Book Reviews

Civilian Technology and the Federal Government

Technology, Economic Growth, and Public Policy. RICHARD R. NELSON, MERTON J. PECK, and EDWARD D. KALACHEK. Brookings Institution, Washington, D.C., 1967. 252 pp., illus. $6.

The past decade has witnessed a very intense and widespread interest in the economics of technological change. This surge of attention has been due to many factors, one of the most important being dissatisfaction among economists with existing explanations of the growth of output per worker. *Technology, Economic Growth, and Public Policy* is a valuable contribution to this new and important field of economics. Primarily a synthesis and interpretation rather than a statement of new results, the book surveys the literature regarding technological change and economic growth, brings together the many diverse strands of fact and argument that are scattered among various journals and books, and relates the results to problems of public policy. There is no pretense of surveying all aspects of the economics of technological change; attention is confined almost exclusively to the relation between technology and economic growth (including problems of adjustment to new technology). The book is a well-executed, concise, and readable treatment of the subject, one which should be of interest to a large number of scientists and engineers.

The authors begin by considering the role of technological change in the process of economic growth. They conclude that, although new equipment and an educated labor force are necessary complements to technological change, technological advance—the application of new knowledge to expand or improve the output of goods and services—plays the leading role in economic growth. Because of the complex interactions among the various factors that affect the economic development of a country, it is very difficult to estimate from historical statistics the precise effects of a nation's rate of technological change on its rate of economic growth. The authors are quite right to point out the limitations of various quantitative studies of the contributions of technological change (one of which concluded that the advance of knowledge contributed about 40 percent of the total increase in national income per person employed during 1929–57); however, as in other parts of the book, they are perhaps too much inclined to rely solely on qualitative judgments. Whether or not they overemphasize the importance of technological change in the growth process, they certainly are right in putting it in a very important spotlight.

Next they discuss the factors determining the rate and direction of technological advance. To economists, invention is an activity characterized by great uncertainty, but one which nonetheless shares most of the characteristics of other economic activities. The general opinion is that the rate of technological change in a particular area is influenced by the same kinds of factors that determine the output of any good or service.

On the one hand, there are demand factors which influence the rewards from particular kinds of technological change. For example, if a prospective change in technology reduces the cost of a particular product, increases in the demand for the product are likely to increase the returns from effecting this technological change. On the other hand, there are also supply factors which influence the cost of making particular kinds of technological change. Obviously, whether people try to solve a given problem depends on whether they think it can be solved and how costly the solution will be, as well as on the payoff if they are successful. For example, the cost of making science-based technological changes depends on the number of scientists and engineers in relevant fields and on advances in basic science.

After describing the various kinds of organizations that create new or improved technology, the authors focus attention on the concentration of industrial research and development in large firms, on certain product lines, and on modest design improvements. They point out that, although large firms tend to spend more (relative to their sales) on research and development than small ones, the largest firms often spend no more (relative to their sales) than their somewhat smaller competitors. They also point out that a few industries account for the bulk of the nation's research and development, but they recognize that there may be advantages in certain industries' specializing more than others in R&D. In addition, they assert that, outside defense and space, industrial research and development tends to seek relatively modest design improvements. In their judgment, this concentration on short-reach applied research and development probably results in more serious distortions of the process of technological change than the concentration in large firms and in a relatively few industries and product fields.

To remedy this distortion, they propose that a National Institute of Technology be formed to provide grants for projects that try to increase significantly the efficiency of a large class of products, that have a reasonable chance of yielding high returns, and that are being neglected by business firms. The emphasis would be on problems lying between academic basic research and specific product development. Support by the institute would carry research and development only to the stage where feasibility and broad-scale attributes of a particular process or product were demonstrated. It would not be designed to bring the technology to the point of operational utility, that stage being left to private initiative. However, under special circumstances where the necessary expenditures are very large relative to private capabilities, the institute would conduct the work through the expensive development stages as well as through the earlier stages.

In addition, the authors suggest that, in a very limited number of cases, a long-run commitment of federal funds for research and development in a particular industry may be justified. To obtain such support, the industry must have a low level of R&D activity, a low rate of technological change, and institutional barriers that deter research

and development by private firms, and, in some sense, the social value of more technological progress in the industry must be high. Finally, they propose that federal purchasing power be used in civilian markets to speed innovation in products which the government buys extensively. An experimental procurement service would promote the purchase of new products, their performance would be monitored and recorded, and the results would be made public.

