Historical Patterns in the Scholarship of Technology Transfer

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ABSTRACT This essay is the first in a series authored by each Editor-in-Chief of *Comparative Technology Transfer and Society* to provide a sense of the scope and range of coverage the journal provides. It offers a historian's view of the development of the scholarship about technology transfer over the past half century, interweaving two primary threads. First, it identifies events and circumstances that have influenced and shaped real-world efforts to move technology in its many guises across boundaries—national, geographic, institutional, organizational, social, or otherwise. These historical situations have had a profound impact on the efforts of American policymakers and leaders in business, government, universities, and nongovernmental organizations who deal with technology transfer. These circumstances have produced significant changes of emphasis in the definition of *technology transfer* at different points in time. Scholars interested in technology transfer have taken their cues from the unfolding events of history, but they have also worked within a variety of disciplinary traditions. The second strand of this essay surveys a number of these disciplinary approaches to the study of technology transfer, with attention to a few principal problems and issues scholars have identified. By connecting historical events and trends within academic disciplines, this essay provides an overview of basic patterns within the scholarship related to technology transfer since 1950.

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Technology transfer—the processes and consequences of moving technological ideas, skills, processes, hardware, and systems across a variety of boundaries—national, geographic, social and cultural, or organizational and institutional—is not a new topic. An enormous body of scholarly literature exists, as shown by a subject search of the OCLC WorldCat database producing several thousand items under the heading *technology transfer*. As Table 1 indicates, most titles appeared after 1960 and scholarly interest exploded after 1980.[1] A subject search of OCLC's Article1st database produces a similar pattern, with increasing numbers of journal articles appearing during the 1980s and 1990s, and the same result follows use of the search term *diffusion of innovations*. This matches the results reported by the bibliographer of diffusion of innovations, who identified 500 publications in 1962, 1,500 in 1971, and 2,730 in 1977 (Rogers, 1962, 1967, 1968, 1977; Rogers & Shoemaker, 1971).

Does this pattern of growing interest justify yet another academic journal? The editors and others behind this project believe it does. In articles in each of the first three issues, each editor will offer a view of the topic and a sense of the promise of *Comparative Technology Transfer and Society*. This opening essay asks, because its author is a historian, how scholarship on technology transfer—primarily but not exclusively in the United States—has grown and changed over time. The key finding is the reach of this published work across a range of academic disciplines, a dispersion that explains why individual scholars are disconnected. This contention is not completely original. A participant in a 1970s workshop observed that "Few expressions represent so many different meanings to so many different people as the often-used phrase 'technology transfer'" (Manning, 1974, p. v). And a commentator at another workshop 3 years later added, "Discussions between researchers as well as the research literature . . . show up the confusing variety of terminology, research approaches, and disciplinary-related assumptions. . . ." (Radnor, Feller, & Rogers, 1978, p. 8).

This historical survey helps to explain these observations by weaving together two parallel strands. First, it identifies specific historical circumstances that brought increased attention to technology transfer activities. The unsurprising finding here is that those who engaged in transfer activities, as well as the primary definition of that activity, changed over time. Key events include World War II and its aftermath, the end of European colonialism, the Cold War, the dawning of the Space Age and the various technological ages that marked the last half of the 20th century, and the

[1]Inevitably, these searches produce duplicate listings, so it is the magnitude rather than the exact number of titles that is important here.

Table 1
OCLC PUBLICATIONS SEARCH RESULTS ON TECHNOLOGY TRANSFER

	BOOKS		*ARTICLES*	
Date	*Technology transfer*	*Diffusion of innovations*	*Technology transfer*	*Diffusion of innovations*
Pre-1950	10	—	—	—
1951–1960	8	9	—	—
1961–1970	138	145	—	—
1971–1980	1,497	541	—	—
1981–1990	3,292	400	—	—
1985–1990	—	—	107	6
1991–2000	3,464	392	—	—
1991–1995	—	—	663	18
1996–2000	—	—	798	49
2001–2002	273	76	322	20

reemergence of global economic competition in the 1970s that ended a period of unique American preeminence. These shifting circumstances created the context within which technology transfer practitioners have operated and imparted a dynamic dimension to the definition of technology transfer. But academics and others who have studied technological diffusion also adjusted and extended their conceptions of what it takes for nations, firms, and organizations to innovate, adopt, and adapt technologies developed elsewhere. Scholars from a surprising number of disciplines have examined this issue, and surveying their work constitutes the second strand of this essay. This essay cannot examine all disciplines interested in the topic, for the list is long. Necessity compels a focus on social science fields and a handful of leading figures and their scholarship. Finally, the coverage betrays the author's nationality by discussing activities in the United States more than other parts of the world. Even so, this survey of historical events and disciplinary developments touches on both audiences that this journal hopes to address: the experts making transfer activities happen and the academics studying those efforts. In the process, it lays out basic patterns in both the changing locus of transfer activities and the foci of academic scholarship. The topic sprawls across an expansive intellectual terrain—one this journal hopes to cover.

TECHNOLOGY TRANSFER, 1945–1970: DEVELOPMENT AND DIFFUSION

Many human activities involve technology transfer. Invention, trade, selling and buying, spying, and copying all involve transfers and diffusion, as do empire building and military conquest. Thus technology transfer is not a modern concept, as shown by historical episodes such as Venetian attempts to acquire the secret of Greek fire from the Byzantine navy during the late Middles Ages, the spread of the printing press across Europe after Gutenberg, or the British struggle to prevent the export of their steam engines and textile machinery; the core technologies of the industrial revolution (Eisenstein, 1980; Harris, 1992; Roland, 1992). Scholarly fascination with the transfer of technology, however, began with World War II and its immediate aftermath, events that also stimulated practical interest in transfer activities. The war-time demonstration of a close connection between science, technology, and the military added a new dimension to the concept of military secrets. Knowing and countering an enemy's technical and industrial capabilities became crucial strategic activities, as shown by the Allied efforts to break German ciphers, the crash research programs to develop sonar and radar, and the flawed American effort to possess the secrets of the atomic bomb.

The twin goals of acquiring knowledge about an enemy's technical activities while tightly controlling one's own technology also appeared in diplomatic discussions at war's end. At Yalta and Potsdam, Stalin insistently demanded the removal of German industrial plants to Russia as reparations. American and British objections to the extent of Stalin's plans were an early point of postwar contention. Even so, Stalin confiscated much German industrial equipment and forcibly removed hundreds of German technical experts, some of whom remained in the Soviet Union for more than a decade.

