ROUTLEDGE REVIVALS

Resource Economics

Selected Works of Orris C. Herfindahl

Edited by
David B. Brooks

RFF PRESS
RESOURCES FOR THE FUTURE

Routledge Revivals

Resource Economics

Only a few economists have vigorously dealt with mineral economics. Among these few, Orris C. Herfindahl has probably probed the most deeply. This volume, originally published in 1974, presents Herfindahl's most significant and enlightening contributions to the field of resource economics. This title will be of interest to students of environmental studies and economics, as well as to professional resource specialists.

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Orris C. Herfindahl

RESOURCE ECONOMICS

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ORRIS C. HERFINDAHL

Edited by DAVID B. BROOKS

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Orris C. Herfindahl was research associate and later senior research associate in RFF's energy and minerals program from 1957 until his death in 1972. David B. Brooks is research director of the Office of Energy Conservation, Department of Energy, Mines and Resources, Government of Canada. The charts were drawn by Clare Ford. The book was edited by Marget Ingram. The jacket design is by Clare Ford. Terry Pagos prepared the index.

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FOREWORD

Only a few economists have dealt much with mineral economics. Among these few, Orris C. Herfindahl has probably probed the most deeply. He was, moreover, one of the first fully competent economists to enter the new field of environment and pollution, which he did with his customary insight and thoroughness. We offer this volume in the conviction that Herfindahl's work in the several related areas contributes significantly to the field of resource economics and should be made readily accessible to students and resource specialists. We hope that readers will be enlightened by this selection of economic writings. Taken along with other pieces not reprinted here, they provide the broadest, most penetrating treatment of the subjects mentioned that we know of.

For those of us who were Orris Herfindahl's colleagues at Resources for the Future, this volume is very special. In gathering this collection of his writings together, we pay our respects to the most exacting economic analyst among us. His judgment was keen and his standards high, whether his own work or that of others was under scrutiny. We always figured that if anything one of us drafted could get past Orris Herfindahl, it would be found acceptable by the profession at large. But Herfindahl commanded more than our respect for his analytical competence: his closest colleagues valued his friendship highly and held him in great affection.

Our special thanks go to David Brooks for the skill and care with which he has selected the items for inclusion here, and for his introductory essay.

January 1974

Joseph L. Fisher
Resources for the Future, Inc.

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INTRODUCTION

DAVID B. BROOKS *

One of Orris Herfindahl's favorite quotations was written by Vilhjalmur Stefansson: "My favorite thesis is that an adventure is a sign of incompetence. . . . If everything is well managed, if there are no miscalculations or mistakes, then the things that happen are only the things you expected to happen, and for which you are ready and with which you can therefore deal." Orris Herfindahl not only liked that quotation, he also lived by it. I was fortunate to have known him in three capacities: as a teacher, as a colleague, and as a camping companion. He approached each task with the same caution and the same insistence that careful analysis would usually demonstrate that surprises could be avoided, that future developments would be an extension of past knowledge, and that analysis could help to indicate the linkages. It is characteristic of Herf, as most of us called him, that he never used words like *breakthrough* or *revolution* and equally characteristic that (at least to my knowledge) he never tipped over in a canoe, despite passing through some very rough water.

Biography

Orris Clemens Herfindahl was born at Parshall, North Dakota, on June 15, 1918. He spent most of his early life around Stanton, Iowa, a Swedish farming community where he early developed a keen awareness of nature and skill at using his hands. These two interests remained with him throughout his life; they were well known to his colleagues and even reflected in some of his work. What is less well

* Research Director, Office of Energy Conservation, Department of Energy, Mines and Resources, Government of Canada.

known to those who knew him only as an economist is that his original love was music. His ability with the clarinet earned him a scholarship to Interlochen Music Camp in Traverse City, Michigan, and he entered the University of Minnesota with the intention of majoring in music. Although he changed his major, first to school administration and then to business administration, he kept an interest in music throughout his life and passed it on to his children. Moreover, it was as a member of the University of Minnesota band that, in his sophomore year, clarinet-player Orris Herfindahl met trombone-player Anna Marie Rogers. Orris Herfindahl always had a sense of humor and was something of a tease, so the story may well be true that Orris would not lend Anna Marie some scores she needed unless she went to the band formal with him. In any case, they were married on August 25, 1940.

Herfindahl's career at the University of Minnesota was a distinguished one, and he was recognized both for his music and for his academic accomplishments. He worked closely with Professor Frederick B. Garver and graduated in 1939 with high honors and a Phi Beta Kappa key. Although his degree was in business administration, Herfindahl had taken a number of courses in economics, and, after a year of graduate study at the University of Minnesota, he accepted a position teaching economics at St. Olaf College in Northfield, Minnesota.

In 1942 Orris and Anna Marie Herfindahl moved to Washington, D.C., where he had taken a job with the National Income Unit of the U.S. Department of Commerce. The war had attracted many extremely able people to Washington, and friendships that would last throughout his life began at this time. Herfindahl next spent three years in the U.S. Navy. His duties there included neither the study nor the practice of economics, but he did teach himself both calculus and German.

