or through government regulation. The central theme is to understand how a firm's market structure is affected. Then the essay goes on to present the idea of environmental strategy, focused on compliance, competitive advantage, or sustainability, either by changing one's own behavior, or that of the market more generally. Examples of each strategic type are drawn from the fifteen company cases in the book. The fourth part of this essay focuses on issues of implementation, particularly organizational innovations needed to affect environmental policy. The last part looks at economic performance.

The last segment of our introductory section, consists of Ronald Coase's essay, "The Problem of Social Cost." This essay, first published in 1960, was one of two cited by the Nobel Committee when it awarded Coase the prize in 1992. Ronald Coase received his Ph.D. in economics from the University of London in 1951, and joined the faculty of the University of Chicago in 1964. His first distinguished essay, published in 1937, was entitled "The Nature of the Firm." In it, Coase explored the role of transaction costs in determining whether economic decisions are made in markets or within firms.

"The Problem of Social Cost" also applies the logic of transaction costs, this time to analyze social problems like pollution. A central insight of the article is that, in the absence of transaction or bargaining costs, externalities like pollution need not give rise to misallocations of resources. Economists had realized that externalities—costs that are not reflected in the prices of goods—can lead to inefficient resource allocation. For example, if the damages of pollution are not reflected in the prices of goods produced using a pollution-intensive process, then consumers will demand more of the goods than they would if these damages were reflected. Coase points out that, as long as the property rights to resources are clearly delineated and as long as transaction costs are negligible, private parties will come to agreements that internalize these externalities, even in the absence of government intervention.

Coase realized that transaction costs in the real world may be significant, especially for problems like pollution. He does not argue that government should never intervene to solve environmental problems. He does, however, point out that government intervention, like private negotiation, entails transaction costs that must be figured in when designing institutions or when trying to predict institutional behavior.

Published in one of the first issues of the *Journal of Law and Economics*, "The Problem of Social Cost" set the tone for the entire subdiscipline of law and economics—that is, the economic analysis of legal institutions and decision-making structures. It also redefined economists' notions of externality problems. This essay is not easy to read. But, given its scope and the depth of thinking about environmental mitigation, it becomes a sort of touchstone for the entire course.

Case

DU PONT FREON® PRODUCTS DIVISION (A)

"Evidence of Ozone Depletion Found over Big Urban Areas; Pattern Widens; Severity Surprises Experts," ran a front-page headline in *The Washington Post* on March 16, 1988. The day before, atmospheric scientists from an interagency governmental research team headed by the National Aeronautics and Space Administration (NASA) had made public new information linking chlorofluorocarbons (CFCs) to the destruction of stratospheric ozone. Ozone depletion, the scientists reported, was more severe and widespread than had previously been anticipated. Furthermore, there was now hard evidence that CFCs had already contributed to ozone depletion over Antarctica. Since stratospheric ozone shielded the earth from ultraviolet radiation, the depletion of the ozone layer was allowing increased levels of radiation to reach the earth's surface. Eventually, this was likely to cause increases in skin cancer rates and damage to crops and fisheries.

CFCs, invented in the 1930s, were now widely used in a variety of industries because they were chemically stable, low in toxicity, and nonflammable. CFCs were the leading heat transfer agent in refrigeration equipment and air conditioning systems for buildings and vehicles. They were used in the manufacture of various kinds of foam, including building insulation. And they were used as solvents and cleaning agents in semiconductor manufacturing and other businesses. In Europe and Japan, they were still widely used as propellants in aerosol containers, although this use had long since been banned in the United States.

Even though no substitutes existed for many of these uses, concern for stratospheric ozone had led, in September 1987, to an international accord under which each country would hold production of CFCs at its 1986 level, and cut production in half by 1999. But the newest scientific evidence cast doubt on whether even these reductions would suffice to protect the ozone layer.

For Joe Glas, who ran the Freon® Products Division of E.I. Du Pont de Nemours and Company, these new findings posed an extraordinary challenge. Du Pont, the world's largest manufacturer of CFCs, received $600 million in revenues from this business in 1987. Citing the uncertainty of the science until the early 1980s, Du Pont had led producers and users in opposing CFC regulation. Recently, though, it had taken the opposite tack, pushing the industry to change its position from opposition to any regulation to support for the international regulatory accord.