The Soviets were not alone, however, in coveting Nazi technology. As soon as the Allies invaded France in 1944, special units immediately behind the advancing front sought out information about the German atomic bomb program. As these experts quickly determined that German scientists had not built a bomb, attention shifted to other Nazi technical programs. Some 3,000 teams with 11,000 engineers, managers, and industrial executives gathered documents, hardware, production plans, and machinery and located German scientists and engineers. One of the most celebrated results was the secret and sometimes illegal movement of tons of hardware, rocket engineers, and scientists (including Werner von Braun) to the United States (Hunt, 1991; Lasby, 1971; Krammer, 1981;

Ordway & Sharpe, 1979). Even after the war, Americans continued to investigate German technology, as in a 1945 study of the transfer of German technology to Japan and a 1946 inspection of the German autobahn by American highway engineers (Jackson & Allen, 1948; US War Department, 1945).

In 1947, an even larger program of transfer soon took shape, this time running to Europe from America. Two years after war's end, the prospects for millions of people remained grim amid the devastation, prompting American leaders to propose aid programs on an unprecedented scale. The resulting Marshall Plan was aptly labeled "the most massive technology transfer in history" (Ahmad & Wilkie, 1979, p. 79). Importantly, the $13.5 billion program provided both food and information about American industrial processes and products. The British, for example, sent managers, engineers, and workers to American factories to study the production capability behind the Allied war effort (Sawyer, 1954). Similar logic guided the American military government's ambitious reconstruction efforts in Japan. These assistance programs helped end individual privation in Europe and Japan and advanced economic recovery while serving the American political goal of slowing the spread of communist governments (Galdi, 1988; Hogan, 1987; Jöhannsson, 1997).

The success of the Marshall Plan influenced the next major historical instance of organized technology transfer—international aid programs for the less-developed world. Pressure to end European colonial rule in Africa and Asia had grown for decades, but the prostrate condition of European nations encouraged nationalist leaders. Britain bowed to the inevitable, granting India and Pakistan independence in 1947 and creating a Dominion that included many new nations in Africa and Asia. When the French, Dutch, and especially the Portuguese hesitated, bloody wars of national determination erupted in Algeria, the Congo, Vietnam, and elsewhere (Hargreaves, 1988; Zinkin & Zinkin, 1964). But new nations founded with much hope faced daunting economic challenges. As Ahmad and Wilkie (1979, p. 79) noted, "These nations soon began to realize that political freedom could not be construed as an end in itself and that achieving it did not automatically ensure the social and economic well-being of their people."

The experience of the Marshall Plan caused many Western leaders to assume that the creation of modern economies might be achieved easily by replicating Western development patterns, especially its technology. One observer noted, "Common to all Western explanations of different patterns of development was the assumption that modernization is essentially a European phenomenon and that Asian development must be analyzed with reference to this European experience. . . ." (Baark, Elzinga, & Bortgstrom, 1980, p. 1). Ahmad and Wilkie (among others) point out that the vocabulary of modernization theory incorporated such pejorative terms as *underdeveloped* before labels such as *more* or *less* developed, *Third World*, and *North/South* came into vogue. Yet Western experts and local political leaders alike embraced this logic in the 1950s, assisted by international organizations that became leading players in transferring Western technology. Private foundations, including the Ford and Rockefeller Foundations, played key roles, as did the United Nations. The United Nations' Expanded Program of Technical Assistance, launched in 1950, over the next 12 years sent 11,000 experts to 150 countries and trained 20,000 students. The United Nations also helped to create the International Finance Corporation in 1956–57, having earlier joined with the World Bank to establish the International Bank for Reconstruction and Development. And in 1960 the two agencies again partnered to create the International Development Agency (Brown & Opie, 1953, pp. 399–406; Hoffman, 1962, pp. 114–15; Rosen, 1985; United Nations Technical Assistance Board, 1965).

The United States government also played a large role in early aid programs. The legislative basis came with the Act for International Development in 1950, which grew out of President Harry Truman's Point Four program (Brown & Opie, 1953, pp. 406–19). Foreign aid, or more accurately technical assistance, soon became a regular element of American foreign policy, although not without occasional domestic controversy. Several books directed to popular audiences highlighted the importance of foreign assistance programs, an indication that the value of overseas development programs was not automatically evident to American taxpayers (Buchanan & Ellis, 1955; Heilbroner, 1963; Hoffman, 1960, 1962; Myrdal, Altmeyer, & Rusk, 1955; Staley, 1954). It was not surprising, however, that the military assistance programs established in 1949 and 1951 were much larger in scale (Brown & Opie, 1953, pp. 439–539).

The prominence of military security programs in the United States highlights the third important development that shaped technology transfer during these years—the superpower confrontation between the United States and the Soviet Union. Cold War competition colored almost every event during the second half of the 20th century, including technology diffusion efforts. Stalin, for example, rejected the Marshall Plan and countered with economic assistance to Soviet satellites in eastern Europe (COMECON) in January 1949, and then embarked upon technical assistance programs to new countries in Africa and Asia. Soviet funding lagged behind the level of US support—$14 billion through 1967 compared to more than $100 billion from the United States. Yet the Soviets achieved high visibility with assistance to Egypt for the Aswan High Dam, and to India for the Bhilai steel mill, in both instances replacing American support (Goldman, 1967, pp. xiii, 30, 61–114).

The common feature of assistance from foundations, the United Nations, World Bank, the United States, or Soviet governments was the automatic assumption that economic development required the transfer of advanced Western technology—hardware, industrial processes, knowledge, and skills (Spencer, 1970, pp. xii–xiii). Accordingly, early aid programs stressed large-scale infrastructure technologies or show-case industrial plants (Solo, 1975). To be sure, experts also focused on improving rural life, but many farm programs emphasized expensive irrigation schemes or the adoption of mechanized processes, hybrid seeds, fertilizers, and pesticides (Rosen, 1985). However well-intentioned, such programs often produced disappointing results, and by the mid-1960s critics argued that large-scale, unidirectional assistance programs were grievously flawed (Ahmad & Wilkie, 1979, pp. 79–82; Richardson, 1979). Many Western experts acknowledged they had underestimated the difficulty of development programs. One economist commented, "Back in an earlier, more naive day, we managed to allow ourselves to believe that there was a purely technological solution—a cheap technological fix—to the problems of poverty and economic backwardness which beset most of the human race . . . [W]e exaggerated from the outset what could be accomplished solely by making Western technologies available" (Rosenberg, 1970, p. 550; also Rosen, 1985). Another expert who had worked in Korea in the mid-1950s remembered,

> We were amazed to find that even though "we knew all of the answers," very few of them worked. Initially we were simply insensitive to the (1) cultural differences, (2) indigenous motivating forces, and (3) different value systems. Often one of the greatest mistakes Americans make . . . is the assumption that the response of foreigners can be predicted upon the basis of our own value system (Strassor, 1974, p. xxii; also Hirschman, 1967).

The experts discovered that development efforts confronted a complex combination of social, political, cultural, and economic factors, including the often differing goals and expectations of American and local experts and officials. The scholars who first encountered these challenges included consultants and experts working within foundations, government, and United Nations technical assistance and development programs or academics supported by research grants. Most focused on how-to questions, but a few developed more general understandings of development and technology transfer programs. Eventually, they highlighted the early mistakes, especially the failure to recognize the interactive nature of transfer and development activities (Cleveland, 1960; Sufrin, 1966; especially Rosen, 1985).

