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1990

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INSTITUTIONS AND THE INTERNATIONAL DIFFUSION OF INFORMATION TECHNOLOGY[1]

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ABSTRACT

The production and use of information technology (IT) in developed countries is well established and growing at a rapid pace. Newly industrializing countries are adopting both IT production and use as national goals. Developing countries are beginning to formulate plans to do the same. The institutional role in the international diffusion of IT is not well understood, but it is clear from the literature on innovation that the institutional role is critical. The paper makes four points. First, a traditional and fairly rigorous way of thinking about innovations – the economic perspective deriving from Schumpeter and Hicks – has been shown by studies from economic history and sociology/communications of innovation to be inadequate for explaining the dynamics of innovative change. The missing element is understanding of differential roles played by institutions. Second, among those promoting the need for institutional intervention there has been a debate about whether innovation is primarily supply-pushed or demand-pulled. The answer to the question has important institutional implications. The evidence, again mostly from economic history, shows it to be *both*, in iterative fashion. Thus institutions *can* intervene meaningfully on both sides. Third, there are two major forms of institutional intervention: influence and regulation. The possible intervention actions of institutions can be encompassed by a 2 x 2 matrix with supply-push and demand-pull on one dimension and influence and regulation on the other. Finally, if government wants to intervene, there are six classes of roles that might be pursued to affect innovation.

1. INTRODUCTION

Information technologies (IT) in the form of computers and communications have been among the fastest growing innovations in both production and use during the past four decades, and the prospects for future growth appear equally bright (Freeman and Perez 1988; Willinger and Luscovitch 1988). IT constitutes an important *innovation* in several respects. First, the production of such technologies has been highly innovative, rapidly adopting and extending new materials and devices such as semiconductor processors and memories, magnetic storage, interface devices, and so on. Second, this production has required and produced innovative design and manufacturing techniques, ranging from computer-assisted design to thin-film deposition VLSI processes. Third, the use of these technologies has required extensive innovation within the consumer organizations, resulting in the creation of new organizational entities, job classes, skill bases, protocols, and norms. Despite uncertainty about the precise economic payoffs of these innovations, the growth in production of these technologies is indisputable, and there is considerable agreement that the application of these technologies has improved organizational well-being. The experience in industrialized countries suggests that these innovations will diffuse to newly industrializing countries (NICs) and developing countries (DCs) in due course. The question arises whether diffusion is a deterministic and passive phenomenon. Active efforts to stimulate diffusion of these innovations have been suggested as a means of improving the welfare of NICs and DCs in rapid fashion. However, there is considerable controversy about how best to proceed with efforts to stimulate diffusion in both production and use of IT. Without a sound understanding of the dynamics of such innovation, there will be little guidance to assist policy makers in both the public and private sectors at the local, national, regional and international levels.

This paper provides a broad perspective on the roles that institutions might play in facilitating the international diffusion of IT. It constructs a framework that incorporates "supply-push" and "demand-pull" perspectives, coupled with influence and regulatory roles of institutions, to provide an account of possible institutional actions on behalf of production and use of IT innovations. It then uses this framework to assess key roles that governments, as particularly important institutional actors, can play in innovation processes.

2. INSTITUTIONS AND INNOVATION FORCES

Despite the agreed-on importance of innovation to economic well being, the subject of innovation is by no means well understood (Tornatzky et al. 1983). Extensive study by economic historians, sociologists, communications researchers, engineers, public policy experts, and management theorists has moved the field forward, but many questions remain.

A key discovery from these many streams of inquiry is the fact that inevitably it is individuals acting in institutional and economic circumstances that make the decisions about whether to exploit innovation in production or use. The relevant question from a policy perspective, assuming one is interested in seeing useful technologies diffuse rapidly, is whether anything can be done to affect the rate of diffusion. This question is usually addressed in the context of public policy options, but the broad question is institutional: what active role might institutions, including governments, take to stimulate adoption of potentially useful technologies? Before addressing this question, we will describe an important "framing" perspective: the supply-push and demand-pull models of innovation.

2.1 Supply-Push and Demand-Pull Models

The broad causal parameters of innovation – the basic "drivers" of change that might be affected by institutional intervention – have frequently been characterized in research literature as "supply-push" and "demand-pull" forces.