After his discharge from the Navy in 1945, he returned to the National Income Unit for several months, and then began the studies that would eventually lead to a doctorate in economics at Columbia University. He spent about two and a half years at Columbia, from September 1945 until the summer of 1948. His thesis advisor was George Stigler, whose exacting neoclassical standards accorded well with Herfindahl's own approach. However, his dissertation was not complete when, along with about twenty other economists, he went to the University of Illinois as an assistant professor under Howard Bowen. The dissertation, "Concentration in the Steel Industry" [27] [1] was finished in 1950, and in 1951 Columbia University awarded Orris C. Herfindahl the degree of Ph.D. in economics.

[1] A full bibliography is provided.

The academic year 1950–1951 at the University of Illinois was highlighted by a struggle between Howard Bowen and his "young turks" arrayed against a coalition of conservative faculty members and political forces in the state. The motivations for the attack on Bowen and his associates were complex and confused. However, late in 1950 after a hearing before the Board of Trustees, Bowen was fired, to the intense and lasting shock of many of his colleagues. Their loyalty to Bowen and their outrage at the tactics used to "get him" were such that within one year more than fifteen faculty members (Orris Herfindahl among them) had resigned—though many of the group continued to meet periodically at informal "Bowen alumni" reunion dinners.

Thus, in 1951 the Herfindahls moved back to Washington, D.C., which was to be their home for the rest of his life. He joined the staff of the Bureau of Mines, U.S. Department of the Interior, which at that time had put together an economics team it has never since equalled. He directed a small policy analysis group that turned out a number of thoughtful internal memoranda on mineral taxation and other such issues.

Apparently those two years with the Bureau of Mines reinforced Herfindahl's earlier interest in the economics of minerals. He had had no particular bent toward the minerals industry when he chose his dissertation topic, but that study of competition in the steel industry began an association with the industry that continued for most of his life. Characteristically, even for his dissertation he had probed more deeply than was required for the immediate question, inquiring into the absolute level of steel and iron ore prices, so that he very quickly became involved in theoretical questions about the long-run supply of minerals. His first published paper [9]—prepared while he was at the Bureau of Mines—dealt with this subject (the paper is reprinted here as selection 4).

In 1953 Herfindahl temporarily left the field of natural resources as such to spend several years in the Washington office of the Committee for Economic Development, where he reviewed, with generally favorable words, fiscal and monetary policies for countercyclical purposes. Several early papers were published that express his views on these matters [10], [12].

In 1957 Orris Herfindahl joined Resources for the Future in Washington, D.C., as a research associate (later senior research associate), and he was to stay with the organization until his death. For the next fifteen years he could usually be found in his office thinking or writing, yet always ready to help a colleague, to criticize a manuscript—or to talk about wilderness camping.

Of these activities, Herf unquestionably found writing to be the

most difficult. He used to remark that writing was the hardest work he did, and he labored over each paragraph, sentence, and even word to ensure that it said exactly what he wanted. He was a stickler for correct use of grammar and syntax. His approach to writing, in fact no different from his approach to economic theory, served him well; the results are both clear and direct. He developed the facility, particularly in his later writing, of adjusting his style to the audience. One cannot mistake the tone of writing in *Copper Costs and Prices,* aimed at other economists, for that in *Quality of the Environment,* aimed at the public. Perhaps he felt a little more comfortable with the works aimed at his colleagues, for the characteristic dry humor, which those of us who knew him well came to look for and enjoy, turns up more frequently in his earlier works.

During the early portion of Herfindahl's tenure with RFF, he continued to emphasize the two subjects to which his doctoral dissertation and his work at the Bureau of Mines had introduced him: mineral resource supply and competition in the minerals industry. He recognized that both, along with the subject of conservation itself, had been neglected by economists and that this neglect was leading to some poorly conceived policies. For the most part his works during this period were fairly technical and aimed at his professional colleagues.

In 1963 he spent several months in India, the first of two significant assignments outside Washington.[2] The trip to India, at the request of the Indian Government, to work on mineral-related aspects of the Fourth Plan [30] was something of a turning point. For one thing, Herfindahl began to consider the general problems of providing natural resource information. For another, from this point on more of his work appeared in the form of reports and oral presentations than in books and economics journals. The invitation also showed that his reputation in the field of mineral economics had spread beyond the circle of his professional colleagues.

In 1966 and 1967 he was Resources for the Future's representative in the office of the Latin American Institute for Economic and Social Planning at Santiago, Chile. Out of this experience he wrote his book on natural resource information [5] (excerpts are reprinted here as selections 13 and 14). Characteristically disdaining a tourist's approach to this assignment, he became fluent enough to converse and later write in Spanish [32], [4], [6], [24], simply by insisting upon living and working in the language once he had acquired a basic classroom knowledge of it.

[2] Appendix A provides a chronological list of Herfindahl's special assignments and consultancies.

In addition to his work abroad, he held several teaching assignments, although his only full-time teaching position after receiving the doctorate came during the summer of 1960 at the University of Colorado. That summer provided me with my first contact with Orris Herfindahl; the impression was a strong one, if a little slow to develop.