University research centers devoted to international economic development housed a number of these consultants. MIT, with the support of the Ford Foundation, developed a Center for International Studies in 1951 that carried out, among others, a long-term study in India. At about the same time, the University of Chicago's Research Center in Economic Development and Cultural Change took shape around the journal *Economic Development and Cultural Change*, which emphasized studies that combined social and economic variables related to the development process. Harvard, also with Ford Foundation funds, created a working group in Pakistan in the mid-1950s and established its Center for International Affairs in 1959. Iowa State University in 1957 set up what became the Center for Agricultural and Economic Development to examine agricultural economics and policy at home and abroad; Yale organized its Economic Growth Center in 1961.[2]

In November 1962, Indiana University opened its International Development Research Center with the help of its own Ford Foundation grant. Faculty research and consulting were central activities until the center closed in 1994 (*Indiana University International Development Institute*, n.d.). A notable early product of the center was Jack Baranson, who earned his doctorate at Indiana in 1965 for a case study of Cummins Diesel's experiences in India (Baranson, 1965, 1967a). At the World Bank, as a private consultant, and as a faculty member at Illinois Institute of Technology, Baranson was a prolific author of bibliographies, reports, case studies, and general studies of technology transfer and multinational corporations. He early focused on Japan and manufacturing, especially robotics, and later studied transfer and development in Eastern Europe (Baranson, 1966, 1967b, 1969, 1970, 1977, 1978, 1979, 1981, 1983, 1991, 2001; Baranson & Roark, 1986). One young scholar starting out in the mid-1970s identified Baranson as a key figure in American technology transfer activities (Hayden, 1976), and his publications made significant contributions to the general literature on technology transfer. Baranson was a fine example of the international development consultant.

Many consultants were economists, an academic audience that paid attention to technology transfer and connected it to the larger issue of eco-

[2] Information about these organizations can be found on institutional web pages: <http://www.journals.unchicago.edu/EDCC/brief.html>; <http://cardsrv1.card.iastate.edu/about_card/faculty_and_staff/history/history_home.html>; <http://www.econ.yale.edu/*egcenter.center.htm>.

nomic growth. Transfer activities often remained implicit in this scholarship, because economists rarely discussed technology itself. They sought to comprehend the economic development challenges facing the newly emerging nations in Africa and Asia using traditional economic categories—trade, national income, productivity, capital accumulation, and employment. Economist Paul Krugman outlined the work of one group of economists during the 1950s on what he called *high development theory* (Krugman, 1996, pp. 1–29). He argued that Paul Rosenstein-Rodan, Arthur Lewis, Albert Hirschman, and Gunnar Myrdal were particularly influential in sketching problems not solely economic in nature. But Krugman suggested that for that very reason, their influence faded, because these writers did not adopt the style increasingly favored by academic economists—formal models. Krugman (1996, p. 27) explained,

> Like it or not, the influence of ideas that have not been embalmed in models soon decays. And this was the fate of high development theory. . . . By the early 1970s (when I was a student of economics) [Myrdal and Hirschman] had come to seem not so much wrong as meaningless. What were these guys talking about? Where were the models? And so development theory was not so much rejected as simply bypassed.[3]

Even so, the topic of economic development remained a central issue facing economists. By generalizing the question, they examined development in industrialized countries as well as in the newly emerging countries of Africa and Asia (Adelman, 1961; Bauer & Yamey, 1957; Okun & Richardson, 1961). A few consciously used England's Industrial Revolution and Japan's development after 1860 to understand the plight of emerging nations (Buchanan & Ellis, 1955; Meier & Baldwin, 1957). Among academic economists, Simon Kuznets was an influential figure whose scholarship covered national income accounting and growth, as well as studies of developing nations (Kuznets, 1946, 1953, 1955, 1956). Kuznets' research was part of a flood of attention to development by economists in the 1950s and 1960s.

The most influential book on economic development to emerge from economic circles, however, was W. W. Rostow's *The Stages of Economic Growth* (1960). This is ironic, in light of Krugman's analysis, for as one observer commented, "Though an economist, [Rostow's] was not an economistic theory . . . [Rostow's] Economic development required not only appropriate economic, technological, and demographic conditions, but al-

[3]Krugman's essay describes the key ideas proposed by these development economists and argues that the main insights have now found their way back into the thinking of economists.

so appropriate social institutions and value systems. Development was a unilinear process" (Worsley, 1984, p. 17). In fact, the subtitle of Rostow's book (*A Non-Communist Manifesto*) highlighted a desire to shape public opinion far beyond the realm of academic economics. Rostow, a key figure at MIT's Center for International Studies, considered the Western development experience universal, a conception that has been justifiably criticized and which few today accept. (Alexander Gerschenkron [1962], on the other hand, also grounded his views of economic development in history, presented industrialization as multilinear, and emphasized the penalties of backwardness.) Even so, Rostow's book advanced academic conversations about development, for like Gerschenkron, Rostow treated development as economic *and* social—suggesting, in fact, a shortcoming in most early economics literature on development (Rosen, 1985, p. 27). In common with most economists, he assumed that economic development required the transfer of Western technology. Rostow (p. xiii) argued that "the degree of efficiency of absorption is taken as a basic measure of growth. . . ." Yet he never discussed the process that allowed such absorption to take place.

Other social scientists outside economics and scattered across the intellectual landscape became deeply immersed in exactly that question after 1960. The path-breaking book that connected several strands of research was Everett M. Rogers' *Diffusion of Innovations* (1962). Trained as a rural sociologist at Iowa State, Rogers began asking questions about technological change in his dissertation after a serendipitous encounter with an article on educational diffusion that alerted him that others were interested in similar questions (Rogers, 1957). His 1962 study examined 506 publications and concluded that several research traditions shared an interest in the adopters of innovations, paid little attention to innovation itself, and emphasized the importance of communication between innovators and adopters. Rogers' vocabulary about diffusion (*innovators*, *early adopters*, *laggards*, *opinion leaders*, and *change agents*) was widely adopted. Subsequent bibliographies and a revised edition of his book brought coherence to diffusion studies (Rogers, 1967, 1968, 1977; Rogers & Shoemaker, 1971). He also adjusted the conceptual framework, after researchers could not extend the diffusion paradigm from individuals to organizations. Rogers characterized technology transfer as a creative act of reinvention, as opposed to the simple movement of unchanging technologies across boundaries (Rogers, 1978).