"Supply-push" assumes that the major motivating force for innovation comes from the production of the innovative product or process itself. There can be no diffusion of innovation without an innovation to adopt, and the innovation itself is created by supply factors. This view has found expression not only as a starting point for studying the diffusion of innovation, but for broader inquiry about the nature of economic and social change. For example, anthropologist Leslie White (1949) has written that innovation precedes and lays the groundwork for all subsequent commercial and social growth; a concept called technological determinism.

On the other hand, it is quite clear that no innovation will survive, despite any amount of "pushing," unless there is some genuine need for it in the world. Moreover, it seems highly likely that enterprising innovators will choose to work first on problems that correspond to existing needs, thereby increasing the likelihood that their innovations will be adopted and used. In this model, the expressed needs of society, as articulated through the mechanism of the market, create a "demand-pull" incentive for innovation. By the mid-1970s the view had emerged that demand-pull forces were dominant in the innovation process (Utterback 1974; Gilpin 1975).

The role of "supply-push" or "demand-pull" forces in the innovation process is important for the assessment of institutional options for affecting diffusion of production and use of innovations. Each presents very different targets for intervention, and each produces different ideological issues for the would-be interventionist. If innovation is basically driven by supply forces, intervention must concentrate on the production of innovations. This will entail stimulating the production and application of factors that go into innovating. These might include a growing supply of scientific and technical knowledge, provision of capital for experimentation and development of prototypes, and support for getting innovative products and processes ready for the marketplace. On the other hand, if the process is mainly driven by demand forces, intervention would require focusing demand on potential sources of supply to stimulate them into action, mobilizing the bias of potential buyers to invest in the innovations, and support of sufficient capital for acquisition of the innovations by the consuming organizations.

It appears from historical studies of innovations that both supply and demand forces are operating at all times in the innovation process. Moreover, the dynamics of the interaction between the forces themselves change depending on circumstances, including the relative state of technical knowledge, the availability of complementary and substitutive factors, the character of the needs of society at any one time, the effectiveness of the market at translating needs into clear demands, and so on. These factors are seen in long-view assessments of technological change within global regions (Landes 1969; Pavitt 1971), between countries (Habakkuk 1962), across domains of knowledge and invention (Carter and Williams 1957), and across industries (Beniger 1986).

Innovation production and diffusion of use is always a complex interplay of economic, technical, social and political factors that does not lend itself to immediate apprehension and understanding. This naturally complicates the options available for institutional intervention in the innovation process, and makes formulation of prescriptive policy very difficult. On the other hand, this situation opens a number of avenues for careful and systematic research on the question of innovation and institutional intervention.

3. INSTITUTIONAL INTERVENTION IN DIFFUSION OF INFORMATION TECHNOLOGY

3.1 The Institutional Role

From the preceding discussion, we see that technical change is a fundamental driver – one of the several "supply-push" forces for innovation. In addition, the needs of society, both as articulated by market forces and independent thereof, play a crucial role in stimulating, or "pulling," continued innovation effort. The mechanisms of innovation have to do with both technical change and institutional change, or the lack of it. In the Schumpeterian view, technological change is a disequilibrating factor. However it is also a source of order in the long-term process of dynamic adjustment to any given change (David 1975). The socio-institutional framework "always influences and may sometimes facilitate and retard processes of technical and structural change, coordination, and dynamic adjustment" (Freeman 1988, p. 2). Moreover, acceleration and retardation in these circumstances are not market imperfections, but are characteristics of the markets themselves. Markets are socially constructed media of information sharing and exchange. They reflect rather than construct the social order around them. Institutions and markets are inseparable from one another.

What, exactly, is meant by institution in this context? We mean the term to include any standing social entity that exerts influence and regulatory authority over other social entities. "Standing" is embodied in Hughes' definition from more than a half century ago: an institution is a persistent feature of social life that outlasts social participants and survives upheaval in the social order (Hughes 1939). The "influence" of an institution is the exerting of persuasive control over the practices, rules and belief systems of those under the institution's sway (Kimberly 1979). The primary means by which institutions obtain such influence are control of the education and socialization processes of individuals, the systematic articulation of particular points of view (e.g., propaganda), and provision of differentially more resources to those social activities deemed "appropriate" and withholding of resources from those deemed "inappropriate." This influence aspect of institutional intervention has been the primary concern of innovation researchers in the public policy arena.[2]

The "regulatory" aspect of institutions is the direct or indirect intervention in behavior of those under the institution's influence, with the specific objective of modifying that behavior through sanction or other affirmative means. As articulated by Boyer (1988b), regulation is implemented by any modality with the following properties: the means of making conflicting decentralized decisions compatible without the need for individuals to bear in mind the logic of the overall system; the ability to control the prevailing mode of resource accumulation; and the means to reproduce existing social relationships through a system of historically determined institutional forms.[3] This aspect of institutional intervention has been of central concern to individuals attempting to shape institutional (especially government) policy for innovation from economic precepts.