He had come to the university to teach a course in mineral economics, and, along with other doctoral candidates interested in natural resources, I was quick to enroll. Earlier courses of the same sort had proved to be pretty descriptive, and I settled back for a relatively easy time. I was mildly surprised when Herfindahl started off by reviewing supply and demand curves, and several days later I woke up to the fact that we were moving headlong into capital theory. Needless to say, it was no snap course. However, the effort at catching up was well worth my while, for a year later it was arranged informally that I could go to Resources for the Future to write my doctoral dissertation; I therefore had the unique opportunity of being Orris Herfindahl's only Ph.D. student.

Throughout the 1960s Orris Herfindahl had also maintained an interest in natural resources other than minerals. Whenever possible, as with his work on conservation, he emphasized resources in general rather than minerals alone. Moreover, he began to take an active interest in water resources and published, in collaboration with his close friend Irving Fox, an article on the efficiency of water resource development [17].

The interest in other natural resources gradually broadened until it encompassed the whole question of the quality of the environment. An initial overview of the problems, *Quality of the Environment: An Economic Approach to Some Problems in Using Land, Water, and Air,* appeared in 1965 and was the first of several studies in this subject area that Herfindahl coauthored with Allen Kneese [3], [25], [7]. Just as with the material on natural resource information, a great deal of this work was aimed at the general public or at government agencies and either remains unpublished or has been incorporated in books and reports.

The last few years of his life were taken up to a significant degree by his collaboration with Allen Kneese on their advanced text in the economics of natural resources [7]; Herfindahl wrote many of the theoretical portions of this work, including some very technical sections on capital theory (the concluding chapter is reprinted here as selection 3). Thus, in this last work he returned in a sense to the starting point of his career, emphasizing the economics of natural resource supply and conservation. His working career had progressed from this topic through applications of economic theory to the min-

erals industry, to natural resource information and to the quality of natural environment, and finally back to the theory of resource supply once again. The text also marks a return to writing largely for his colleagues rater than for the public. Perhaps this book will prove to be a companion volume to that text, albeit at a less advanced level, for many of the ideas developed at length in the text can be found in their original form in the selections published here.

No one who knew Orris Herfindahl at all well could fail to be impressed by two special characteristics: his interest in philosophy and his love of the out-of-doors. He was a sincerely religious man and coupled this to his lifelong interest in both philosophy and economic theory. He was always searching for explanatory systems on a universal scale, and this is what is common to his interest in religion, in philosophy, and in economic theory. He loved to argue ethics, with points strongly stated, in order to see where they led. In fact, one of his great strengths was that he never forgot the ethical basis of economics, and he re-emphasized this wherever he could (see, for example, selections 3, 5, 6, and 17). For the most part he found that neoclassical economic theory, which he knew thoroughly, measured up quite well in terms of his ethical-religious precepts, but as a good economist he tried to make these values explicit and periodically asked himself whether they still made sense.

Politically, the same precepts were reflected in a strong, almost Burkeian conservatism and respect for traditional values. Herfindahl preferred to use the word *liberal* in its original nineteenth-century sense to emphasize his reliance on individualism and on free market forces. Thus, in today's world he was innately a conservative, but he was in no sense a reactionary. He combined at every stage a deep honesty about and a sensitivity for social problems. Although these could not always be reconciled with his market economics, he was always aware of their importance.

Perhaps not so different from this philosophical-religious bent was his feeling toward nature. It was as if he found God in the wonder of nature. It was a rare weekend that he and his family were not on a river or in the mountains on a trip lasting from a few hours to several weeks. He and Anna Marie led a Girl Scout program in canoeing for many years. He taught many people, myself included, to begin to handle a canoe in white water with some skill, though few of us ever reached his level. In my mind I can still picture Herf in the fifteen-foot, keelless fiberglass canoe that he made himself, looking over a stretch of white water, unerringly picking the best course, and then effecting the descent without so much as grazing a rock.

In a canoe or on foot, Herf accepted nature on its own terms; he used motors only for initial access, and firearms not at all. He and Anna Marie designed and made much of their own equipment, including tents and sleeping bags. Parents of a devoted family, they took backtrips of a week or longer with the four children—Anne (Mrs. William Sare), Henry, Cynthia, and Erika—that others would have hesitated to take with adults. Together they hiked in the Wind River Mountains of Wyoming, in Teton National Park, in Dinosaur National Monument, South Yellowstone, and other places. He also led a four-week, 500-mile canoe trip down the Hanbury and Thelon rivers in the Northwest Territories of Canada, a trip on which his son Henry, Irving Fox, and I accompanied him. It is accurate to say that, for the most part, Herf both conceived and planned these trips and that their success—their lack of "adventures"— was in no small measure the result of his planning. One of the basic elements in this planning was a list that I still use in preference to the dozens of others that have come my way since (see appendix B). Just as important, Herfindahl was exacting about his own physical conditioning and swam, ran, and exercised regularly throughout the year. In preparation for a trip he would read everything he could get on the history of the region and on previous trips. And he would review maps and photographs in great detail, committing much to memory and the rest to notes. This attitude toward operating in remote areas, together with his feeling for countryside, is well expressed in his article on our canoe trip, reprinted as appendix C.