Despite this change, Du Pont was severely criticized in the press and in Congress for not doing even more. A New York University physician, testifying at a House of Representatives hearing on ozone depletion, had recently described a "near epidemic" increase in skin cancer rates. Senate hearings on the issue were scheduled for March 30, and Du Pont officials would have to testify. Joe Glas now needed to decide whether the Freon® Products

Forest Reinhardt, Ph.D. candidate in Business Economics, Harvard University, prepared this case under the supervision of Professor Richard Vietor as the basis for class discussion rather than to illustrate either effective or ineffective handling of an administrative situation. The contribution of the National Wildlife Federation is gratefully acknowledged.

Harvard Business School case 389-111.

Division should let the regulatory process run its course (do nothing), take an active role in support of or in opposition to further controls, or take some unilateral action such as cutting back its own production.

THE CFC BUSINESS

CFCs were a class of chemical compounds containing carbon, fluorine, and chlorine. Each of the CFCs was suited to one or two industrial applications; although some applications could use any of several CFCs, substitutability across CFCs tended to be limited. There were two main classes of CFCs: chlorofluoromethanes, and chlorofluoroethanes. The Du Pont Company, which had invented most CFCs, marketed them under the trademark "Freon®."

The first group, chlorofluoromethanes, consisted of two commercially important variations. CFC-11 was used, in the United States, primarily as a blowing agent for foams. The end products ranged from the soft foams used in mattresses, furniture, and car seats (about 20% of blown foam applications), to foams used in food packaging and as the insulation in refrigerators (about 20%), to the rigid foams used as insulation in the construction of new buildings (60%).

CFC-12 was used primarily as the coolant in refrigeration systems, including home refrigerators and air conditioners for buildings, cars, and trucks. Its secondary uses included foam blowing. In Europe and Japan, CFC-11 and CFC-12 were also widely used as aerosol propellants.

The other major class of CFCs, the chlorofluoroethanes, consisted of CFC-113, CFC-114, and CFC-115. CFC-113 accounted for more than 95% of the total use of chlorofluoroethanes. They were used primarily as solvents in the electronics and defense industries to clean high-value electronic components like printed circuit boards. In the United States, this use accounted for about half of CFC-113 demand; other applications included metal degreasing, dry cleaning, and cleaning medical implants and guidance systems.

A similar class of compounds, HCFCs, was composed of carbon, chlorine, fluorine, and also hydrogen; although not strictly CFCs, these were sometimes lumped into the same category. The most important HCFC was HCFC-22. About a third of HCFC-22 production was used as raw material in the manufacture of polytetrafluoroethylene (better known under its Du Pont trademark "Teflon") and other polymers. Significant end uses of HCFC-22 included air conditioning for buildings (but not for vehicles) and commercial refrigeration equipment.

A third class of compounds, called Halons, shared many of the same properties (including the propensity to deplete stratospheric ozone as CFCs). Halons were similar to the chlorofluoromethanes but included bromine as well as chlorine and fluorine. Production of Halons, however, was small relative to that of CFCs. They were used mainly in commercial and military fire protection systems.

Production

CFCs were produced by reacting simple chlorinated organic compounds (called "chlorocarbons") with hydrofluoric acid (HF). The principal chlorocarbons used in CFC manufacture were all basic commodity chemicals produced by several firms in the United States. In 1988, no American CFC producer was integrated backward into chlorocarbons because buying them cost less than producing them in-house. But in Europe and Japan, most CFC manufacturers also produced their own chlorocarbons.

HF was produced by reacting calcium fluoride (fluorospar) with sulfuric acid. Du Pont mined its own fluorospar and made HF, but also bought some HF under long-term contracts. Most firms purchased fluorospar and used it to make HF. HF was highly acidic and reactive, and was thus expensive and somewhat dangerous to transport.

CFC-11 and CFC-12 were produced by reacting HF with carbon tetrachloride in the presence of a catalyst. The process was relatively simple. CFC-11 and CFC-12 were typically produced together, since their raw materials were the same, and then the resultant mixture was distilled to separate the two compounds. The plants used to produce these products averaged 50 million pounds of capacity per year.