Our concern in the sections that follow centers on the influence and regulation institutions might exert in shaping the international diffusion of IT.

The immediate form of institution that comes to mind in such discussions is government, and indeed, government is a powerful source of institutional influence and regulation. However, there are other powerful institutions that can affect diffusion of IT. We list and describe below the institutions that are referred to in this paper:[4]

Central and local government authorities. These include both national government agencies as well as influential sub-units of government such as provinces, prefectures, states, municipalities, etc.

International agencies. This includes mainly the international "outreach" agencies of developed countries (e.g., US-AID) and the mission agencies of broad international organizations such as the United Nations (e.g., UNIDO, ESCAP, UNCRD, APDC).

Professional and trade and industry associations. These are typically national in character, though some might be international in influence. They include scientific and technical societies, organizations of professionals such as physicians and lawyers, trade and industry associations, and labor unions.

Higher Education institutions. While some of these can be seen as instrumentalities of government, in most cases the research-oriented educational institutions form a special class of influential organizations.

Trend-setting corporations. Within any given country, powerful companies performing important functions can have dramatic influence on innovation (e.g., AT&T in the U.S. prior to 1985).

Multi-national corporations. These organizations have demonstrated important influence in the movement of technology throughout the world, and might in fact constitute a primary institutional mechanism of diffusion of certain high-technology innovations such as computers.

For the sake of clarity and expediency, we do not address the discussion below to specific institutions. Rather, we review the possible institutional roles in diffusion according to broad classes of "supply-push" and "demand-pull" activities that might contain roles of any or all of these institutions.

3.2 Forms of Institutional Action

The discussion below is organized around two dimensions of potential institutional action. On one dimension are the "supply-push" and "demand-pull" forces that institutions might exert. On the other dimension are the two dominant roles of influence and regulation that institutions can play. In the cells are examples of kinds of specific actions in which institutions might engage. The outcome of this array is shown in Figure 1. Each of these actions can be classified as one of six general kinds: knowledge building, knowledge deployment, subsidy, mobilization, standard setting, and innovation directive. We elaborate each kind of action below, highlighting the arguments for/against the action, and noting the kinds of institutions that might be involved. For each item listed, its position in Figure 1 is noted by presence in one of the cells, from I to IV.

3.3 Knowledge Building

Knowledge building is undertaken to provide the base of scientific and technical knowledge required to produce and exploit innovations. An obvious form of knowledge building is sponsored research that helps build the base of knowledge necessary for innovative activity (Cell I, Figure 1). This kind of activity is often supported by governments, but governments are by no means the universal or direct institutional sponsors of such research, and the modes of support vary from country to country. In the U.S., the government role in research support is very large but is supplemented by support from other institutions such as private foundations and companies. In most large Western European countries, the national governments support most basic research. An example in information technology is the Alvey project in the U.K., which focused on four areas of enabling technologies and associated research: software engineering, man-machine interface, intelligent knowledge-based systems, and very large scale integration (BDI 1982). In expensive and difficult research areas, a solid tradition of international cooperation has emerged. The ESPRIT project of the European Economic Community is an instance of such multinational cooperation in knowledge building activities in advanced microelectronics, software technology, advanced information processing, and documentation standards (EC Commission 1983). In Japan, the government supports comparatively little of the nation's research activity, but government plays an important role in mobilizing the very large corporate investment in research around particular topics of identified national importance. In the Fifth Generation Project, coordinated by the government, researchers come from a variety of places, including eight large companies and two national laboratories (Feigenbaum and McCorduck 1984). In Korea, the government has announced a plan for the development of scientific technology by 2000, with the development of VLSI capability a top priority (Jae 1990).

Knowledge building can take place through the support of basic research with limited immediate application potential, or through support of applied research that will hopefully yield particular kinds of utilities. The huge U.S. biomedical research establishment embodies both kinds of research in large measure, ranging from the most basic investigations into the nature of living organisms to the most practical assessments of treatments for diseases. Also, institutions can have multiple objectives for supporting knowledge building activities. The U.S. programs for development of nuclear science and technology were guided by expectations about payoffs to both military application and power generation, and the vast majority of research funds in this field were from the government (Nelson 1988). The bulk of U.S. government funding for the development of computer technologies, however, was aimed at military objectives, while research aimed at commercial application was left largely to the private sector (Flamm 1985, 1987). Finally, institutions can change their funding modalities over time. For example, the U.S. commercial aircraft industry was literally built on government sponsored R&D from 1945 through 1965, but when the needs of military aviation and commercial aviation diverged in the late 1960s, the R&D burden shifted dramatically onto the civilian aircraft companies (Mowery and Rosenberg 1981).