In November 1972, Orris and Anna Marie Herfindahl left for a hiking trip in the foothills of Mt. Everest in eastern Nepal, a trip that had been a long-time ambition for both. Flying in from lower elevations, they joined an organized trip already in progress at 10,000 feet. Moving fairly quickly on foot to elevations of 17,000 feet, Herf, despite his fine physical condition, developed a severe case of high-altitude pulmonary edema. The attack built up slowly, and, in the absence of medical advice, its seriousness was not recognized early enough. Even cutting the length of the hike and beginning to move downhill was insufficient. He died on December 16, 1972, before medical help could be obtained. As Herf wrote in the article on our canoe trip: "The final cause of disaster often cannot be traced clearly to any specific lack. Instead a whole series of little inadequacies seem often to exert more and more pressure until . . ." He was fifty-four years old at the time of his death. All of us who knew him feel the loss of his thoughts, his honesty, and his combination of penetrating criticism and subtle humor.

The Organization of the Volume

Orris Herfindahl's work can be divided into five major topic areas; each constitutes one section of this volume. In order of presentation, these areas are:

(1) the nature and scope of resource economics;
(2) natural resource supply and conservation;
(3) the application of economics to the minerals industry;
(4) the supply of natural resource information;
(5) the quality of the natural environment.

The five topic areas, and the selections within each, are reviewed briefly below. First, however, the general criteria for selection should be indicated. Within the overriding criterion of providing students and specialists with a compilation of Herfindahl's main ideas, some emphasis was given to lesser known or unpublished materials. An effort has been made not only to achieve balance among the five topic areas, but also to reflect the several audiences for which Herfindahl wrote—his colleagues, government, and the public—and to include the main themes he emphasized throughout his career: the conviction that natural resources can and should be studied by conventional economic methods; investment as a process (mineral exploration, information); the use of measurement in economic analysis (concentration of industry, data on the environment); and pure theory-cum-philosophy (long-run price of minerals, ore deposits as capital). These themes will be reviewed very briefly in the final section of the introduction. Finally, none of the work that was originally presented in Spanish has been included. To do them justice, such works should appear in the original; the same ideas and approaches can be found in his English works.

The Nature and Scope of Resource Economics

Always a penetrating critic, Orris Herfindahl reserved his sharpest sallies for those who contended that resource economics was a special discipline, distinct from traditional economics. Of course, he recognized that study of the economics of natural resources required an extensive knowledge of industrial activity and technology, as well as of physical-biological relationships. But these were differences of application, not of principle. This point of view is brought out unmistakably in the first selection in the volume, "Is Resource Economics Unorthodox?" The final sentence, in which Herfindahl advises people studying natural resources "not to abandon conventional economic principles but rather to learn enough about the problem at hand to apply them usefully," is characteristic of his whole approach. The

article was written in 1969, but it would have been little different had he written it at the very start or the very end of his career.

Herfindahl was almost equally sharp in his criticism of those people who pointed to the normal working out of supply and demand as "problems." Rising or falling prices for some commodity may indeed create problems, but the fact of changing prices does not in itself constitute a problem. He expressed this view orally in many contexts, but, to my knowledge, only wrote it expressly in an unpublished work prepared for a House of Representatives Republican Task Force on Earth Resources and Population, from which the second selection is excerpted.

Finally, although I have in general avoided taking excerpts from the Herfindahl-Kneese text in resource economics, an exception was made for the final chapter of the text, entitled "Time for Stock-Taking," which, according to Allen Kneese, was largely Herfindahl's work. This is a rather philosophical view of what economic theory has been able to do, and of what it has not been able to do, in the way of analyzing the economics of natural resources. It was one of the last things that Orris Herfindahl wrote and is as suggestive of paths for the future as it is reflective of the road already traveled.

Natural Resource Supply and Conservation

The material in this area may well be regarded as the most important of Herfindahl's career. It is significant both for its advances in thinking about certain aspects of resource supply and also for its exposition of several subjects that others often left analytically empty and thus useless for policy purposes. However, it forms a relatively small part of his written work, which is a tribute to the careful thought process and tight writing style that are always present, but particularly noticeable when he turned to theory.

Throughout most of this work, Herfindahl is interested in industry output rather than the output of a single mine, a point sometimes neglected by critics. Therefore, when Herfindahl concludes that the quantities available for commercial exploitation are very large in relation to consumption, he is referring to very broad geographic areas, not to a single country, much less to a single mine. Furthermore, in most of this work he abstracts from noncompetitive influences on price, largely because he did not believe that, over the long term, they were dominant. Finally, he also neglected such complicating factors as recycling of metals, in this case not because he felt that they were unimportant, but because they were unnecessary complications which, if pursued, would only reinforce his theoretical and empirical conclusions.

The first selection is his first published article, which, although little known except to specialists, is a clear primer of the principles of resource supply for a firm or an industry producing an exhaustible resource. The article provides references to and a brief discussion of the literature on the economics of exhaustible resources.

