Role of Knowledge in Economic Growth

Richard R. Nelson

A principal task of any economic system is the generation of information to guide production units in choosing among alternative inputs, techniques, and outputs. Much of the traditional theory of the operation of a competitive economy is directed toward exploring the question: To what extent and under what conditions will the structure of prices established by competition encourage efficient allocation of the economy's human and material resources? Efficiency is defined in the sense that output of each product is maximal, given total available resources and the output of other products, and the composition of output is of the highest possible value, given the distribution of income in the economy. In a very real sense this is a theory of information generation and processing. The messages generated are the array of market prices. These prices imply different degrees of profitability for different economic activities. The various activities are assumed to be expanded or contracted in accordance with their profitability. In short, the economic system is viewed as a huge analogue computer that generates and processes information to guide economic decisions. This information processing theory of an economic system has played a prominent role in the analysis of planned economies as well as in that of market economies.

In recent years the economists' interest in the role of information and knowledge in an economic system has increased and broadened greatly beyond its traditional focus. The principal reason is the growing body of empirical evidence that technological advance and rising levels of education play a very great role in the process of economic growth. Although economists have long suspected as much, it was easier, in the absence of strong empirical evidence, to pay lip service to these factors but to continue to focus on such topics as the growth of labor and capital rather than to try to deal seriously and deeply with the process of technical change and the role of education. However, when the data suggest that, in the absence of technical change and rising levels of education, the growth rate of the American economy would have been only about half of what it actually has been, the issue can be ignored no longer.

When data compiled by comparing different industries and that compiled by comparing firms within an industry, both suggest that there is a significant correlation between prior expenditure for research and development and subsequent growth of productivity, clearly those interested in understanding and predicting the increase of productivity must begin to study the mechanisms involved. When the data show a high correlation between the per capita income of a particular region in the United States and the average educational attainment of its citizens, as well as between the incomes of individuals and their educational attainment, there is a clear need to examine the functions of educated people which call forth such high remuneration and which seem to be so productive. It is clear that the production and distribution of knowledge is intimately connected with long-range economic progress; therefore, a better understanding of the processes involved is essential, to improve long-range projections of economic growth and to improve the formulation of economic policy.

Traditional economic analysis treats the role of information and knowledge in guiding the allocation of resources in a quite sophisticated and illuminating way. What is needed is an equally illuminating treatment of the role of knowledge in economic growth.

An economist interested in these kinds of problems will be somewhat disappointed with Fritz Machlup's book, **The Production and Distribution of Knowledge in the United States** (Princeton University Press, Princeton, N.J., 1962. 436 pp. $7.50). Machlup is concerned principally with identifying and quantifying the inputs and outputs of the knowledge-producing parts of the economy and only secondarily with analyzing the function of knowledge and information in the economic system. Although it is not quite fair to criticize a book that does one useful job for not doing another, this is in fact my major criticism. The subject is so important and so interesting and this book's title and early pages appear to promise so much that it is faint praise to say Machlup has done a very skillful job of examining and describing certain aspects of the economics of the knowledge-producing industries in the United States and that he has collected a vast quantity of useful data.

The focus of the book is set in chapters 1 through 3 where the author defines what he means by knowledge, differentiates between knowledge used as an end product or consumption item (for example, a work of fiction) and knowledge used as a factor of production (for example, an engineer's advice on production scheduling), and essentially sets his task as that of measuring the production and distribution of different types of knowledge. In these chapters Machlup deals only superficially with the difficult problem of analyzing the various roles and functions of knowledge in an economic system.

He then explores various knowledge "industries": education, research and development, communications, information machines, and information services (legal advice, among others). The flavor of the book is suggested by the fact that, in his chapter on education, Machlup does not explore the reasons why education is productive and remunerative. Rather, he sets himself the task of trying to measure total resources absorbed in education in the United States: education in school, training on the job, training in the armed forces, instruction in church, education on television, and education in the home. For several of these categories (such as education in school) Machlup has dredged up a fascinating set of useful statistics. For others (such as education in the home) he has to make do with clever estimates. In sum, he concludes that the value of resources absorbed in

The author, a former member of the President's Council of Economic Advisers, is now with the Rand Corporation.

education outside the formal school system accounts for more than a quarter of the total. Machlup also does a very thorough and imaginative job of collecting and developing statistics on the communication industries. But it should be noted in passing that his statistics on research and development are essentially a rehash of readily available data compiled by the National Science Foundation.

After presenting the available data on the various knowledge-producing industries, Machlup estimates that, in 1958, the total production of these industries amounted to approximately $136 billion. Turning next to occupations which are related to the production of knowledge, Machlup finds that the incomes of the relevant occupational groups (professional and technical workers, clerical workers, and the like) were approximately 30 percent of total incomes in 1958 and that the percentage has risen significantly in recent years.