Substantial scientific and technical knowledge building activity is necessary for production of innovations, but it is not clearly required for diffusion in use. In fact, several studies of Japan's remarkable economic growth, which was highly dependent on adoption and institutionalization of innovative industrial practices, suggest that much of this progress was made possible through "learning by using" that did not require substantial in-place bodies of scientific and technical know-how (Rosenberg 1982; Johnson 1982). In general, we conclude that *institutional intervention to promote knowledge building is essential to sustained production of innovation in the field of IT, but it is not absolutely required for successful diffusion in use.*

Knowledge Deployment. The objective in knowledge deployment is to stimulate the dissemination of new knowledge, either in the form of knowledgeable individuals and organizations, or in the form of repositories of knowledge in the form of archives and libraries of scientific and technical facts. The most obvious form of knowledge deployment is the general provision of education to the population (Cell I, Figure 1). The creation of a literate and educated population has been shown to be essential to any broad innovative tradition (Mathias 1972; Easterlin 1965). The provision of education is usually carried out by government entities in most countries, but in some there is a substantial component of educational service provided by private non-profit or profit institutions (e.g., religious organizations, private schools). Beyond provision of

	Supply Push	Demand Pull
Influence	Knowledge building Funding of research projects Knowledge deployment Provision of education services Encouragement of in-migration of knowledgeable individuals and organizations Subsidy Funding development of prototypes Encouragement of capital markets to support R&D activity Provision of tax benefits for investment in R&D (e.g., investment tax credits, rapid depreciation) Innovation directive Direct institutional operation of production facilities for innovation I	Mobilization Programs for awareness and promotion Knowledge deployment Training programs for individuals and organizations to provide base of skilled talent for use Subsidy Procurement of innovative products and services Direct or indirect provision of complementarities required for use Direct of indirect suppression of substitute products or processes II
Regulation	III Knowledge deployment Require education and training of all citizens Innovation directive Establishment of requirements for investment in R&D by organizations Subsidy Reduction in general liabilities for organizations engaging in innovative activity Modification of legal, administrative, or competitive barriers to innovation and trade Standards Establishment of standards under which innovative activity might be encouraged	IV Subsidy Establishment of standards for products and processes that facilitate adoption and/use Standards Require particular products or processes to be used in any work for the institution Require conformance with other standards that essentially mandate use of particular products or processes Innovation directive Require that specific innovatibe products or processes be used at all times

Figure 1. Dimensions of Institutional Intervention

educational opportunity, there is the corollary act of mandating education to a particular level; for example, requiring children to attend school through age 16, or through grade 10 (III). Such broad mandates might include, along the way, components of IT-related education. For example, in Taiwan every vocational school student must take at least four courses in computer application and basic information technology (Cheng 1990). Mandates regarding education are usually the sole province of the government.

Another form of knowledge deployment is the encouragement of already knowledgeable individuals and organizations to come into the country or region and establish operations (I). This is a major objective of immigration laws that give preference to individuals with special skills, and of industrial and commercial development activities that favor certain kinds of businesses and industries. Such actions are usually carried out by governments, although private corporations, local development organizations and trade/professional associations might play a significant role in establishing such practices. The multinational firms appear to play a major role in such knowledge deployment processes (Vernon 1971, 1977; Encarnation 1989). For example, the government of Singapore has established training institutions in several areas of information technology in collaboration with major corporations, including the Institute of Systems Science with IBM, a data communications education center with AT&T, and a software development center with assistance from Japanese corporations.

Still another form of knowledge deployment is aimed at stimulating the use of innovations by training a cadre of potential users (II). This kind of activity might be performed by government agencies, but it is also frequently performed by trade and professional associations, unions, and companies with an interest in providing the necessary human talent to exploit an innovation. Such programs have played important roles in major innovation efforts in the past (Rosenberg 1982). In Taiwan, a national-level examination, jointly administered by the Ministries of Education and of Economic Affairs, was put into force in 1984. Three levels of examinations are held: systems analyst, senior programmer, and programmer. Each year between 2,000 and 4,000 people register to take these examinations, and about 10 to 15 fifteen percent pass them. A high percentage of those who do pass are not graduates of IT-related instruction programs (Cheng 1990). Testing is not the only mechanism available for the purpose of building special skills. The government of Singapore provides a program called ITPOWER that contains 56 hours of instruction aimed to equip office workers with basic skills to use personal computers for common office applications.