The six research traditions in diffusion studies Rogers identified all predated World War II. Anthropology had the longest record, whereas rural sociologists had produced the largest body of scholarship. He also found research in fields he called *early sociology*, *education*, *industrial* (including economic history), and *medical sociology*. By 1971, Rogers added two other traditions (communications and marketing) and several areas populated by smaller groups of scholars—agricultural economics, psychology, geography, speech, economics, and sociology (Rogers, 1962; Rogers & Shoemaker, 1971). Agricultural change in developing countries was one of the most common topics (Fliegel, 1968; Griliches, 1957; Herzog, 1968; Rogers & Niehoff, 1967; Ramachandran, 1975; Ryan & Gross, 1943; Sargen, 1979). Yet not all diffusion research was responding to the international development problems of the 1950s. A number of case studies appeared in industrialized nations on such topics as the diffusion of bank charge accounts, semiconductors, cable television, shopping centers, solar power, and home computers (Gross, 1974; Rogers, 1979; Rogers, Daley, & Wu, 1982; Sheppard, 1975; Tilton, 1971).

Researchers in other scholarly fields who became interested in diffusion after the war (market researchers, for example) also found their best cases in the developed world. A few scholars, in fact, came to see diffusion of innovations as a special case of the more general pattern of *social change*. Gerald Zaltman, a management scholar who was influenced by Rogers' work, emphasized this idea. Zaltman and other researchers found that diffusion theory better explained activities by individuals than organizations. By the mid 1970s, Zaltman had focused on planned change, and with Robert Duncan produced a landmark book in which diffusion was a subset of the larger question (Zaltman & Duncan, 1977; Zaltman, Duncan, & Holbek, 1973).

Zaltman's work demonstrated how the internal dynamics of academic disciplines could drive scholarly conceptions of technology transfer. Although Zaltman's research was not divorced from real-world concerns, it was motivated by a desire for internally consistent theoretical frameworks. This situation also explains developments in geography, a field where movement across space and time is a fundamental concept. Surprisingly, Rogers reported that only a fraction (0.6%) of the existing published research within the diffusion paradigm came from geographers (Rogers & Shoemaker, 1971). In fact, geographers were pursuing a different set of questions about diffusion, but in the 1970s, Lawrence A. Brown at Ohio State set out to connect the existing research traditions within geography to the patterns delineated by Rogers.[4] Brown identified two research approaches to diffusion among geographers. One tradition stemmed from Carl Sauer and focused on the landscape, motivated by the question of

[4]For more information about Brown, see his web page at Ohio State, URL: <http://thoth.sbs.ohio-state.edu/>.

whether simultaneous invention or diffusion better explained the existence of ideas and techniques in more than one place. In the 1950s, the work of Torsten Hägerstrand, who emphasized location and focused on the underlying issues related to diffusion, moved geographers in a different direction. Brown, reflecting Rogers' influence, proposed a third path that emphasized the importance of market and infrastructure factors in the diffusion process and attached special importance to diffusion agencies. Brown joined social scientists who placed emphasis as much on the supply side of the transfer process as on the adopters (Brown, 1968, 1981; Brown & Hanham, 1970; Hägerstrand, 1952, 1967). The result was further encouragement of research on technology transfer by geographers, much of it from Brown's students, some focusing on development questions (Hoy, 1978; Hoy & Berry, 1980; Freeman, 1979; Forbes, 1984; Mountjoy & Potter, 1989). By the 1990s, geographers such as Peter Hugill published sophisticated studies of diffusion that highlighted international trade and communications technologies against the backdrop of political economy (Hugill, 1993, 1999).

Nearly every scholar who sought to define approaches to diffusion of innovations cited Rogers' work. But Rogers' influence was especially clear in communications. Although trained as a sociologist, Rogers had always focused on communication in diffusion, his academic appointments were in communications departments, and his books emphasized communication and technology transfer (Mahler & Rogers, 1999; Rogers & Svenning, 1969; Rogers & Steinfatt, 1990; Roy, Waisanen, & Rogers, 1969). Rogers was not alone in grasping the importance of communication to transfer questions. Anthropologists had long acknowledged the difficulties of communicating across cultural boundaries, and technical assistance programs brought these concerns into sharper focus. Scholars working in intercultural communications were especially open to this topic (Carlisle, 1967; Oliver, 1962) and have remained attuned to technology transfer issues (Beamer & Varner, 2001) even as researchers in other areas also examined the communication issues such activities posed. Management scholar Thomas Allen emphasized the significance of communications within research and development organizations, for example (Allen, 1979; Earley & Gibson, 2002; Mockler & Dologite, 1997; Schneider & Barsoux, 1997). A few scholars focused specifically on communication and international technology transfer, including anthropologist Susan Scott-Stevens (1987), Frederick Williams and David V. Gibson (1990), and Steven Doheny-Farina (1992). This last work was especially significant for its perspective on the challenges facing technical communicators within transfer activities.

One final area of scholarship related to technology transfer and international development needs to be mentioned—research on values and ethics. Many development experts from the West initially presented their efforts as value neutral, but this stance proved hard to maintain as the social and cultural elements of technology transfer became apparent. The social disruptions that followed the introduction of modern technologies initially were accepted by local political leaders as a necessary cost of economic development. By the 1970s, however, attitudes began to change. In 1977, for example, Zaltman included a chapter on the ethics of social change in his study of planned change, identifying this as a "neglected topic" (Zaltman & Duncan, 1977). That same year, Denis Goulet published *The Uncertain Promise: Value Conflicts in Technology Transfer* (1977), in which he laid out the position that technology transfer without attention to social consequences was brutally disruptive. Others who shared this outlook promoted rules governing the behavior of multinational corporations engaged in transfer activities. Groups at the United Nations and experts in developing nations were especially interested in this idea (Perlmutter & Sagafi-nejad, 1981; Singer, Hatti, & Tandon, 1988, pp. 2, 669–776).

Another visible attempt to connect values and technology transfer emerged in the appropriate technology movement (Betz, McGowan, & Wigand, 1984; Eckaus, 1977; Evans & Adler, 1979; Schacht, 1980; Pursell, 1993, 1999). A formative event was the publication of E. F. Schumacher's *Small Is Beautiful: Economics as if People Mattered* (1973). Within a short period of time, his plea to consider alternative development programs that matched solutions to the needs, culture, values, and goals of recipients was widely accepted within the developing and industrialized worlds alike, since massive infrastructure and development projects had produced little real improvement in their transplanted settings. Further, the rhetoric of appropriate technology reinforced emerging environmental concerns. The result was an outpouring of popular and scholarly writing on appropriate technology and institutional efforts to act upon those ideals. United Nations agencies were especially supportive in the 1970s, launching pilot projects on various forms of appropriate technology. The United Nations' Industrial Development Organization published a series of case reports on appropriate technology and launched a serial publication (Diwan & Livingston, 1979; Khor, 1980; O'Kelly, 1978; United Nations Advisory Committee on the Application of Science and Technology to Development, 1972; United Nations Industrial Development Organization, 1979a, 1979b, 1979c, 1979d, 1980).

