The Future of Science

Scientific Progress. A Philosophical Essay on the Economics of Research in Natural Science. NICHOLAS RESCHER. Blackwell, Oxford, and University of Pittsburgh Press, Pittsburgh, 1978. xiv, 278 pp., illus. $18.95.

Nicholas Rescher prefaces this philosophical essay with the claim that "influential voices sound all around us with predictions of an imminent end to scientific progress." Readers who have not heard the alarm are likely to be surprised by Rescher's insistence that he addresses the question of limits to scientific progress at a time when the scientific community is suffering a "failure of nerve" and a "crisis of self-confidence" reminiscent of what beset the aristocracy on the eve of the French Revolution. Rescher grossly exaggerates its urgency, but the question he raises is nevertheless of considerable interest. His major contribution is to recognize the possibility that limits to the advance of science need not depend on the finitude of nature or on man's capacity to comprehend it. Instead, Rescher argues that the binding constraint on scientific progress is economic; he claims that the technology of producing scientific knowledge is subject to diminishing returns.

Rescher's central concern is to analyze the determinants of the rate of scientific progress. For a philosopher he pays surprisingly little attention to the more fundamental problem of defining what constitutes scientific progress. For purposes of his central argument he simply measures scientific progress by the number of "first-rate findings" in a given time period. This standard begs the obvious question of what is a first-rate finding, but, on the rather strong assumption that this criterion can be made operational, it offers two principal advantages. First, scientific progress is not identified with increase in the total volume of scientific publications; indeed, it is arguable that publications are a better measure of scientific input than of scientific output, since they are a requisite of career advancement rather like education. Second, Rescher's quantitative approach to measuring progress sidesteps the controversial issue of whether scientific knowledge is cumulative. It has become orthodoxy among philosophers of science that scientific advance is not merely a matter of generalizing older theories to encompass a broader range of phenomena; often new theories annihilate older theories, changing utterly the context in which phenomena are perceived and interpreted. Measuring progress by first-rate discoveries is not inconsistent with this view, since first-rate discoveries may either extend an existing paradigm or overturn one.

Rescher's somewhat simple-minded operational measure seems adequate for his purpose, but he cannot resist the temptation to comment briefly on the deeper issues. He bows grudgingly to Thomas Kuhn by begging the question whether there has been "improvement" in the adequacy of scientific theories to comprehend the world, but he insists that scientific progress can also be understood as improvement in man's control over nature in a technological sense. This conflation of scientific and technological progress is wholly unilluminating.

Rescher seeks to explain the rate of scientific progress by constructing a theoretical model rather similar to models of economic growth. The structure of his model—and lamentably the arbitrariness of his crucial assumptions—suggests that his real source of inspiration was not an imminent crisis in the scientific community but the recent neo-Malthusian literature on the limits to economic growth. Rescher does not assume that the stock of potential scientific discoveries is finite, but he does postulate that the phenomena giving rise to significant findings are distributed logarithmically over parameter space. In other words, as technology extends the range of feasible experimental conditions (higher energy levels, lower temperatures, and so on), the maintenance of a constant flow of additions to the stock of first-rate findings requires a constant flow of order-of-magnitude extensions in the parameter range. While this "findings-distribution" assumption has some intuitive plausibility, Rescher offers no evidence to support it.

A second crucial link in the argument is the assertion that the cost of experimental apparatus rises more than proportionately with extensions in the accessible range of parameter space. This premise, together with the assumption concerning the distribution of findings, suffices to assure that an exponential increase in the resources devoted to science will yield only a linear increase in first-rate findings. Over time a constant exponential growth of resources will thus produce a steady advance of science in the sense of a constant stream of first-rate findings per unit time. Rescher asserts that recent history confirms the validity of this proposition, but his evidence is fragmentary and not particularly compelling.

The final step of the argument is the most troublesome. Rescher simply assumes that economic growth will cease, and therefore that the resources annually devoted to scientific inquiry will reach an upper bound. Under such conditions, the prior two assumptions compel the conclusion that first-rate findings will be distributed logarithmically rather than uniformly over time; thus, first-rate findings will occur with decreasing frequency. Scientific progress will not end, but it will observe Rescher's "law of logarithmic retardation."

The virtue of this modeling effort is that it calls attention to some crucial determinants of the rate of scientific progress. In the language of economics, these are (i) the "supply" of potential scientific discoveries inherent in the structure of the natural world, (ii) the technology, or "production function," relating resource inputs to scientific outputs (findings), and (iii) the supply of resource inputs available for scientific inquiry, which depends on, among other things, the rate of growth of the economy as a whole. A principal defect of Rescher's work is that he makes highly restrictive, arbitrary, and empirically unsupported assumptions about the form of these supply and production functions. There are a wide variety of alternative assumptions that would not compel a conclusion of deceleration in scientific progress. Even if one accepts Rescher's unverified assumption about the distribution of potential discoveries, sufficiently rapid improvement in the technology of inquiry may offset for a considerable time any tendency toward deceleration of scientific progress. Rescher cites two examples of research apparatus (telescopes and particle accelerators) where costs have increased more rapidly than performance. But it is not difficult to cite powerful counter-examples, most notably the enormous reduction in the costs of computation. As in economic growth models from Ricardo to Meadows, it is

an empirical question whether technical progress offsets the diminishing returns inherent in nature.