Generally speaking, knowledge deployment activities are the foundation of institutional interventions to stimulate innovation. Without the ability on the part of a significant number of individuals in the population to apprehend innovation potential, or to recognize the prospects for exploiting an innovation, it is essentially certain the production of innovations and their diffusion in use cannot take place. The dynamics of this necessity go beyond the first-order fact that without innovative people there can be no innovation. In some cases, innovative people rise up out of otherwise poorly educated populations, and at least in theory might contribute to the innovativeness of the region. However, such lone innovators are soon discouraged by lack of support or recognition for their talents, and either lose their innovative incentives or migrate to regions where their innovations can be appreciated. *It is doubtful, therefore, that any significant diffusion of IT will take place without serious and sustained institutional interventions for knowledge deployment, and the extent of diffusion is likely to be correlated with the extent of knowledge deployment.*

Subsidy. A subsidy is provided whenever an institution, having resources of its own (from any source), defrays the otherwise unavoidable costs to innovators and users in the process of innovation and diffusion in use. Subsidies take a variety of forms. In a sense, both knowledge building through institutional grants and the provision of general education are subsidies for innovation. But the intent of knowledge building and education is much broader than to facilitate innovation, while subsidy is generally a targeted activity to achieve a specific end, such as an increase in the indigenous production and/or use of computer systems. Thus, we use subsidy to describe institutional activities designed to produce specific innovative outcomes.

A good example of subsidy for innovation is the funding of prototype development and demonstration projects that help to prove concepts and reveal possible improvements (I). Such subsidy is often provided by government, through one means or another, but this is not always the case. Funding can be provided, as noted under knowledge building above, by other institutional sources. The European Economic Community, for example has allocated ECU 23 million for pilot projects that demonstrate innovative new applications of information technology (CACM 1990). Less direct but perhaps as potent as subsidies are the encouragement of capital markets to make funds available for innovative activity (I) and acquisition of innovative products or processes (II). These mechanisms are generally tools of government agencies, effected through preferential treatment on loan guarantees, provision of tax breaks, and so on, which are usually instrumentalities of governments (I). For example, the Singapore government's Small Enterprise Computerization Programme encourages small enterprises in Singapore to implement computer systems by subsidizing the cost of external expertise and providing low-interest loans for hardware and software purchase (II) (Raman 1990). In Taiwan, the Ministry of Economic Affairs has similarly provided assistance to computerize small and medium sized firms (Cheng 1990).

Another powerful form of subsidy is institutional procurement of innovations. This is a particularly dramatic form of intervention when the institution is a large buyer, as in the case of military procurement by governments or procurement of communications equipment by national telephone companies. By specifying particular requirements, innovative developments and production can thus be stimulated. The power of this instrument is dramatically shown in the case of U.S. government procurement in the areas of aircraft, spacecraft, electronics and computers. The effectiveness of this instrument goes beyond its direct application as a form of influence on demand (II). It can also be a mandate that innovative products or processes be used as a condition of aid for support from the institution for any reason. An example would be the required use of particular accounting innovations for administration of institutionally funded programs (IV). In this instance, the subsidy is for something else, but the innovation is required nonetheless.

A subtle but often essential kind of subsidy is direct or indirect support for provision of necessary complements to be used with innovative products or processes (II). Perhaps the most obvious two complements related to IT are establishment and maintenance of reliable and continuous electrical power and telecommunications services (Flamm 1985). The establishment of roads, harbors, and other physical improvements are other examples. A different kind of subsidy can be provided by proscribing or prohibiting the use of substitutes for the innovation in question (II). Examples are giving preference to domestic products or services, limiting the foreign content of products, or taxing imported products and services. Rules of Origin are used to determine application of customs tariffs. For integrated circuits, the EC Commission in 1989 reinterpreted the governing principle as "the operation of diffusion," which will require diffusion of integrated circuits to be built in the EC countries. This is potentially significant for GSP countries that export most of the integrated circuits assembled in their countries (II) (Chiarado and Mussehl 1990). The protective tariffs and import restrictions of Brazil, India, and Japan on certain information technology products and services are also well known. In these cases, the institution provides a relative advantage, and thereby an effective subsidy, by making the use of alternatives more costly or impossible. This can be an especially important instrument for forcing out older ways of doing things by specifying that they cannot be used in work for the institution.

