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TECHNOLOGY AND WARSHIP DESIGN: COMMENT, OVERVIEW, AND BIBLIOGRAPHY OF THE ECONOMICS OF TRANSIENCE

by

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"Technology and Warship Design: Capturing the Benefits," the essay by Capt. W.F. Fahey, USN, that won the 1978 Admiral Richard G. Colbert Memorial Prize, was earlier published in this *Review*.[1] Captain Fahey's essay is important because it stresses the benefits to the Navy that could be derived from both a broader understanding of technology and a more systematic approach to the exploitation of existing techniques. As the innovation cycle (invention-development-innovation-diffusion) becomes shorter, he emphasizes the need for better formal education in this area. Arguing that "At no military school is there to be found a course on pure technology and how to deal with it,"[2] Captain Fahey expresses the opinion that ". . . in our War College, Postgraduate School, and Naval Academy, we need courses that will teach what technology is and how to exploit it."[3] Over the past several years I have taught a course at the Naval Academy that may meet several of the objectives Captain Fahey has in mind. My course deals with the economics of technical change, and although I am not certain of the exact connotation of his term "pure technology," I believe we would agree that economic factors play a role. There are strong strands of economics running through his article and at several points he alludes to the idea best summarized by: ". . . technology requires that the economics of permanence be replaced with the economics of transience."[4]

I am in general agreement with this thesis. Additionally, I am convinced that economics has a large role to play in the study of technology. This is an area where I sense, however, that interest is only now beginning to emerge. For these reasons I am anxious to describe my "Economics of Technology" course. Below, I provide a brief introduction to this subject and recommend in some detail topical readings, many of which are used in the course. In addition to describing the course and explaining the integration of several of the topics, I supply a fairly extensive bibliography. Because several appropriate readings are by British authors, bibliographic material frequently is not easily found. The materials recommended, however, do not require an extensive knowledge of economics and treat the technology aspect in reasonably concrete ways. Finally I raise an issue concerning the "economics of transience" and the thesis presented by Captain Fahey as they relate to what I see as a change in the roles of men and weapons on the battlefield.

To quote Captain Fahey again, "The most important step in capturing the benefits that technology offers is to gain an understanding of what technology *is*, and what its economic implications are."[5] To understand technology better and assist in exploring its economic implications, some introductory ideas presented in my course are an appropriate starting point.

Much of the study of the pervasive influence of technological change emanates from papers written in the midfifties by Abramovitz[6] and Solow.[7] Using quite different approaches, both concluded that only a very small portion of the long-term growth in America's output could be explained by an increasing quantity of "real" inputs, specifically capital and labor. The difference between actual long-term output and that which could be "explained" by observable changes in production processes, became known as "the residual." Its size, often estimated at 40 to 50 percent of the total growth, to quote Abramovitz, is a "measure of our ignorance" about how the economy grows. Attempts to quantify factors that explained this residual took place during the sixties and culminated in Denison's *Accounting for United States Economic Growth, 1929-1969*.[8] Denison, in broad terms, studies five factors that might be responsible for economic growth in addition to obvious expansion of labor and capital inputs: (1) improvements in the quality of labor, (2) improvements in the quality of education, (3) improvements in capital, (4) improvements in resource allocation (e.g., movements off farms), and (5) economies of large-scale productions. After exhaustive study of these factors, and others, he found that fully one third of our growth had not been explained. This remaining growth he attributed to the incorporation into our economy of advances in our technological, managerial and organizational knowledge.

This brief review stresses the importance of these intangible elements of change to the macroeconomic growth of our economy. The problems are then left primarily to microeconomists and economic historians who search for underlying causes of, and explanations for, the observed macroeconomic phenomenon. The microeconomic side of the economics of technology builds on the subject within economics known as industrial organization but carries the analysis of several aspects of that subject somewhat further. In microeconomics a firm sells an existing product. Theory is used to determine how the business establishes a price-quantity combination that maximizes its profit under various market structures. Industrial organization addresses rivalry among firms that is based on product differentiation as well as pricing behavior. The microeconomics of technology goes a step further. It attempts to analyze how the existing product, or newly differentiated product, came into being and how it became refined so as to meet market need and acceptance. Additionally, it explores changes in production processes and the effect of these changes on production costs.