Appropriate technology found strong support in many quarters of the developing world. M. M. Qurashi, secretary of the Pakistan Academy of

Sciences, authored two influential books on the topic (1978, 1981). In some quarters, however, appropriate technology seemed only the latest example of patronizing attempts by the West to limit developing nations (Chafy, 1997; Shriver, 1972, pp. 550–1). Political leaders often preferred showcase development projects over small-scale, local projects. From that viewpoint, dams showed better than wells with hand pumps that a new nation was “catching up.” Political leaders were not alone in their skepticism of appropriate technology projects, for the reasons identified by Ethan Kapstein in a study of the Rockefeller Foundation’s attempt to introduce solar cookers in Mexico. The project failed, not only because of technical problems, but also because of social issues, including the local residents’ conclusion that if development experts did not utilize cookers at home, why should Mexicans (Kapstein, 1981). Despite these challenges, consideration of the appropriateness of the technology to be transferred has become a key consideration in technology transfer policy, especially under the more recent label of *sustainability* (Basu & Weil, 1998; Guertin & Gray, 1993; Hazeltine & Bull, 1999; Hamd Haidari, 2001; Linder, 1997; Patsalos-Fox, 2001).

HISTORIANS AND TECHNOLOGY TRANSFER

Scholars of the history of technology and economic history have often examined the process of technology transfer. Historians of technology initially did so as part of their attempt to follow the development of specific inventions and technical systems; these early scholars often tracked the flow of ideas or the movement of hardware and technicians across time and space. For example, Joseph Needham’s monumental effort to chronicle the history of science and technology in China included attention to technical interchanges with Europe, such as the transfer of rockets, gunpowder, printing, porcelain, and textiles (Needham, 1969; Needham, with Ling, 1954–2000). Other historians have followed the movement of technology, including British scholar Arnold Pacey (1990), and military historians interested in weapons, fortifications, and tactics (DeVries, 2002; McBride, 2000; McNeill, 1982; Parker, 1988).

Early historians of technology studied the design of artifacts and hardware, paying attention to the internal logic of technological development rather than broader social considerations. Technology transfer was an important issue within this internalist framework, because scholars often sought to identify precursors of components or ideas (Staudenmaier, 1985, pp. 123–34). Such research rarely generated sophisticated theoretical conclusions, but many historians contributed to better understanding of the dynamics of technology transfer. The formative years for the history of technology in the 1950s coincided with the focus on international economic development. Not surprisingly, Rostow's *Stages of Economic Growth* drew the attention of American historians to the spread of the Industrial Revolution from Britain to the United States. The result was a body of literature on the diffusion of steam engines, textile manufacturing, and iron into the United States during the 19th century (Jeremy, 1981; Pursell, 1969; Stapleton, 1987; Wilkinson, 1963), while others explored the roots of America's dynamic technological growth (Ferguson, 1979; Hindle, 1981). These studies emphasized that successful transfers required moving people, not just hardware; they also demonstrated the failure of the English to prevent transfers. Economic historian Nathan Rosenberg's crucial insight was that the machine tool industry was the pivotal agency of diffusion in 19th-century America (Rosenberg, 1976, 1982).

Given the extensive interest in economic development after 1960, historians also paid special attention to transfer activities by two other nations. Industrialization in the Soviet Union seemed important for many reasons, including the Soviet claim that socialism was a better model for developing countries. Several historians produced overviews as well as case studies showing how important transfer had been for the Soviet Union (Bradley, 1990; Dalrymple, 1964; Dorn, 1979; Holliday, 1979; Sandberg, 1989; Sutton, 1965, 1968, 1971). The case of Japan assumed similar importance, not only because that country alone in Asia had built an industrial economy, but also because of its rapid recovery from wartime devastation (Inkster, 1981; Koizumi, 2002; Matsumoto, 1999). In both cases, history informed the efforts of other developing nations seeking to industrialize and modernize.

Numerous other cases have served the same purpose. Historians of technology have been examining technological development in former European colonies, focusing on the role of technology transfer in India and elsewhere in Asia (Adas, 1996, 1997; Headrick, 1981, 1988; Kumar, 1991; MacLeod & Kumar, 1995; Parayil, 1992; Sangwan, 1988; Todd, 1995). Other studies track transfer episodes in developed nations, including the electrification of Finland, technology transfer in Scandinavia, and the movement of technology out of Germany after World War II (Bruland, 1992; Judt & Ciesla, 1996; Myllyntaus, 1991). And marvelous case studies continue to appear, including recent studies of the transfer of rice cultivation techniques from Africa to the American colonies, and the development of the electron microscope (Carney, 1996; Rasmussen, 1999).

Taken together, this historical research offers several general findings germane to those on both ends of technical assistance programs. Most importantly, historical analysis emphasizes that successful transfers rest on the exchange of people, not just machines, drawings, blueprints, patents, or other technical literature. Moreover, historians found that transferring technology required creative efforts; avoiding dependency required adaptation, not blind adoption, of imported ideas and machines. Adaptation required not just basic levels of preparation, but also support networks (Ruttan & Hayami, 1973; Staudenmaier, 1985, pp. 125–8). The most recent scholarship on the development of technology has further extended the importance of adaptation by emphasizing the important role of users in the successful introduction of many technical systems, both consumer oriented and for industry (Kline, 2000).

Historical case studies also highlight a basic paradox about technology transfer. On the one hand, historians report that even those with a strong desire to copy, emulate, or adopt a technological process or artifact can find it difficult to do so. Many 19th-century manufacturers and government officials in Europe and the United States, for example, discovered to their chagrin how difficult technology transfer could be even when the social, economic, and technical gap was not large. Yet it proved just as impossible to hold onto industrial "secrets," as the English repeatedly learned. The hard lesson was that patent controls and legal restrictions against the export of machines, drawings, or blueprints of textile machinery and steam engines, or the emigration of technicians and operatives who knew those machines, could not keep industrial secrets in England (Harris, 1992, 1995, 1996; Jeremy, 1981; Lindqvist, 1984).

TECHNOLOGY TRANSFER IN THE 1970s: NEW VIEWS, NEW INSTITUTIONS

In the 1970s, scholars in international relations began to pay attention to technology transfer. According to John McIntyre and Daniel Papp (1986, p. 13), "International technology transfer has emerged as a separate field of inquiry in the 1970s as a consequence of the accelerating awareness of the economic interdependence of nations and of the central role of technology in international relations." This particular academic foray into transfer questions grew out of a different impetus than the postwar scholarship driven by concern for international economic development. Moreover, whereas the bipolar world of the superpowers remained a fact of life, international relations scholars increasingly perceived competition between nations that was less ideological and more economic in nature.

They argued that the extensive attention devoted to technology transfer between north and south had obscured the importance of technology flows between Western countries, between developing nations themselves, and between the democratic-capitalist and communist blocs. McIntyre and Papp proposed an “international technology transfer regime” that integrated economic as well as political, ideological, strategic, diplomatic, and legal constraints shaping diffusion (p. 17).