Caught in a web of arbitrary assumptions describing the technology of scientific inquiry, Rescher does not perceive that his argument for the deceleration of science is ultimately dependent on the cessation of economic growth. He is surely correct in recognizing that there is a connection between scientific and material progress, but it is ironic that the principal conclusion of a closely reasoned argument about the future of science rests on an unexamined premise about the future of the economy.

RICHARD LEVIN
Department of Economics,
Yale University,
New Haven, Connecticut 06520

Pressures Toward Bigness

The Visible Hand. The Managerial Revolution in American Business. ALFRED D. CHANDLER, JR. Belknap Press of Harvard University Press, Cambridge, Mass., 1977. xvi, 608 pp., illus. $18.50.

The view that the large, multiunit corporation is one of the most influential institutions in American society would doubtless command instant and widespread agreement. There is, to be sure, disagreement whether the influence has on balance been benign or malignant, but those at both ends of the political spectrum agree on the capacity of the large corporations to shape our lives and perhaps the destinies of our children. And yet, if one defines the role of social science as that of explaining our present situation, it has to be admitted that its accomplishments with respect to these central institutions have been distinctly modest. Although the corporation has been intensively studied from many specialized perspectives, our understanding of why it has taken its precise present forms and what factors account for its size and its explosive growth in the 20th century is still notably deficient. Far too much energy, for example, has been expended on painting business leaders as robber barons or industrial statesmen and far too little on analyzing the genuine but somewhat elusive functions of administrative coordination. For clearly such coordination is an important aspect of enterprises consisting of increasingly numerous and more and more highly specialized activities.

In *The Visible Hand* Alfred Chandler, who is perhaps the closest and most careful student of American corporate history, offers what must be regarded as the most ambitious attempt to date to explain large-scale corporate enterprise in light of the historical forces that have given it life and shape.

The title of the book serves to announce its central theme. Adam Smith's *Wealth of Nations*, published in 1776, presented an analysis of how the market mechanism in a capitalist society could be relied upon to bring about an efficient allocation of the society's scarce resources. So long as individual households and firms were free to pursue their own interest without impediment or restraint, and so long as the marketplace was permitted to register accurately, through changes in price, the ever-altering conditions of supply and demand, individual self-seeking could be relied upon to serve the public interest as well as the private. Adam Smith's invisible hand represents, thus, the guidance to resource use offered by the forces of the marketplace. Such a system of market-regulated allocation was adequate so long as small-scale enterprise remained economically efficient. But these conditions, Chandler believes, began to be rendered obsolete around the middle of the 19th century by the emergence of forces favoring growth in the size of the business unit. With such growth the marketplace was more and more displaced as a mediating force by managerial decisions inside the firm, or rather the boundaries of the firm gradually expanded to internalize flows and transactions that had formerly been mediated through the marketplace. In this manner, administrative and allocative decisions by the visible hand of management substituted for the invisible hand of the marketplace in coordinating supply and demand. Such coordination made possible a more efficient utilization of capital and reduced the transaction and information costs of business operations.

What accounted for the increasing advantages of bigness that inexorably enlarged the role of a specialized managerial class? It is difficult to do justice to Chandler's answer to this central question, for in providing it he spends 600 pages marshaling and analyzing historical evidence. The essence of the matter lies in a combination of rapidly expanding markets and technological innovations. The introduction of new coal-using technologies and the unique opportunities offered by the railroad and telegraph made possible vast improvements in economic efficiency, but the improvements were attainable only through unprecedentedly high volumes of production and high-speed processing of materials.

> The new sources of energy and new speed and regularity of transportation and communication caused entrepreneurs to integrate and subdivide their business activities and to hire salaried managers to monitor and coordinate the flow of goods through their enlarged enterprises. The almost simultaneous availability of an abundant new form of energy and revolutionary new means of transportation and communication led to the rise of modern business enterprise in American commerce and industry [pp. 77–78].

There was another essential element to the speed of growth of large-scale business enterprises, with their hierarchies of full-time salaried managers, in the years between the Civil War and the First World War. The immense increase in scale of operations—typified by the case of the railroads themselves—meant a huge investment in capital and a consequent high ratio of fixed to variable costs. Such conditions quickly proved to be incompatible with atomistic competition of the kind celebrated by Adam Smith a hundred years earlier. The relentless pressure of fixed costs and the evident unworkability of uncontrolled competition led to extensive experimentation with new organizational forms in the last 20 years of the 19th century. As Chandler's analysis of the experience of the railroads makes abundantly clear, decisions to combine large bureaucratic corporations into even larger units, and thus to internalize their activities and transactions, did not reflect further opportunities for cost reduction through administrative coordination but rather were desperate responses to competitive pressures.

The combination of cheap power and the new opportunities offered by technological revolutions in transportation and communication led not only to the spread of a mass-production factory technology but to a system of mass dis-