In the CFC-113 process, perchloroethylene was combined with chlorine to produce hexachloroethane, which was then reacted with HF in the presence of a catalyst to make CFC-113. This two-step process was substantially more difficult to manage than the one-step process used for CFC-11 and CFC-12. Chemical engineering expertise in the manufacture of 11 and 12 was not transferable to 113 production, and it was beyond the technical capability of many of the smaller American firms to make CFC-113 cost-effectively. "Every time they try it, they screw up," said one plant manager. CFC-113 manufacture also required dedicated plants: facilities designed to produce CFC-11 and CFC-12 could not be used economically. Plants for CFC-113 tended to be smaller than CFC-11/12 plants. The average plant had a capacity of 30 million pounds per year.

To produce HCFC-22, chloroform was reacted with HF. This, too, required dedicated plants. More difficult to make than CFC-11 and CFC-12, it was somewhat easier than CFC-113. HCFC-22 plants tended to be about the same size as CFC-113 plants. An average-sized plant designed to make CFC-11 and CFC-12 could be retrofitted to produce HCFC-22 for about 20% of the original investment and a 50% reduction in production volume.

Hydrochloric acid (HCl) was produced in large quantities as a by-product of CFC manufacture. If the acid were not sold as a chemical, it had to be neutralized with caustic soda before disposal (unless dumped into the ocean, where dilution would mitigate its effects). Allied-Signal was the only American CFC maker with a permit, valid through 1991, for ocean disposal of HCl.

CFC manufacturers used several measures to lower their costs. The most important technical factor was the yield, the ratio of actual production to the level that could theoretically be achieved. Increasing yields required incremental tinkering with the production process. Manufacturers also attempted to avail themselves of scale economies in raw materials purchasing and in capital costs. Investment in CFC-11 and -12 plants at an efficient scale cost 50 to 60 cents per pound of annual capacity.

Marketing

CFC-11 and CFC-12 were commodity chemicals sold through elaborate distribution channels. While large purchasers like General Motors and General Electric bought their supplies directly from manufacturers, most of the production in the United States was sold through a network of independent distributors who typically dealt in more than one company's products. Sales of CFC-113, by contrast, were typically handled by distributors dedicated to the products of a single firm.

In Europe, the channels were somewhat different. Each manufacturer had a dedicated distributor network that did not handle other firms' CFCs. Further, in each of the larger western European countries, one firm had traditionally dominated the market. In Japan, distributors also tended to be dedicated to a single manufacturer.

Competitors

Only one firm—Du Pont—produced CFCs in all three major CFC markets: North America, Europe, and Japan. Value to transportation cost ratios were low. CFC-12 had to be shipped under pressure in steel containers, and a 20,000-pound container cost $40,000. CFC-11 and CFC-113 could be shipped in drums, but even for these compounds it cost seven to ten cents per pound in freight and handling for a transoceanic shipment. For this reason, trade among regional markets was small in proportion to overall production. In 1986, only 8% of U.S. consumption was imported from Europe (mostly from Britain by ICI).

Most of the major CFC producers manufactured a full line of products, but there were a few exceptions. Du Pont Nederland, for instance, made only chlorofluoroethanes and HCFC-22, and bought CFC-11 and CFC-12 for resale. Outside purchases to round out product lines were standard practice, since distributors wanted to be able to offer a full line to their customers.

Shares of 1985 capacity in each of the three markets are shown in **Exhibit 7**. The figures are aggregated to show total CFC production and capacity, but the shares within each major segment (CFC-11 and -12, HCFC-22, and CFC-113, -114, and -115) tended to be similar. The major exception was in the American market, where Du Pont and Allied were the only producers of CFC-113.

CFCs AND OZONE DEPLETION

CFCs were used widely because of their chemical stability and other distinctive properties. They did not react readily with other materials during the manufacture of final products or while those final products (like refrigerators) were being used. This stability also meant that, once released to the atmosphere, CFCs would not react with other effluents to form smog. Nor were CFCs toxic to humans.

CFCs could be released to the atmosphere immediately upon use (if, for example, they were used as solvents and then allowed to evaporate), or they might remain locked into a final product (a rigid foam, for example, or a refrigerator) for several years after manufacture. But sooner or later, all CFCs created were released to the environment.