Within this regime, international relations scholars identified several important topics. One important question concerned the international structure erected to prevent the spread of nuclear weapons, bringing nuclear nonproliferation efforts into the technology transfer orbit (Arnett, 1996; Carlton, 1995; Schiff, 1984). Indeed, the spread of nuclear weapons technology to India, Pakistan, South Africa, Israel, and perhaps other nations confirms again the paradox that transfers are equally difficult to make or prevent. But since the demise of the Soviet Union, a major concern has been preventing the movement of experts and nuclear materials from the former Soviet Union to states seeking to develop nuclear capabilities (Beres, 1986; Foote, 1982; Kressley, 1995; Seshagiri, 1975; Zinberg, 1995).

Another effort to restrict the flow of technology that attracted significant attention among international relations scholars and policymakers concerned the Soviet Union. During the Cold War, the United States and its NATO allies attempted to prevent the Soviets from acquiring advanced technologies with military applications. Even so, leaders of the Soviet Union managed to acquire many strategic technologies from the West. Evidence of their success included the Ryad computer (copied from the IBM 360 series), close emulation of several Western aircraft and the Space Shuttle, and Soviet acquisition of machining technology for producing submarine propellers. During the 1970s, policymakers and academics debated intensely the significance of such technology transfers to the Soviet Union, especially computers and software. American businessmen argued restrictions were ineffective, because Soviets could find what they wanted elsewhere. Indeed, international business scholars recommended increased American business behind the Iron Curtain to strengthen détente and extend American influence (Hayden, 1976; Macdonald, 1990; Sternheimer, 1980). But political conservatives disparaged the concept of détente and adopted a phrase from Lenin to make their point—*Selling the Rope to Hang Capitalism* (Gustafson, 1981; Perry & Pfaltzgraff, 1987). Ronald Reagan’s election as president in 1980 resulted in substantial tightening of existing mechanisms for restricting the flow of advanced technologies from West to East (Bertsch & McIntyre, 1983; Gustafson, 1981;

Kemme, 1991; Maksad, 1989; Noble, 1975; Schaffer, 1985; Yergin, 1980; Wasowski, 1970).

The parallels between this situation and the numerous efforts to acquire British steam engines or textile machinery at the end of the 18th century are apparent; in both cases the developers of advanced technologies could not prevent their transfer. In the Soviet case, however, the surreptitiously acquired technology did not translate into improved technical capabilities (Goldman, 1987a). An additional aspect worthy of note concerns the little-studied issue of espionage as a mechanism of technology transfer. Most attention to this question has been journalistic, although historian John Harris examined French attempts to gain access to British secrets during the Industrial Revolution with spies. Kristie Macrakis examined the Stasi's technological espionage program during the Cold War, and only Stuart Macdonald has written about industrial espionage as technology transfer. Anecdotal comments about industrial spying during the dot.com boom in the 1990s suggest a need for further research in this area (Hanson, 1987; Harris, 1995, 1996; Lowenthal, 1980; Macrakis, 2000; Melvern, Anning, & Hebditch, 1984; Macdonald, 1993; Metcalfe, 1988; Paine, 1986; Croft, 1994).

The demise of the Soviet Union shifted the emphasis of practitioners and international relations scholars on technology transfer in interesting ways. First, in some quarters the problem reversed itself so that the task now became one of encouraging, not restricting, Russian attempts to borrow technology and the necessary Western institutions and governmental structures supportive of free markets (Burghart, 1992; Dyker, 1999; Goldman, 1987b). Second, two other nations emerged in the 1990s as places where US officials sought to restrict technology flows. First, to Iraq, where questions about weapons of mass destruction have been a major issue for more than a decade. After the Gulf War, Iraq accepted international inspectors who searched industrial and military sites and found evidence of chemical, biological, and nuclear weapons programs. The porous economic and trade sanctions imposed after the war, as well as the cat and mouse game played with United Nations inspectors, again demonstrated the difficulty of controlling technology flows (Herring, 2000; Pearson, 1999; Stahl & Kemp, 1992).

The other country where restriction of technology movement assumed special importance was China. Such efforts were not new, but in the eyes of American policymakers, China replaced the Soviet Union in importance in the 1990s. Confirmation of the importance of these efforts apparently came with the accusation that Hughes Aircraft did too much to assist China's rocket program in the mid-1990s (Cox, 1999; Fulghum & Anselmo, 1998; Gilley & Holloway, 1996). The unproven allegations of espionage by nuclear weapons scientist Wen Ho Lee at the Los Alamos weapons laboratory drew even more media attention (Kan, 2000; Stober & Hoffman, 2001). Both cases support the comment of McIntyre and Papp regarding the centrality of technology transfer to the international relations community.

In fact, study of technology transfer in China could be even more interesting than these cases suggest. In numerous ways, China presents intriguing opportunities to examine the process and dynamics of technology diffusion. Obviously, the linkage of technology transfer and economic development in China allows comparison with the experience of other developing nations. Equally instructive may be the issue of government controls on Internet use in China, an intriguing effort to control the development of an imported technology (Harwit & Clark, 2001; Huang, 1999; Lacharite, 2002). Legal disputes about intellectual property and patent rights in China, an issue attracting significant complaints from Western computer software and entertainment firms, also are technology transfer issues (Feng, 1997; Heath & Sanders, 2001; Morrison, 1996; Paradise, 1999). Finally, the impact of the education of tens of thousands of Chinese students at universities outside China will furnish a long-running opportunity for examining training and education as transfer mechanisms (Chafy, 1997).

Scholars of international relations place primary attention on the state, because governments often set the rules for transfers across national boundaries. Certainly much discussion about transfers for international development has focused on state actors. But the 1970s witnessed a reorientation of the definition of technology transfer in the United States, with new emphasis placed on the efficient movement of technologies between organizations within the same society, as opposed to movements across national boundaries. This approach did not so much displace attention to international transfers as develop a parallel track. This focus was not brand new; Rogers' first bibliography in 1962 identified diffusion studies that looked beyond governmental and nongovernmental agencies. In fact, historians and many social scientists initially focused on individuals and occasionally on multinational corporations. But attention to intra- and inter-organizational diffusion initially was not easily accommodated by the diffusion studies paradigm, and by the late 1960s and early 1970s, transfers between organizations became a much more important topic.

Initial American attention in this direction focused on the boundary between government research agencies and the private sector. Whereas agriculture extension programs had worked at this task since the late 19th century, the first government agency to promote industrial transfers across this boundary was the National Aeronautics and Space Administration (NASA). The agency early on decided to help justify the massive public investment in space by highlighting the civilian spin-offs of space technology. In 1966, NASA leaders established the Technology Utilization Program, and thereafter devoted substantial resources to helping companies commercialize new ideas. NASA also launched the first government publication on technology transfer (*Spinoffs*) and used every opportunity to publicize transfers from space technology, such as flat wire computer cable, health monitoring technologies, and Nomex fabric, at its visitor centers and on extensive web pages[5] (Gurney, 1979; Lesher & Howick, 1966; Ruzic, 1976; Taylor, 1970).

