Book Reviews

Technological Change

Patterns of Technological Innovation. DEVENDRA SAHAL. Addison-Wesley Advanced Book Program, Reading, Mass., 1981. xviii, 382 pp., illus. $34.50.

Economic analysis of technological innovation has followed two main approaches. The first, represented by the work of Edwin Mansfield, Zvi Griliches, and Edward Denison, relates macro-level dimensions of technological change (contribution to growth of output or interindustry productivity differences, rate of diffusion) to sets of economic variables (profitability, costs of an innovation). The second, a micro-level approach, represented by the work of Nathan Rosenberg, Bela Gold, and Richard Nelson, uses the evolution of a given technology or the behavior of specific firms as a unit of analysis to identify the factors and processes that affect the changing economic environment of a firm or industry and the changing characteristics of a technological innovation. Devendra Sahal's *Patterns of Technological Innovation* is an ambitious and impressive, but not always convincing, attempt to integrate these two research traditions.

The book involves a search for regularities in the origin, diffusion, and development of new techniques. Reflecting its genesis in a series of previously published articles, it covers such a wide variety of topics—relationships between science and technology, diffusion of innovation, technological cycles—that its many striking propositions cannot possibly be examined in a single review. The central theme of the book, however, is the diffusion of innovation; likewise the focus of this review.

Sahal combines several themes in the literature to advance two principal propositions concerning the diffusion of innovation. The first, a "diffusion via learning" hypothesis of technological change, suggests that innovations seldom remain unchanged during their adoption. Increased use of a technique often hinges upon improving its functional aspects and discovering new uses for it. In turn, both forms of learning are related to the accumulation of production experience. One of the major themes advanced by Sahal is that diffusion of technology is inherently a multidimensional phenomenon: during the time a new technology substitutes for the old, it usually undergoes numerous changes. This is an idea reminiscent of George Terborgh's concept of "functional displacement" (expounded in his *Dynamic Equipment Policy*, McGraw-Hill, 1949), which finds restatements and evidence in the studies by Gold and Rosenberg. Sahal further supports this multidimensionality argument by presenting case studies of the diffusion of the farm tractor, digital computers, transportation equipment, and means of generating electrical power.

In conjunction with this first proposition Sahal argues that the process of technological innovation is object-specific, that is, the development of every technology involves a learning process that is at least partly unique. Because technological learning is context-dependent, interindustry transmission of technical know-how is minimal.

Sahal's second proposition relates to the influence of scale on the characteristics of innovations: "The evolution of a technology often proceeds along more than one pathway so as to meet the requirements of its task environment. This is reflected in the fact that there exist many different types of the same technology, at least during the initial stages of its evolution" (p. 116). As evidence, Sahal points to the emergence of different locomotive technologies, yard switching, road freight, and road passenger service; and different farm tractors, the track type, the wheel type, and the garden variety. A converse proposition is also advanced: the process of development is often retarded because of the lack of adaptation between a technology and the larger system in which it will be used. The diffusion of an innovation (and the relative presence of competing technologies) thus depends on whether the scale of the large environment and the characteristics of the innovation are appropriately matched during evolutionary changes. Sahal combines these influences to contend that "innovative activity involves as many instances of deadlock as of progress," and further, "many seemingly instantaneous advances in technology are in fact based on prolonged development effort" (pp. 110–111). These are not new findings; however, they are given a new force because Sahal has rooted them in the intricacies and constraints of engineering design, such as the influence of rules of thumb on the design of steam locomotive engines.

Sahal underpins his arguments in two different ways: econometric testing of hypotheses and formulation of "lawlike relationships" akin to Boyle's law. Sahal's econometric tests provide passing support for his proposals, being subject, however, to many reservations concerning model specification, quality of data, and levels of significance. The case studies themselves are of uneven quality. The strongest of the studies is that of the diffusion of farm tractors, but even it falls short of the quality of single case diffusion studies such as Moses Musoke's study of the diffusion of tractors for cotton production (*Explorations in Economic History* **18**, 347 [1981]). I found the search for lawlike relationships disquieting and most often unconvincing, representing truncation of the complex processes that Sahal so astutely analyzes into simple relationships and receiving scant support in the empirical tests.

Overall, the book is a mixture, at times impressive, at times overreaching, of fresh insights, potentially important restatements of propositions that have failed to sufficiently influence theoretical or policy thinking, and underdeveloped theoretical or empirical arguments for strongly presented generalizations. It is a book to be read for the freshness and profuseness of its ideas, not for the convincing quality of its findings.

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Water Stress in Plants

The Physiology and Biochemistry of Drought Resistance in Plants. L. G. PALEG and D. ASPINALL, Eds. Academic Press, New York, 1981. xvi, 492 pp., illus. $70.

After many years of being able to do little more than document the degree of plant growth reduction or damage in response to "water stress," plant scientists have had two decades of tremendous progress in stress physiology research. In the '60's significant improvements and advances were made in meth-