Before discussing the research and development required to bring new products to the market, it is useful to discuss a few terms. First, we distinguish between science and technology. Science is directed toward increasing knowledge. Technology is directed toward *use*. It should be clear then why economists are more interested in technology than *science*: new ideas (or products) affect the economy only when they are put into use. Second, a technique is a way of doing something;

thus technology is the set of all known techniques. Should this set expand, technological change has occurred. Science, of course, may have an important role to play in expanding the number of ways of doing something, but more frequently it is not directly responsible. Technology builds on technology, in general, not on science. Most technological change results from incremental improvements, not dramatic ones often associated with scientific discovery. Thus it should be emphasized that technological change is evolutionary, not revolutionary.

Appropriately defined, technology has a broader meaning than is commonly recognized. It is best thought of as "tools in the general sense, including machines, but also including linguistics and intellectual tools and contemporary analytic and mathematical techniques. That is, . . . technology (is) the organization of knowledge for practical purposes . . . . Its pervasive influence on our very culture would be unintelligible if technology were understood as more than hardware."[9] Thus every discipline has its technologies. In economics, for example, these include the gross national product accounts, macroeconomic models of economic activity and the isoquants and indifference curves used in microeconomics. Technological change of an economic sort will occur, for example, if we should attempt to employ "tax-based incomes policies" to deal with inflation.

Much of the intellectual legacy in the microeconomic area goes back to Joseph Schumpeter. He was the first to raise fundamental questions about the economic role of invention (was it endogenous or exogenous to the economy?), innovation and the resulting structure of industry and competition in his paper "The Instability of Capitalism."[10] To Schumpeter, invention (discovery) and innovation (first use of an invention) were distinctly different activities and were carried out by different individuals with different motives. In capitalism, the entrepreneur had the all important role of unleasing gales of "creative destruction" whereby innovation caused the new to replace the old and industrial fortunes to rise and fall. But this pure form of capitalism, according to Schumpeter, was disappearing as research and development became routine in large firms run by mere managers, not entrepreneurs or risk-takers. Managed firms and large oligopoly industries, Schumpeter held, were becoming necessary in order to carry out the increasingly complex and expensive research and development function required now that most of the simple, inexpensive inventions had been made. While this trend would make industry and thus the economy more stable, it would also make it less dynamic and less responsive to change than competitive capitalism.

Schumpeter's ideas were the intellectual springboard for economists to examine the economic role of invention, innovation and diffusion of new processes and products as well as the type of industrial structures most conducive to dynamic economic growth. These questions, if they can be satisfactorily addressed and the results of the inquiries implemented, bring us full cycle—back to the observed macroeconomic phenomenon of economic growth.

But, primarily, it is these microeconomic questions that provide the grist for my course. We begin by a historical look at the machine tool industry which more than any other provided, and still provides, the basic machine technology required for enhancing the output of the capital stock of the country. This is followed by a section on creativity and patents. Theories of invention are discussed. The incentives provided by patents and the limitations of various patenting schemes are explored.

The generation of new technologies is the next section. It is now assumed that the product or process is available,

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albeit in crude form, and the concern is with the economic conditions—essentially demand related—that may speed the process by which refinements occur and the product or process becomes ready for diffusion into the economy. Assuming, now, that the product is in some sense "ready" to be used, the innovation step and subsequent diffusion are studied in more detail.

Before considering the effects of market structure, some attention is given to theoretical aspects of production within a firm. The relationships between technical change and engineering production functions, optimal scale of plant, and cost functions are explored. Following this examination at the level of the firm, some theoretical aspects and empirical evidence of the effect of market structure—perfect competition through monopoly—on research and development behavior are discussed.

With this background, the student is well prepared to study industrial research and development. Subjects are wide ranging and include determinants of R&D spending, characteristics of technologically progressive individuals and firms. R&D as a barrier to competition, R&D as a determinant of a firm's growth, offensive and defensive strategies for firms with different technology implementation objectives and factors related to the technical, marketing and economic success of new products. The section is completed by an introduction to the Navy's RDT&E Manual and an attempt to compare military and industrial research and development management procedures.