What happened to these released CFCs was long thought to be a matter of little concern, because of their stability. An industry consortium to study the environmental fate of CFCs was formed in 1972. Then, in 1974, Mario Molina and Sherry Rowland, two chemists at the University of California at Irvine, postulated that the CFCs could be responsible for widespread destruction of stratospheric ozone. According to this theory, CFCs tended to migrate slowly to the stratosphere, the upper level of the atmosphere between 15 and 30 miles above the earth's surface. There, they were broken into their constituent elements by ultraviolet radiation from the sun. The chlorine atoms released could then act as a catalyst in a series of reactions that converted ozone (O_3) into oxygen (O_2). Because the chlorine acted as a catalyst rather than as a reagent, a single chlorine atom could destroy large numbers of ozone molecules. And because CFCs persisted for long periods before breaking down to form free chlorine, the effects of today's use of CFCs would not be felt for decades or even centuries.

In the lower atmosphere (the troposphere), ozone was an artificial pollutant, one of the characteristic and most unhealthy constituents of "smog." Nations spent billions of dollars trying to control its levels. In the stratosphere, however, ozone blocked out some of the ultraviolet radiation from the sun and prevented it from reaching the surface of the earth. Depletion of stratospheric ozone would thus allow higher levels of ultraviolet radiation to reach the earth. Higher rates of skin cancer in humans, as well as damage to crops and fisheries, were likely to result. A 1% decrease in stratospheric ozone concentrations could result in a 2% increase in the amount of ultraviolet radiation reaching the earth's surface. In turn, a 1% increase in cumulative exposure to ultraviolet radiation was expected to result in a 2% increase in the incidence of skin cancer. (See **Appendix B** for a summary of these environmental concerns.)

The ozone depletion mechanism postulated by Rowland and Molina was, as CFC manufacturers and users were quick to point out, only a theory. Empirical verification was unavailable in 1974, and could not be expected for years because of the difficulties in measuring actual levels of stratospheric ozone. Some 300 million tons of ozone were created and destroyed each day in a dynamic stratospheric equilibrium. Ozone levels in the stratosphere varied widely, for natural reasons, over the course of each day, each year, and each multiyear sunspot cycle. Further, even if a trend toward lower ozone concentrations could be detected, it would be difficult to be sure that CFCs were responsible.

Government agencies, academic institutions, and industry groups built computer models to simulate the chemical and physical processes that determine ozone levels in the stratosphere. The models used data on estimated chlorine-ozone reaction rates, the persistence of chlorine in the stratosphere, the effects of other stratospheric contaminants, and global meteorological patterns as inputs, and used the data to assess the effects of various levels of CFC loadings.

Ozone concentrations were affected not only by CFCs but by a host of other natural and man-made gases, including carbon dioxide, oxides of nitrogen, and methane. Thus, the problem of matching observations to models was significant. It was compounded by the "one-dimensional" nature of the models. Actual ozone concentrations over time were different not only at different altitudes but at different latitudes as well: since the models predicted only averages across all latitudes, they were difficult to verify using empirical data. In response, scientists tried to develop "two-dimensional" models that predicted ozone concentrations at different latitudes and altitudes over time.[1]

Almost as soon as the news of Rowland and Molina's work reached the popular press, American consumers began switching to nonaerosol packaging for common household products like deodorants. U.S. sales of CFCs peaked in 1973. The U.S. Environmental Protection Agency, with other governmental departments, considered it prudent to ban certain "non-essential" uses of CFCs. The ban took effect in 1978; its main impact was to stop the use of CFCs as aerosol propellants, except for essential medical and military uses. At the time, the United States consumed about half of all CFCs manufactured worldwide, and aerosol uses accounted for about half of this consumption. Manufacturers of personal care products and of aerosol containers used in industry switched to other propellants, including carbon dioxide and simple aliphatic hydrocarbons like propane and butane.

With a few exceptions—Canada, Norway, and Sweden—other OECD governments did not impose comparable bans on aerosol uses of CFCs. The European Economic Community did promulgate voluntary, nonbinding guidelines for CFC aerosol uses in 1980, and

1 Because both kinds of models also had a temporal element, the "one-dimensional" models were actually two-dimensional and the "two-dimensional" models really three-dimensional. In counting the dimensions of a model, however, the temporal dimension was ignored.