Today, almost every technical agency of the federal government supports technology transfer programs, and many have published extensive web pages. The roots of this development lie in concerns voiced in the early 1960s about the efficacy of the massive government investment in research and development. Agencies (especially NASA) launched internal reviews that reported a steady stream of successes (Robbins, Kelley, & Eliott, 1972). But external studies by public administration scholars were less effusive, highlighting the limited dissemination of research results paid for by government agencies. Samuel Doctors produced the first studies, using NASA as the core of his work (Doctors 1969, 1971). Others urged attention to the positive example of agricultural research, and researchers examined the ability of state and local governments to adapt (Doctors with Eliason, 1981; Doctors, Lambright, & Stone, 1981; Feller, Menzel, & Engel, 1974). A prominent public administration scholar working in this area was W. Henry Lambright, who had also begun by studying NASA but soon turned to other transfer topics (Lambright, 1969; Lambright, Flynn, Teich, & Lakins, 1979). A National Science Foundation study in 1974 highlighted a key problem with all government programs, noting that without measures of effectiveness, firm conclusions about success and failure were impossible (Roessner, 1974).

The struggles of American industries against international competition

[5]Current information on NASA spin-offs can be found at various NASA web pages, starting from <http://sti.nasa.gov/tto/spinoff.html> and <http://www.thespaceplace.com/nasa/spinoffs.html>. Members of the author's generation who grew up watching the first manned space flights may recall Tang, the powdered orange juice, as the first "space food." NASA worked with food companies to produce edible meals in space, eventually even making the freeze-dried ice cream sold at its visitor centers today. But Tang was a marketing, not a technology transfer, success, because General Foods placed it on the market in 1959. Tang caught on with kids who wanted to eat what the astronauts ate! See <http://www.retrofuture.com/spacefood.html>.

in the 1970s reinforced in many quarters the desire to implement more effective government transfer programs. Problems in steel, shipbuilding, textiles, shoes and garments production, automobiles, and consumer electronics made competitiveness the buzzword of the 1980s. Labor costs were a factor, along with poor quality control and outdated manufacturing techniques, but a technology transfer dimension appeared in the superior ability of Japanese firms to develop commercial products from basic ideas originating in the United States. The Japanese had long demonstrated a creative capacity to borrow; Buddhism and the alphabet came from China, for example. Postwar examples include the refinement of statistical quality control during the 1950s and 1960s, the development of inexpensive transistor radios in the 1960s, the implementation of the basic oxygen process and continuous casting in the steel industry, and consistent success in consumer electronics, including televisions, stereo components, videocassette cameras and players, and compact disk players (Kenney & Florida, 1993; Nelson, 1990; Vogel, 1979).

American responses included renewed attention to the flow of science and technology from laboratories to the marketplace, but this time universities as well as government agencies were under discussion. Repeating points made in reports issued a decade earlier, new studies found American institutions of all types transformed concepts into products too slowly. This time, however, the serious economic challenges from abroad led to significant policy adjustments that altered the landscape of research and commercialization (i.e., technology transfer) activities. Federal and state governments not only pumped money into university research, but also inaugurated programs to facilitate the transfer of findings more quickly and easily into commercial products. Perhaps the most important example was the Small Business Innovation Research (SBIR) program established by Congress in 1982 with the requirement that proposals include investigators from both universities and business. State governments launched similar initiatives to promote economic growth via partnerships between universities and business; examples included Pennsylvania's Ben Franklin program and New Jersey's Thomas Edison program (Dickson, 1984; Lambright & Rahm, 1992). In 1980, Congress passed the Bayh-Dole Act (officially the Patent and Trademark Law Amendments Act), which allowed universities to license and patent any results that emerged from federally funded projects and grants. This bill altered the landscape of university research activities, so that universities no longer saw patents and business start-ups as distractions, but a primary goal (Branscomb, Kodama, & Florida, 1999; Frye, 1985; Matkin, 1990; Mowery, Nelson, Sampat, & Ziedonis, 2001; Nelson, 2001; Schacht, 1994).

Another effort to stimulate federal technology transfer activities took shape at the end of the Cold War. The national laboratories (Los Alamos, Lawrence-Livermore, Brookhaven, Sandia, Argonne, etc.) until then had primarily conducted research on nuclear weapons and energy, but this mission was diminished by the easing of tensions with Russia. A combination of survival instincts and the challenges of global competition led federal leaders to reconfigure the labs to include research on civilian technologies that could be moved quickly into the marketplace. Results have been mixed, but this mission is now part of the post-Cold War federal research program (Bopp, 1988; Ham & Mowery, 1997; Jaffe, Fogerty, & Banks, 1998; Jaffe & Lerner, 2001; Mowery, 1998; Rood, 2000; Scott, 1993, 1994).

These policy changes were paralleled by renewed scholarly attention to related technology transfer issues. Economists and economic historians in particular found that events of the post-1970 period raised intriguing questions regarding economic development as they identified a new category of nation—newly industrializing countries (NIC). Events in Taiwan, Korea, and Brazil coming on the heels of the "Japanese miracle" were an exciting new topic of study (Enos & Park, 1988; Rosenberg, 1977). Economists approached this topic differently than colleagues in international relations, focusing less on government and more on transnational corporations. Indeed, a few economists strongly challenged international development programs run by government and nongovernmental agencies precisely because they ignored market mechanisms (Dorn, Hanke, & Walters, 1998).

Several scholars, including Nathan Rosenberg, Giovanni Dosi, Danish economist Bengt-Åke Lundvall, David Mowery, and many others, defined a research area that emphasized technological innovation. Richard Nelson was perhaps the key figure here, because he extended Rosenberg's long interest in technological change. Nelson had grappled with economic development since the 1960s, bringing experience from two stints as an economist at RAND (1957–1960, 1963–1968) and 2 years as a Senior Member of the Council of Economic Advisors (1961–1963). His published research dealt with technological innovation, government policy, and diffusion; his 1982 book with Sidney Winter positing an evolutionary theory of economic change attracted significant attention (Nelson, 1966; Nelson, Peck, & Kalachek, 1967; Nelson & Winter, 1982; Nelson & Yates, 1978).