The second selection is a remarkable piece of writing entitled "What Is Conservation?" delivered as a lecture at the Colorado School of Mines, first printed in *Three Studies in Minerals Economics* [2] in 1961, and reprinted many times since. In this paper Herfindahl, following Ciriacy-Wantrup's lead,[3] gives economic content to the idea of conservation and shows that the same term had been used in the past to mean different and even conflicting things. It is characteristic of Herfindahl for several reasons. For one thing, after the case had been made, it all sounds very simple; one tends to forget the long period of thought that preceded the writing. For another, the work combines philosophical and practical content. It is soundly based in economic theory, with a touch of general philosophy as well. Moreover, although there are no mathematical symbols in the paper, one can feel them just below the surface. Finally, the article is straightforward and direct with sentences whose meaning cannot be mistaken; one might disagree with Orris Herfindahl, but one was seldom confused by him. Thus, in discussing one of the most popular definitions of conservation (see selection 5), he writes:

> When this definition is read off rapidly—conservation is the use of natural resources for the greatest good of the greatest number for the longest time—the three superlatives have a delightful ring. If this is conservation, how could anyone be opposed to it? No one could be, of course, unless he stops to ask himself how three variables can be maximized at the same time. Imagine a father trying to distribute a bag of candy to his children so as to maximize the amount of candy received by each child who gets candy *and* the number of children receiving candy *and* the length of time the candy will be visible.

The third selection is a portion of a paper entitled "Goals and Standards of Performance for the Conservation of Minerals," in which Herfindahl spends considerable time destroying, on both practical and ethical grounds, the notion that capital in general ought to be accumulated for the future. Only the shorter portion relating specifically to conserving minerals is presented here. Whereas the general proposition on saving capital never had much practical content, ideas about saving minerals for the future are very much alive today. In fact, the excerpt is reprinted partly because it helps to clarify ideas that have

[3] S. V. Ciriacy-Wantrup, *Resource Conservation* (Berkeley: University of California Press, 1952).

recently reappeared, notably in the limits-to-growth debate, and partly because it can be compared with Herfindahl's later works on the quality of the natural environment (see especially selection 18), to show the changing nature of his concern for the future.

The final selection for this area is "Depletion and Economic Theory," a paper contributed to the book, *Extractive Resources and Taxation*. This paper presents most of the important aspects of the economics of supplying minerals over the long term, and includes material published in earlier similar studies (for example, "The Long-Run Cost of Minerals," in *Three Studies in Minerals Economics*). While maintaining that the "basic and definitive treatment" was given to the same subject by Hotelling in 1931,[4] Herfindahl reinterprets the material in a more modern context and makes it more accessible to the average reader. Moreover, by use of comparative statics he is able to indicate the likely effects of the sorts of change that will be important in a modern world, as with new technology or growing demand. Finally, and again characteristically, Herfindahl does not stop with the theory, but goes on to ask whether the facts of mineral prices accord with the theory. Needless to say, he finds that they do; had they not, he would have immediately gone back and reevaluated the theory. The theory of mineral supply has been refined a little since this article was published,[5] but its heart can be found here.

Application of Economics to the Minerals Industry

This topic area includes the largest single block of Herfindahl's writing and is no doubt the area for which he is most widely known. Certainly it is the work that first brought him to the attention of policy makers in government. One of his major contributions was simply recognizing that, although the minerals industry had been largely neglected by economists since the turn of the century, economic theory could usefully be applied to it. Of course, there had been many books on minerals and on topics that could be called mineral economics, but only a few had substantially involved the use of economic theory for explanatory purposes. Most tended to be descriptive surveys reporting what had happened and suggesting what might happen, but seldom asking "why" or "so what."

[4] Harold Hotelling, "The Economics of Exhaustible Resources," *Journal of Political Economy*, Vol. 39 (April 1931), pp. 137–175.

[5] Richard L. Gordon, "Conservation and the Theory of Exhaustible Resources," *Canadian Journal of Economics*, Vol. 32 (August 1966), pp. 319–326; Paul G. Bradley, "Increasing Scarcity: The Case of Energy Resource," *American Economic Review*, Vol. 63 (May 1973), pp. 119–125.

The selections in this section all emphasize the more theoretical portions of this body of work, including applications of concepts from structure of industry and capital theory. To some extent, this means that Herfindahl's policy prescriptions have been slighted. However, in the end he was far more interested in his analysis, which is not time-bound, than he was in policy prescriptions specific to a particular date or a particular administration. Moreover, the policy prescriptions themselves were not unique. Many can be put forward after institutional analysis, or for less well-founded reasons, so that in most cases others were advocating the same things.

Two other characteristics emerge in these selections. First, Herfindahl's facility for dealing with numbers comes to the fore here, where he had to demonstrate the applicability of his conclusions, something that was less immediate in abstract questions about resource supply. Second, in reading these works, one cannot but be aware that Herfindahl knew very well the industries with which he was dealing. He followed his own statement that one of the few reasons for distinguishing resource economics, apart from a small amount of particularly applicable theory, seemed to be the need to know more about the industries under study than was necessary for manufacturing or service sectors.

