THE ROLE OF SCIENTISTS IN TECHNOLOGY TRANSFER: COLLABORATION BETWEEN PUBLIC AND PRIVATE SECTOR RESEARCHERS

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Technology has been defined as "the application of science, especially to industrial or commercial objectives" (McTague, 1988). The benefits of technology, such as improving standards of living and stabilizing the global economy, are widely accepted. Resource allocation and policies to promote technology development are intensely debated. In order to determine how to promote technology development, one must understand the origins and processes by which new technology evolves. This presentation will discuss the importance of technology transfer between researchers in public institutions, such as government and university labs, and private industry for evolution of new technology. Considerations for what scientists can do to minimize the barriers which currently hinder technology transfer are reviewed.

ORIGINS AND EVOLUTION OF NEW TECHNOLOGY

Historically, the origins of new technology have been considered wholly dependent upon new discoveries in science. Science is knowledge of the world and technology is the application of this knowledge to objectives (Bopp, 1988). Science and technology form an assembly line; scientists generate ideas, and technologists transform the ideas into inventions. A society seeking new technology should therefore invest in pure science and new technology will flow spontaneously from new discoveries in science.

The assembly line model for science and technology has influenced more than two generations of science policy makers and scientists in the United States. The model was promoted by a small, influential group of science leaders, who wrote in the 1945 report entitled *Science, the Endless Frontier*, "New products, new industries, and more jobs require continuous additions to knowledge of the laws of nature . . . This essential new knowledge can be obtained only through basic scientific research" (Wise, 1985). The US National Science Foundation (NSF) has reprinted *Science, the Endless Frontier* three times since it was first written. NSF used this report to establish and justify its policy to prioritize funding for nonapplied or nondirected science research (theoretical and/or experimental studies of new or unexplored natural phenomena).

Historians of science and technology now challenge the assembly line model. The late historian Derek de Solla Price argued that technology and science are autonomous disciplines, each creating their own knowledge base, and proceeding independently of one another. New technology grows mostly out of old technology and often proceeds without the necessity for understanding the basic science underlying it. The transfer of information between science and technology is not one-way; technological advances can move science forward as well as science moving technology forward (Wise, 1985).

Price's views appear to be supported by the studies of Lagrish, who categorized 84 award-winning innovations to their origins in industry, university, or government research facilities. Lagrish concluded that "the role of university as a source of ideas for [industrial] innovation is fairly small" and "university sciences and industrial technology are two quite separate activities which occasionally come into contact with one another" (Allen, 1977).

Other studies have attempted to trace the origins of technological advances. Project Hindsight, sponsored by the US Department of Defense in the 1960's, identified 710 events that led to the development of 20 military systems during the previous 20 years (Isenson, 1969). Only 0.3% of the events were classified with the research objective as undirected science—advancement of knowledge for its own sake without regard for possible application. Project Hindsight concluded applied research was most productive in developing new technology in the short-term (less than 20 years) and that undirected research may contribute to new technology in the long-term (30-60 years). A subsequent study of civilian innovations by IIT Research Institute, Project TRACES, sponsored by NSF confirmed this concept of the longer-term impact of science on technology by extending the horizon beyond 20 years to trace the origins of six technological innovations back to underlying basic sciences (Wise, 1985).

If technology is an autonomous body of knowledge enriched but not driven by science, how should public policy and resource allocation be directed to enhance technology development? Resources for nondirected scientific research conducted by government and university laboratories should not be eliminated. Businesses tend to underinvest in long-term discovery research, from society's point of view, because the high cost of discovery makes a profitable return on the investment risky and difficult. Since 1981, Johnson & Johnson provided $180 million in research funding to Scripps Institute. This funding resulted in only one potentially marketable product; a drug for treating hairy cell leukemia, which affects 6,000 people annually. The gain for an individual firm for a research discovery is sometimes far less than the total gain to society due to the application of the discovery to other unrelated industries (Metz, 1988). Discoveries made by government and university laboratories have resulted in new technology for separate and unrelated industries; laser technology was developed for military purposes, but has utilitarian applications ranging from surgery to garment manufacturing.

CLOSING THE GAP BETWEEN INVENTION AND INNOVATION

A fundamental problem in technology development is the gap that often exists between the invention (conceptualization of a new idea) and the innovation (development of the idea into a product or process that is utilized)(Gruber and Marquis, 1969). This gap probably exists because the assembly line model promoted the concept of a one-way transfer of knowledge from science to technology and encouraged isolationism of scientists in public institutions from industry. Although the assembly line model has been rejected, the philosophy that public sector scientists should not closely collaborate with industry, particularly with any one company, to develop new technology still pervades the scientific community today. In the US, 28,000 patents have been issued to federal laboratories, yet only 5% of these patents have been licensed for commercialization (Bopp, 1988). Policy makers question whether the $18 billion per year spent by the US government on research conducted in federal laboratories is being appropriately allocated to enhance technology development.

Many countries have abandoned the assembly line model in recognition that successful innovation is often circular and represents a complex blend of skills. One reason for the rise of Japan to technological eminence is their establishment of an infrastructure, such as Science Cities, to formalize cooperative research between industry, government, and university scientists. Tsukuba is an example of a Science City, established in 1963, and encompassing 50 public sector and 70 private sector laboratories (Ziemba and Schwartz, 1992). In the US, the establishment of land-grant universities and the cooperative extension service are credited with succesful development and transfer of technology to farmers. Nonetheless, no formal national policies exist for technology transfer in urban entomology. What are the barriers which prevent public and private sector researchers from collaborating with industry to develop new technology for urban insect control? What can researchers do to help remove these barriers?

ACCESS TO THE IVORY TOWER

Technology transfer occurs through people, and scientists in public institutions can play an essential role in interacting person-to-person with industry to develop new technology. Scientists must not