Two subjects bring the course to a close. The first deals with the effect of technology on use of the factors of production. Included are readings and discussions stressing first, the role of labor and labor organizations in the design of production facilities, and second, raw material shortages and innovative responses brought on by changing factor prices. Lastly the course deals with a few international aspects of technological change. Comparisons are made between the level of U.S. technology and that of other countries and reasons are advanced for passing production capabilities to less developed nations over the course of a product's life cycle. Additionally, some evidence on planning and forecasting of technological change is presented.

While several of these topics may appear to have little relevance to the paper by Captain Fahey that initiated this exploration into the economics of transience, they are a package designed to get the student to thinking about the economics of change. Although the military may be rather inclined to think of the economic aspects of technological change as being primarily hardware related, there is a growing realization that change has an equally large influence on the services' manpower requirements and use. The recent book by Binkin and Kyriakopoulos, *Youth or Experience? Manning the Modern Military*[11] makes several pertinent arguments in favor of experience.

Experienced manpower, they hold, may be preferred in the future because of costs, demographic patterns and advances in technology that have transformed the occupational needs of the armed forces.[12] If they are right and if Captain Fahey is right (and I believe they are), we may be witnessing an important shift in the relative importance of men and their weapons on the battlefield. While it is a gross generalization, I would argue that in the history of warfare the survival of equipment often has taken priority over the survival of men. If our military manpower is becoming more costly, scarce and less expendable, our hardware is becoming relatively more expendable. This argues, I believe, for Captain Fahey's position with respect to our military hardware: "the economics of permanence must be replaced with the economics of transience."

In a review of *The Production and Application of New Industrial Technology* the reviewer states that the area of technological change is "a field all economists believe to be important, but which relatively few of them have explored."[13] It is my hope that the ideas and bibliographic material presented here will provide some insights and possibly some research ideas that noneconomists will feel are worthy of further study. In particular, those who have an appreciation of the economics of transience may wish to explore the changes in the relative importance of soldiers and their weapons in the art of warfare.

NOTES

1. W.F. Fahey, "Technology and Warship Design: Capturing the Benefits," *Naval War College Review*, Winter 1979, pp. 41-48.
2. *Ibid.*, p. 44.
3. *Ibid.*, p. 48.
4. *Ibid.*, p. 45.
5. *Ibid.*, p. 44.
6. Moses Abramovitz, "Resource and Output Trends in the United States Since 1870," *American Economic Review*, May 1956, pp. 5-23.
7. Robert Solow, "Technical Changes and the Aggregate Production Function," *Review of Economics and Statistics*, August 1957, pp. 312-320.
8. E.F. Denison, *Accounting for United States Economic Growth, 1929-1969* (Washington: Brookings Institution, 1974).
9. Emmanuel G. Mesthene, "The Role of Technology in Society," in Albert H. Teich, ed., *Technology and Man's Future* (New York: St. Martin's Press, 1972), pp. 129-130.
10. Joseph Schumpeter, "The Instability of Capitalism," *Economic Journal*, 1928, pp. 361-386.
11. Martin Binkin and Irene Kyriakopoulos, *Youth or Experience? Manning the Modern Military* (Washington: Brookings Institution, 1979).
12. *Ibid.*, p. VII.
13. Paul B. Manchester, *Rev. of The Production and Application of New Industrial Technology*, by Edwin Mansfield, et al., *Journal of Economic Literature*, March 1979, pp. 131-133.

TOPICS AND SUGGESTED READINGS

	Topics	Readings (from Bibliography)
1.	Machine Tools	43
2.	Invention	50; 4, Chap. 3
3.	Patents	4, Chap. 11; 3, Chap. 3; 32
4.	Technology Generation	44, 52; 29
5.	Innovation and Diffusion	1, Chap. 4; 3, Chap. 6 and 7; 4, Chap. 4; 45
6.	Technology of Production	39; 35; 41
7.	Market Structure and Technical Advance	3, Chap. 5; 4, Chap. 2 and 5; 5, Chap. 5, 6 and 8; 31; 38
8.	Industrial R&D	1, Chap. 3; 4, Chap. 6; 56; 55; 27; 51; 37; 28; 36
9.	Labor and Factor Prices	2, Chap. 5; 40; 47; 48
10.	International Aspects	4, Chap. 7; 26; 57; 54
11.	Planning and Forecasting	33; 1, Chap. 7; 2, Chap. 6

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