The first three selections all come from Herfindahl's first major work, *Copper Costs and Prices: 1870–1957,* published in 1959. The first selection is chapter 3 of that book, which provides the most succinct statement of Herfindahl's view of investment in minerals as a systematic process. Supporting the now widely accepted view that an ore deposit is better treated as a form of capital than as "land," Herfindahl pointed out that the capital good is produced by exploration and development of the mineral deposit. (In the minerals industry, the word *exploration* refers to the search for new deposits, whereas the word *development* refers to the preparation of known deposits for production.) Thus, the production of ore deposits is a part of the output of the industry at the same time that other ore deposits are typically serving as inputs to a production process that results in metal.

While no one denies that the process of developing ore deposits is systematically based on expectations of profit, it was and is maintained that exploration is not a systematic process, but rather a matter of chance discoveries or politically determined decisions. Even today such views are common, reinforced by the industry's emphasis on the high risks it faces in exploration. Herfindahl did not deny that exploration might be risky, though he noted many ways in which this risk could be moderated, but he did attack the ideas that the volume of exploration was independent of profit expectations and that the

volume of discovery (that is, the value of capital produced) was independent of the volume of exploration. The distinctions are important. If discovery is accidental, the supply of mineral resources available for exploitation at any one time is a random variable. If, however, exploration is systematic, we can expect that discovery will be responsive to long-run trends in supply and demand, and, with appropriate qualifications, we can undertake economic analysis on the minerals industry, using prices (which are generally known) as proxies for costs (which are generally unknown). It also means that over time about as much will be spent in finding ore deposits as the ore deposits are worth, though of course the value of individual discoveries need not have the same direct correspondence with their cost.

The second selection from *Copper Costs and Prices* is a brief discussion of concentration in the copper industry, something that is at the heart of the book and described most clearly in these several pages. In this section Herfindahl uses a concentration coefficient he developed for his Ph.D. dissertation, which combines in one measure the number of firms in an industry as well as their relative sizes.

The final excerpt from *Copper Costs and Prices* is taken from the conclusions. It could almost as well appear with his work on resource supply, for it tells us what can be learned about copper resources from price and cost trends. He emphasizes that conclusions about the deterioration (a word he preferred to depletion) of copper resources cannot be very useful unless one carefully defines deterioration and incorporates notions about economic as well as physical availability. By showing that the systematic nature of exploration underlies the long-run stability in the price of copper, he is able to conclude that, with respect to the response of long-run supply to demand, "copper does not appear to differ from commodities outside the mining industry."

The next selection is a book review, written in 1957, in which Herfindahl puts forward his view of an ore deposit as a form of capital and describes in some detail the difficulties this raises for measuring input and output in the mining industry. The review might well be read by anyone trying to apply statistics to this industry. Here again Herfindahl's knowledge of the mining industry and his ability to make that knowledge meaningful in an economic context is evident.

The last selection in this section is the text of a history of metal mining in the United States from 1839 to 1909, the period in which the United States emerged as a major world producer of metallic minerals. This study was originally published by the National Bureau of Economic Research and is still available; therefore the detailed appendix tables and notes are not reprinted here. In this work, more

than any other, Herfindahl deals directly with the statistics of the industry and attempts to make long-term series showing output, employment, and productivity. He also discusses the technologic changes that have occurred in the industry and points out differences both among commodities and among regions.

Supply of Natural Resource Information

As noted above, Herfindahl's work on the supply of natural resource information began with his trip to India in 1963. Of course, earlier studies on exploration had already involved him in a subject related to the acquisition of information. However, this trip, and subsequent shorter assignments with United Nations agencies, gave him the opportunity to organize his thinking further and prepared him for his South American assignments.

The culmination of this work was *Natural Resource Information for Economic Development* [5], in which Herfindahl treats the provision of information as an investment like other investments. As an investment, information costs money and also creates the opportunity to earn more money. If it is collected too early, money is wasted because it sits idle; if it is collected too late, returns on its use will be less than they might otherwise have been. Similarly, either too little or too much may be spent on information because its collection is subject to diminishing returns. All these considerations are treated in a fairly difficult and abstract chapter of the book. Together with the theory, however, is a great deal of data on the costs of obtaining information, on the sorts of information available in South America, and on the institutional structures that seem most likely to be effective and efficient in providing information. It is this institutional material that the selections in this section emphasize. In contrast to much of the theory of the long-run supply of minerals, it is difficult to think of ways to test the theoretical models here. To some degree they are formal representations of conclusions that can be obtained by simpler reasoning. On the other hand, as demonstrated by the experience of many countries and many projects, we have a great need for the institutional conclusions to which this theoretical approach led Herfindahl. Hence, the first selection is chapter 6, "Some Guidelines for Organization and Administration," reprinted in full with the exception of one appendix.

The appendix to chapter 2 of the same book, "The Question of Exploration Strategy," is also reprinted. This is a little-known but very useful attack on the idea that systematic drilling on some grid pattern would be an ideal method to gain geological information and

locate mineral deposits. Such a view, Herfindahl points out, misconceives both the goal of an exploration program (which should be to increase the size of our real output, not simply to increase information) and the criteria for determining when enough exploration has been done (which is a matter of the net present value of ore found by successive unit outlays on exploration).