In the 1980s, Nelson played a key role in defining the study of newly industrializing countries. Key phrases in the vocabulary adopted by Nelson and his colleagues included *national systems of technical innovation*, *institutional learning*, *organizational capabilities*, and *absorptive capacity*. They talked about *technonationalism*, which Nelson described as "combining a strong belief that the technological capabilities of a nation's firms are a key source of their competitive prowess, with a belief that these capabilities are in a sense national, and can be built by national action" (Nelson, 1993, p. 3). Thus, even in an age of multinational corporations, these scholars assumed national policies could assist the movement, adoption, and adaptation of new technologies within and between firms and when necessary across national boundaries (Dosi, 2000; Dosi, Giannetti, & Toninelli, 1992; Dosi, Nelson, & Winter, 2000; Dosi, Teece, & Chytry, 1998; Kim & Nelson, 2000; Lundvall, 1992; Mowery & Nelson, 1999; Nelson & Pack, 1999; Ostry & Nelson, 1995). David Mowery, for example, examined research collaborations as part of the American national innovation system, considering not just linkages between university and government laboratories and corporations, but also the connections those firms had outside the United States. In one case study, he focused on the desire of the Japanese to acquire knowledge and experience in airframe and aircraft design through joint ventures with Boeing (Mowery, 1987, 1988). In short, technology transfer was a central mechanism in the rapid growth of newly industrializing countries during the 1980s and 1990s. The pessimism about American firms competing against these rapidly growing states evaporated during the 1990s, but the focus on economic growth through technological acquisition remains a dominant question among economists and economic historians alike.

CONCLUSION

This overly rapid survey of technology transfer and the motivations for academic scholarship has suggested that the meaning of the term for practitioners has broadened significantly even as this topic has become centrally important to a growing number of academic fields. Space restrictions preclude covering more of them, and the essay probably does not do justice to several that are included here. The other editors of *Comparative Technology Transfer and Society* promise to fill some gaps in their introductory essays in the next two issues of the journal. Still, there are inevitable holes in the coverage. So, as a final indication of the breadth the journal hopes to achieve, let me quickly mention several other fields where scholars are fruitfully examining technology transfer. For example, scholars of management and business have been pursuing the meaning of changing business structure and environments for technology transfer (Agmon & Von Glinow, 1991; Liker, Fruin, & Adler, 1999; Miller & Garnsey, 2000; Murtha, Lenway, & Hart, 2001; Teece, 1976). Business historians offer detailed case studies, and legal scholars concerned with patents, licenses, and intellectual property also have things to say about diffusion. Exciting work is underway in science and technology studies (STS), where scholars have moved beyond a simplistic notion of the impact of technology on society to emphasize instead a two-way interaction between technology and society and culture. This point of view reinforces the understanding that successful technology transfer activities must involve creative adaptation, even as they make problematic the term *resistance* when applied to diffusion (Etzkowitz & Leydesdorff, 1997; Guston & Keniston, 1994; Slaughter & Leslie, 1997).

Another field that will be covered in a later essay is information technology, where practitioners face significant technology transfer challenges (Gruber, 2001; Kaye & Little, 1996; Larsen & McGuire, 1998). Computers appear to be a universal technology (witness the almost complete dominance of English within programming and mark-up languages), but their adoption and use in different cultures suggests reality is much more complex. The development of a wired world, and overcoming various digital divides, is a technology transfer issue of the first order.

Other aspects of technology transfer have been explored since Rogers first categorized the scholarship—agriculture and medicine, for example. But newer topics have also attracted the interest of researchers. Thus, research is emerging on technology diffusion and the environment, focused on the transfer of pollution control technology and strategies (Barnett, 1995; Rappaport, 1993). This work shades into the growing literature on sustainability.

Finally, certain geographic regions and countries seem to hold special promise for research on technology transfer. China has been mentioned already. Attention should also be devoted to India, primarily because so many scholars in that country have undertaken substantial research on the diffusion of innovation and technology transfer. No doubt this stems from India's history as a former colony and a developing nation, with the result being a series of studies examining the history of colonial and postcolonial activities in technology transfer. That history includes interesting episodes during the colonial era as well as during the postwar period. Since 1945, India has witnessed the Green Revolution, the development of an industrial economy, and the interesting effort to play the Soviet Union and United States against each other as India tried to chart a path for the nonaligned movement.

Scholarship in India on technology transfer, however, has gone well beyond historical studies. In 1973, the government created a center for the study of science, technology, and development at the Council of Scientific and Industrial Research (CSIR). In 1981, the center became one of 39 institutes within the CSIR and was renamed the National Institute of Science, Technology, and Development Studies (NISTADS). The current faculty includes 47 members, one-third with social science degrees and the remainder with backgrounds in engineering and science. This research group has examined the process and dynamics of diffusion work, as well as the relationship of transfer programs to economic development. Topics span the spectrum from rural development to high-tech trends and intellectual property issues (Jamal, 1999; Kharbanda & Jain, 1999; Visalakshi, 1999). These researchers take an active role in relevant policy discussions on biotechnology, the ethics of transfer, and the effort by India to transfer technology to other developing nations.[6] When the NISTADS group is added to the faculty at Indian universities and Indian scholars at institutions around the world, the community of Indian scholars interested in technology diffusion may be one of the largest in the world (Balasubramanyam, 1973; Jain, 1994; Jha, 1994; Kumar, 1988; Lall, 1982, 1985; Mehrotra, 1990; Sahu, 1988; Tyabji, 1995, 1998, 2000).

Clearly, technology transfer has become a sprawling multidisciplinary topic of scholarship over the past 40 years, one with numerous dimensions and aspects, pursued along multiple, occasionally intersecting pathways. At a mid-1970s workshop on technology diffusion, historian of technology Melvin Kranzberg (1978, p. 364) commented that the existence of multiple disciplinary perspectives "does not result in myopia, but rather in different angles of vision. The result is that diffusion is clearly viewed as a multifaceted phenomenon." This comment still rings true, as does the sense that the number of scholars engaged within any one academic community is not large, so much of the research is organized at the subdisciplinary or field specialty level. This dispersal across academic disciplines and subdisciplines means that individual researchers may be unaware of related studies just across the intellectual horizon. Another scholar attending that workshop observed that diffusion research "is still so fragmented by specialized concerns," a fact that was "a reflection rather of the fragmented nature of any emerging field, and the enormous range of disparate elements that characterize this one" (Radnor, Feller, & Rogers, 1978, p. i). In some respects, this comment still characterizes scholarly work on the topic of technology transfer. But the most important point is that the "enormous range" has grown even larger, suggesting that the journal has an opportunity to bring together the work of scholars across many different boundaries.

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[6]Information on NISTADS can be found at <http://nistads.res.in/contents/about.htm>.

The editors of this new journal have no illusions of bringing unity to this topic of study, for as several earlier commentators remarked, no integrated theoretical structure exists to hold this scholarship together (Brown, 1981; Rogers, 1962; Radnor, Feller, & Rogers, 1978). As McIntryre and Papp (1986, p. 15) commented, "That scholars from so many disciplines address the issues related to technology transfer may paradoxically preclude the successful search for integrative theoretical frameworks." However, the editors do hope that they can turn this problem into an opportunity, and by incorporating into the journal the work from all of the fields discussed above—and others as well—create a forum for scholarly exchanges about this interdisciplinary topic.

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