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).

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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 underestimate their value in assisting industry to focus beyond perceived existing customer needs, wants, and preferences. Scientists can provide the vision for industry to revolutionize markets and create new ones. In a study for NSF, Battelle Columbus Laboratory (Metz, 1988) reviewed ten major twentieth century innovations to identify factors important in the innovation process. They found that in nine out of ten innovations, a technical "champion" was important. In three cases, this champion persisted despite unfavorable market analyses.

In the US, NASA tried many techniques and spent considerable money to promote transfer of space technology to private sector, commercial applications. Researchers Roberts and Wainer could only demonstrate effective transfer of space technology when scientists left university laboratories to establish their own businesses; no other mechanism demonstrated successful transfer (Allen, 1977). The NASA experience does not mean that scientists must leave their institutions to transfer technology, but does emphasize that scientists should consider an extension of their roles to include active and direct participation in the commercialization process. Experience also indicates the need for specialists in public and private sector institutions who function as liaisons for technology transfer.

Scientists in public institutions and private industry should review and, when appropriate, recommend changes to their institutions' policies to encourage interaction between public and private sector researchers. The US government recognized the importance of this interaction in the Federal Technology Transfer Act of 1986 (Public Law 99-502). This act established Cooperative Research and Development Agreements (CRADA's) which enable federal scientists to work closely with private sector industry to commercialize technology based on scientist's research. CRADA's provide federal scientists with direct feedback from industry on what research industry needs and familiarize federal scientists with the challenges in commercializing a product or process. In 1986, the White House Science Council Federal Laboratory Review panel report recommended that personnel exchange programs with the private sector should be enhanced (Metz, 1988). Policies enacted must preserve the mission of public sector research to foster the public good through discovery and dissemination of new knowledge.

PATENT AND PUBLISH OR PERISH

The publication of research in refereed journals is the traditional method by which scientists establish their reputation as an authority in their field and by which institutions evaluate the research performance of their scientists. Scientists in public institutions, particularly universities, are generally not instructed about the patent law or encouraged to file patents. Nonetheless, historical experience has shown that ideas that are published as "public domain" and not patented tend not to be developed commercially. Inventions are only one step in the process of innovation and commercialization. Other steps include identifying a need, market, or problem, perfecting and testing the invention, raising the fixed and working capital, developing a manufacturing process for a product, and marketing and servicing the product or process (Kozmetsky, 1988). No company will undertake this costly investment if its competitors can incorporate the same ideas into their own products. The cost to develop a new chemistry for insect control, which includes conducting the efficacy, toxicology, environmental fate, formulation, and process chemistry research and constructing the manufacturing facility, can now exceed $100 million. Exclusive licensing of patents provides the protection and thus incentive for a company to develop an idea into a commercial product.

Scientists in public institutions may perceive that patents prohibit publication or presentation of research and limit further academic research on a discovery. Neither are true. A patent application should be filed before the invention is publicly disclosed in written publications or oral presentations. The "research exception" in patent law, although not clear cut, generally ensures that the inventor and other scientists worldwide can conduct research on patented technology.

Scientists in public institutions should be encouraged to learn the fundamental concepts about patent law and licensing, and their importance in technology transfer. The University of Utah formed a new Technology Transfer Office (TTO) in 1986 which has taken a pro-active role in educating university researchers about the technology transfer process (Major, 1991). TTO conducts a variety of seminars and presentations to teach faculty, staff, and students about patents and licensing. TTO developed two brochures, *Inventions and Technology Transfer* and *Patent Basics for University Researchers* which were sent to all university research personnel. TTO also sends research personnel a newsletter *Innovations* which highlights TTO activities, recent disclosures, and issues involving patents and licensing. Annually, inventions disclosed by research personnel have quadrupled at the University of Utah since TTO was formed in 1986. If public institutions want to encourage researchers to file patents, mechanisms must be in place to review and file patent applications rapidly so publications are minimally delayed (Nelsen, 1991). Specialists in public and private sector institutions who function as liaisons for technology transfer can assist in identifying discoveries which could be patented and marketable technologies which could be developed from these discoveries.

MANAGING THE LOSS OF INNOCENCE—REVENUE SHARING FOR INVENTORS

The Federal Technology Transfer Act of 1986 (Public Law 99-502) established guidelines for distributing royalties to inventors in federal laboratories. Government publications promote sharing licensing fees and royalties by scientists and their research agency as a benefit of technology transfer (USDA-ARS, 1992). Most universities also have written policies for sharing revenues with inventors. Revenue sharing can motivate scientists to participate in the technology transfer process, but also creates the issue of conflict-of-interest. Will personal financial gain from licensing and commercializing a patented invention bias how the inventor evaluates alternative technologies and interacts with companies other than the licensee?

Scientists at public institutions should encourage their institutions to establish conflict-of-interest guidelines, if none currently exist, for technology licenses. For example, scientists should disclose any potential conflict of interest to sponsors when negotiating research agreements and the institution should designate a co-principle investigator to oversee research on a project where conflict-of-interest may be an issue (Tom Major, personal communication). In addition, the guidelines should protect the mission of public institutions to generate and disseminate new knowledge. In universities, guidelines should encourage collegial sharing and publication of research and discourage favoring students or faculty working on company projects (Nelsen, 1991). Concern over conflict-of-interest by revenue sharing should not dissuade scientists from participating in the technology transfer; the scientist always has the option of declining his/her revenue share.

CONCLUSIONS

Technology transfer between scientists in public institutions and private industry is one essential step in the evolution of new technology. Public-private sector collaboration often produce advances in new technology that exceed what could be accomplished by scientists working separately. The barriers which hinder collaboration between public and private sector scientists are not simple or easy to remove. The challenge for the scientific community is to overcome these barriers while retaining integrity, impartiality, and vision in research. The challenge for every scientist is to develop a personal research philosophy which defines the individual's role in the technology transfer process.

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