In addition to collecting a considerable body of data on the production and distribution of knowledge, Machlup has also provided a number of interesting ideas on public policy. In his chapter on education he suggests that the nation aim to cut down on the average number of years of schooling per student and to increase the length and academic content of each school year. In his chapter on research and development, he argues that perhaps the nation is spending too much on industrial R&D.

His suggestion for compressing the primary and secondary school curricula is based in large part on data (originally developed by Theodore Schultz) which show that the cost to the nation of providing a year of education for a student in his middle teens far exceeds the costs of providing a year of education for a primary school student. A large part of the costs of high school education is not included in the school budgets; instead, it represents earnings that the student foregoes by not entering the labor force. For example, in 1956 the average cost for a year of high school education was approximately $2000 per student; of this amount, approximately $600 represents school costs and $1400 represents earnings the student has sacrificed by remaining in school.

Machlup believes that educational experiments in the United States and the experience of educational systems in other countries strongly indicate we could provide the equivalent of our present 12-year education in less than ten years and that we could thus reduce significantly the costs to the nation of providing such an education. Under the Machlup proposal, students would be younger when they complete their high school education and, hence would enter the labor force earlier. The objections to this proposal are numerous and obvious. Machlup deals effectively with some but not with others.

Machlup's suggestion that the nation may be spending too much on industrial R&D stems from the argument that the supply of scientists and engineers is quite inelastic in the short run and that a sharp increase in industrial R&D, such as we have experienced in recent years, can be obtained only by bidding scientists away from the universities.

In collecting and interpreting a vast quantity of data on the production and distribution of knowledge in the United States Machlup has performed a very valuable service. He also has provided several interesting ideas on public policy issues. If his book does not touch many of the most important conceptual problems of the economics of knowledge, it does provide data that can be used by others to shed some light on these problems.

Research on the Antarctic

Antarctic Research. The Matthew Fontaine Maury Memorial Symposium. H. Wexler, M. J. Rubin, and J. E. Caskey, Jr., Eds. American Geophysical Union, Washington, D.C., 1962. x + 228 pp. Illus. $10.

The Royal Society International Geophysical Year Antarctic Expedition. Halley Bay, Coats Land, Falkland Islands Dependencies, 1955–59. vol. 3, *Seismology and Meteorology*. Sir David Brunt, Ed. Royal Society, London, 1962. xviii + 382 pp. $23.

[*Both of the volumes reviewed here are reports of research carried out as a result of the International Geophysical Year.*]

The AGU's monograph contains the papers presented at the Matthew Fontaine Maury Memorial Symposium, which was held at the Tenth Pacific Science Congress (1961). The volume is dedicated to Maury who, when he was superintendent of the U.S. Depot of Charts and Instruments, urged international cooperation in Antarctic research and attempted to interest his colleagues abroad in such a venture. In April 1861 Maury culminated his efforts by dispatching official letters with detailed discussion of his proposal for international cooperation in Antarctica to the Ministers of Portugal, Italy, the Netherlands, Spain, Great Britain, France, Russia, Brazil, and Austria. But the Civil War intervened, and it was almost 100 years before Maury's dream came true. Then 60 nations did pool their resources in the vast cooperative IGY, and 12 of them also participated in research in Antarctica.

The scientific papers are divided into two parts: (i) Geography, Solid Earth, and Upper Atmosphere and (ii) Meteorology, Oceanography, and Glaciology.

There are ten papers in the first section and 14 in the second. Eleven of the authors are from the United States, six from the U.S.S.R., three from Argentina, two from the United Kingdom, two from New Zealand, and one from Australia.

Because I am a seismologist, I found most interesting George P. Woolard's paper "Crustal structure in Antarctica." Woolard bases his conclusions on seismological, gravitational, and topographical observations. The seismological data come from refraction studies over several traverses. Woolard concludes that the total thickness of the crust under Western Antarctica is about 32 km but that under Eastern Antarctica it is about 42 km; that there is no significant difference in the velocity structure in the upper 5 km of the two parts; and that the continent is in isostatic equilibrium.

The dedication to Maury was written by Harry Wexler, who died in August 1962; the volume also contains a memorial to Wexler and one to Edward C. Thiele who was killed in an air accident in Antarctica in 1961. J. Tuzo Wilson made the opening remarks at the symposium, and these are also recorded in the monograph.

In the introduction to the Royal Society's volume Sir David Brunt, the editor, gives the history of the organization of the IGY, particularly with respect to Great Britain and the Halley Bay Expedition. The list of alphabetical abbreviations that follows was especially pleasing to me; although I have often heard them used, I do not know (or I have forgotten) what they stand for.

Forty-eight pages are devoted to a paper entitled "Seismological observations," by J. MacDowall and E. M. Lee.