The final two selections are adaptations of the work on information. The first, "Economic Considerations in Assessing the Role of Remote Sensing in Country Development," applies the book's conclusions to a single exploration technique; the second, "The Value of Mineral Surveys to Economic Development," applies similar principles to a single industry. Herfindahl is really asking how the government of an underdeveloped country (or an agency advising that country) can make use of (1) remote sensing, or (2) mineral surveys to maximize the return to the country, given (*a*) its inherent endowment in mineral capital, plus (*b*) its willingness to invest in information-gathering techniques. In all these studies, Herfindahl carefully focused on the right questions, explicitly avoiding such questions as whether remote sensing or mineral surveys *would* lead to increased production. As he says in one paper, "To ask this question is something like asking, 'Does investment pay?' The answer in both cases is yes, if properly done."

The Quality of the Natural Environment

As Orris Herfindahl turned in the last five years of his life to questions involving the natural environment, he was undertaking a labor of love. He once commented to me that he would have liked to have spent more of his time studying water resources instead of mineral resources. He might well have specialized further in these problems had it not been an area in which he was personally involved; I can also recall his stating that self-involvement was the death of sound analysis. Whether one agrees or disagrees with this principle, it is hard to deny that a source of strength he found it to be. In any event, after his return from Chile, he did focus extensively on this area in his writing, though in his thinking it goes back much earlier.

Although he would not have maintained that much of this work was original (nor indeed that his work on the economics of exhaustible resources was), he was among the first to understand the importance of externalities in a modern context and to unite material on economic relationships with that on physical-biological relationships. Almost all of the major principles detailed in weightier books on pollution and the environment can be found in a descriptive format

in *Quality of the Environment* [3], the little book he coauthored with Allen Kneese.

This work modified to some degree Herfindahl's earlier optimism about market processes. Though it is never entirely explicit, he seemed to be working toward a distinction between two types of environmental problems: those such as the discharge of effluents into air and water and onto the land, with which the market system could (at least in principle) deal quite adequately; and those which involve such matters as preservation of natural beauty or congestion, as well as the possibilities for climatic disruption and destruction of life support systems, for which market processes seemed less than adequate. It is probably fair to say that natural areas in particular took on, for Herfindahl, the character of a merit good that ought to be provided by society. At the same time, he foresaw that the forces that would lead to recognition of natural areas as merit goods (e.g., the growing popularity of wilderness camping) could in themselves jeopardize the very values that the merit good was supposed to provide. Hence, he urged that a longer time horizon was appropriate for analysis of and policy concerning such issues than could be justified for, say, mineral exploration or investment in development.

To a greater extent than elsewhere, Herfindahl wrote about the environment for a general audience, not for his colleagues. Much of his work in this area, including the first two selections for this section, was presented orally and has been hitherto unpublished. The paper entitled "Effects of Resource Depletion and Economic Growth on the Quality of Life" is probably the best single expression of Herfindahl's personal views about appropriate environmental management, and one of the very few in which his biases show through clearly. Moreover, in translating significant portions of the work of Ortega y Gasset, he demonstrates both his inclinations toward philosophy and his knowledge of Spanish. The other paper, "Can Increasing Demands on Resources Be Met?" is included partly for comparison with the earlier excerpt on the conservation of minerals (selection 6), a topic Herfindahl dismisses in the first few pages of this paper in order to talk about what he now sees as the more important problems—the side effects of supplying natural resources. He also draws a distinction between various kinds of pollutants in terms of their dispersion and cumulative effects and in terms of the likelihood that market processes can be designed to cope with them. The final selection for this topic area is a short excerpt from *Quality of the Environment,* which captures some specific comments concerning natural areas. Here again, Herfindahl was thinking well in advance of others about a particularly

difficult problem of environmental management and was searching for a policy approach consistent with individual choice and market processes.

Perspective

Shortly after I was asked by Resources for the Future to compile this memorial volume, I began to wonder whether it should be a history of Herfindahl's ideas or a review of his most important contributions. The question seemed particularly relevant, since we wanted not simply a memorial on the bookshelf, but a volume that would serve as a reference and a guide to Herfindahl's work for students and resource specialists. It is a special tribute to Orris Herfindahl that, in the end, there was no conflict between the two conceptions of the book. His ideas were remarkably consistent over time and over a variety of topics. The main reason for this, of course, was that he brought a consistent philosophical framework to bear on all the problems he considered. This framework included both his ethical beliefs and neoclassical economic theory. Several themes derived from that economic theory run throughout Herfindahl's work.

First among these themes is the principle that no special discipline of resource economics or mineral economics is needed to deal with natural resources. Natural resources are economic goods, and therefore more or less conventional theoretical and empirical economic analysis can explain their supply and demand relationships. Moreover, and what is not entirely the same thing, Herfindahl made it clear that natural resources not only *can* be studied by methods of conventional economics, but *deserve* to be so studied. (One might argue that the latter was the greater contribution because natural resources, and particularly minerals, had been largely neglected by modern economists until about 1950.) At the heart of all Herfindahl's work is the belief that natural resources present problems worthy of an economist's attention and perhaps even requiring some specialized knowledge before analysis, but that the basic concepts are at most only special cases of the economic theories so usefully adapted to other sectors of the economy. For this reason, Herfindahl much preferred to be thought of as an economist, not as a resource economist, much less a mineral economist. From time to time he expressed the fear that he would be trapped in the field of mineral economics; that is, that the demands on his time as a result of his reputation in this one area would leave him no time to pursue newer and, for him, more interesting problems.