To those who have followed recent developments in this area, the relationship between these proposals and the ill-fated Civilian Industrial Technology Program will be apparent. In 1963, the Department of Commerce proposed the Civilian Industrial Technology Program to encourage and support additional research and development in industries that it regarded as lagging. The proposal met with little success on Capitol Hill. Industrial groups opposed the bill because they feared that government-sponsored research could upset existing competitive relationships. The program also included an industrial extension service, which was later established by the State Technical Services Act in 1965. Nelson, Peck, and Kalachek criticize the latter legislation for failing to stress sufficiently the use of the new extension service as an experiment to determine the benefits and costs of aiding firms that are technical laggards.

This book represents the thinking of some of the best and most influential workers in this field, men who have had an opportunity to participate at times in policy-making as well as to conduct relevant research. To a considerable extent, the limitations of the book reflect the important limitations of the basic fund of knowledge in this area. As the authors admit, there is little evidence to support some of their judgments and policy proposals. For example, what solid evidence supports their belief that undue emphasis on short-reach applied R&D "represents a far more serious distortion than concentration in large firms and in a few industries and product fields"? Fully aware of the difficulties in constructing an explicit model to provide estimates of social rates of return from research of various kinds, the authors make a determined effort to reach policy conclusions without such estimates. Their conclusions are very interesting and their discussion is worthwhile, but, as they recognize, the results are limited significantly by the weakness of the relevant base of fundamental knowledge.

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Concepts and Concept Learners

Experiments in Induction. EARL B. HUNT, JANET MARIN, and PHILIP J. STONE. Academic Press, New York, 1966. 261 pp., illus. $9.50.

The activity of "concept learning" may be defined as follows: "Given a set of objects which are to be partitioned into two disjoint sets, to find a description which is valid for all objects in one set and is not valid for any object in the other set." When one attempts to form a precise mathematical model for such an activity, however, one finds this definition woefully inadequate. The word *object* and the word *description* themselves need definition. In the consensus of workers active in modeling concept-learning activities, the following definition seems to be acceptable:

The act of concept learning is meaningful only when it is carried out in a specified environment. An environment is specified by setting down a set of properties (often called "dimensions") by which objects can be distinguished. Each dimension has a set of values. No object can have more than one value in the same dimension. An object in the environment is completely specified by specifying its value in each of the dimensions.

A description is a statement made in a language designed to reflect the structure of the specified environment. The language has a set of unary predicates as its building blocks—predicates which stand for sentences like "This object has value A of dimension B." The language also has auxiliary logical symbols by which predicates can be combined to yield compound sentences. Since each individual object satisfies the conjunction of a unique set of predicates, any concept can be described as a rather large sentence in what the logician calls a "normal form." (We shall not consider here the cases when the set of dimensions and values is not finite, although we thus exclude some important classes of concepts.) However, the idea of expressing a concept in normal form is impractical in any device of realistic size (including any physically realizable neural mechanism of the human brain). A concept learner has to come out not with just a description of a set of objects but with a "simple" description.

One often makes a second, more exacting demand of a concept learner. It is expected that a correct description be obtained by the learner with the knowledge of only a few objects from the set to be described and only a few from its complement. This is clearly an impossible task unless the class of sets to be described is somehow restricted and this restriction is reflected in the structure of the concept learner.

When the logical connectives in the language specifying the environment are restricted to "and," "or," and (under duress) "not," one can design a concept learner which yields simple descriptions of some sets of objects and more complicated descriptions of other sets of objects. A number of concept learners of this nature have been designed and investigated by the authors of *Experiments in Induction.* The descriptions the authors have used are expressed in "tree" form so that conjunctions are the simplest and hence the most easily generalizable of the connectives. A number of specific methods (not necessarily logically complete or efficient) have been suggested and tried for cases where the concept is not expressible as a conjunction. The performance of these learners has been studied statistically by varying the order in which the objects are presented to them and has been compared with that of humans. It would be very interesting to make a logical study of the learners to find out why concepts are learned more efficiently for some sequences of presentation than for others, especially in view of the authors' tentative conclusion that the use of specially selected methods for presenting evidence does not improve the learners' performance.

At this early stage of experimentation it is obviously unfair to expect that the concept learners designed so far will be of practical utility except in very special cases. As the authors have pointed out, the problem of developing proper dimensions (a new set of concepts) for the purpose of simplifying the most frequently occurring sets is an important problem meriting further attention. (This problem is called "feature extraction" in a related field.)