The second major theme is that of investment. Herfindahl was always interested in the process of investment, and he brought this

interest to bear on subjects that had previously received little systematic treatment. The first of these subjects was, of course, conservation, a field in which he knocked down a number of platitudes and inserted some well-defined and operational propositions. He maintained that conservation was simply an investment process in which some things were preserved for future consumption or future enjoyment; thus an action leading to conservation was, according to Herfindahl, neither good nor bad in itself, but could be either, depending upon how one evaluated the resulting shift in the time stream of benefits and costs.[6] He looked at the gathering of information in much the same way. Again he cleared away misconceptions about resource and mineral inventories, maintaining that expenditures on data, particularly those oriented toward project construction or regional development, are investments and therefore subject to all the pitfalls—diminishing returns, incorrect forecasts, and the like—that surround other investments. Similarly, Herfindahl's ideas about investment in mineral exploration, evident in his early work, really make it a form of information gathering. He was understandably proud of having established that exploration could be viewed as systematic investment in the production of ore deposits and that, though occasional accidental discoveries would continue to turn up, they by no means dominated the normal market processes leading to discovery. As with conservation and resource inventories, additional exploration was neither good nor bad but was to be rationally evaluated by comparison of costs and returns over time.

A third theme that runs throughout much of Herfindahl's work, although only a few are specifically concerned with it, is the idea of measurement. As emphasized above, Herfindahl was a master in seeing behind statistics to the real goods and services they represented, a trait that one reviewer attributed to his early experience in the National Income Unit. Whatever its source, from his doctoral dissertation, in which he measured changing concentration in the steel industry, to his final works on environment, he felt that theory must eventually be put forward in the form of testable propositions. He spent considerable time finding appropriate and adequate measures for the propositions he himself put forward, no easy task, given the problems of dealing with ore deposits and the natural environment. One of his

[6] See also Edward S. Mason's response to Ciriacy-Wantrup and Herfindahl in "The Political Economy of Resource Use," *Perspectives on Conservation*, Henry Jarrett, ed. (Baltimore: The Johns Hopkins Press for Resources for the Future, Inc., 1958), pp. 161–162. Mason suggests that it is too late to make *conservation* into a value-free term, though he accepts their view of its economic meaning.

last works is almost a catalog of possibilities for obtaining the data needed to test models of environmental pollution [25].[7]

The final theme is in some ways the most characteristic and the most difficult to treat—his insistence that economics must rest on explicit ethical principles. Thus, his work generally reflects the assumption that the market system is basically benign, a view that accorded well with his desire for systematically finding and providing orderly philosophies, as well as with his conservatism. Needless to say, he accepted such modifications of market results as were required by the existence of externalities and economies of scale, but for much of his career he believed that the market would provide, if not the best of all possible worlds, at least an economically and ethically acceptable one. The word *ethically* was of course critical, for he accepted the results of the market system only because he also accepted its ethical underpinnings, notably the lack of coercion of man by man, and the responsibility of each individual for his own actions. He consistently developed his models and policy conclusions within this framework. Additional ethical values were incorporated without difficulty in his early work by making adjustments in order to improve the distribution of income.

As Herfindahl's attention turned toward the environment and natural areas, and more generally toward the quality of life, he became less certain. In a 1972 memo to his colleagues at Resources for the Future, he wrote: "The events of the last decade or so have shown that the perennial apprehensions of many persons about the prospects of mankind for a long-continued enjoyment of a high standard of living were justified". In the face of this conclusion, he found it difficult to reconcile some of his personal values with the workings of the market system. On the one hand, he saw no way to avoid losing certain things he valued highly, unless individuals exercised self-restraint; on the other hand, he saw little evidence that self-restraint was growing any more common than it had ever been. Society could of course impose restraints (though Herfindahl was by no means sanguine about the politics of this), but this in turn challenged the individualistic values also critically important to him.

Such trends no doubt account for the note of pessimism that appears in some of his later work, notably in "Effects of Resources Depletion and Economic Growth on the Quality of Life" (printed as selection 17). And it may explain his return to theoretical work in the last years of his life, which can be seen as a retreat from policy

[7] Herfindahl was largely responsible for part 3 of this paper, entitled "Data Needs Suggested by the Models for Analysis of Environmental Pollution."

applications in order to find a new path that could circumvent the dilemma. One characteristic of nineteenth-century economic liberals (among whom Herfindahl numbered himself) and twentieth-century political liberals (with whose goals he had much sympathy) alike is a faith in and a mistrust of man. Orris Herfindahl was aware of his duality of thought in this regard; much of his study of philosophy and work in economics can be seen as an effort to reconcile the two.

Thus, the heritage that Orris Clemens Herfindahl leaves is to be found not only in his contributions to the study of natural resources, but also in the ethical precepts that were incorporated with them. His family and his associates received these directly. Others have the opportunity to learn of them through his writing.

PART ONE

The Nature and Scope of Resource Economics

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