Finally, there are important but indirect subsidies in the form of reducing barriers to production of innovation by individuals and organizations (III). One kind of subsidy restricts the risks associated with innovation, as with the U.S. government's legal restriction of maximum liability for any single nuclear power accident. This effectively eliminates the catastrophic loss potential from such accidents, and makes private investors more willing to use nuclear power generating innovations. A second kind of subsidy modifies the barriers to competition in the use of an innovation, such as restricting commercial returns from use of an innovation to particular parties. This is precisely the objective of patent and copyright laws, which restrict the right to a return from the use of an innovation by requiring payment of license and royalty fees established by the patent or copyright holder. As an example of the modification of legal and administrative barriers, the EC Commission has taken the initiative to eliminate legal and administrative obstacles in the areas of intellectual property including software, the authentication of electronic transactions, suppression of electronic fraud, and improved means for dealing with the liabilities of information services (CACM 1990).

We believe that *subsidies are crucial instruments of institutional intervention in both the production of innovations and diffusion of use in the area of IT.*

Mobilization. Mobilization basically means the encouragement of decentralized actors and organizations to think in a particular way with respect to an innovation. By encouraging a positive or negative view of an innovation, diffusion will be affected. Mobilization is a subtle force and can be found in all of the above. For example, there is no doubt that the pro-science curricula of most public schools in the United States are intended, whatever their actual results, to encourage students to accept scientific viewpoints and, if possible, pursue scientific careers. The intent of the term as used here is more precise, however, and addresses institutional action taken specifically to encourage the use of particular kinds of innovations. The main institutional instruments for this kind of mobilization are promotional and awareness campaigns (II). These include advertising to support use of the innovation (e.g., "Buckle Up For Safety"), staging of major events (e.g., Consumer Electronics Show), and establishment of social traditions (e.g., National Information Technology Week). Highly successful examples of social traditions are the annual Information Technology Week in Singapore and the annual Information Month in Taiwan. Each event is built around trade expositions, seminars, publications, and opportunities to provide the interested public with hands-on experience using new information technologies. In Taiwan, Information Month events are held in all major cities, and gross attendance is often more than 15 percent of the country's population (Cheng 1990).

There is a special, and we believe, significant mobilization role played by higher education and professional associations that has not been well addressed by past research. This is the role of mobilizing the self-interest and organizational interests of significant actors within organizations to see innovation as necessary to organizational welfare. Although difficult to measure directly, we believe this has been a particularly important component in the spread of use of IT in both private firms and public agencies alike. The emphasis on strategic importance of particular technologies for competitive positioning, especially in the context of global markets is one example. Given that this advice is targeted to highly placed executives within large firms with multinational operations, such mobilization could be an important force in the global spread of innovative capability (Chesnais 1988; Henderson 1989).

It is not easy to determine whether such mobilization efforts have a dramatic effect on actual innovative practices. They might, for example, have the same fuzzy and ill understood effects that advertising has on consumer behavior generally. Regardless of the net effect of such efforts, it is clear that simple mobilization efforts can have little effect on actual innovation without the other interventions of knowledge building, knowledge deployment, and subsidy. Nevertheless, such efforts can have a marked catalytic effect in the presence of these factors. Thus, *mobilization efforts, in conjunction with other institutional interventions, can have a stimulating effect on innovation production and diffusion of use with respect to IT.*

Standard Setting. Standard setting is a form of regulation aimed at constraining options of decentralized actors and organizations in line with larger social or institutional objectives. Standards are socially constructed; they are agreements or "treaties" among interested parties to describe one way of doing things as "preferable." They can be completely voluntary, as many standards promulgated by professional and trade associations are, or they can have the force of law. Standards appear as components of knowledge building, knowledge deployment, and subsidy instruments. They both derive from and help direct the course of knowledge building activities, and they significantly influence the codification of knowledge as it is deployed in the society. Standards are an important mechanism for imposing meaning and order on a corpus of knowledge that otherwise provides too many potential options to be socially applicable.

There are some notable examples of standard setting in the IT arena. For example, the EC Commission has acted to support standardization in the area of database access with respect to harmonizing procedures for computer networking, formats for data transfer, and criteria for description of data bases (IV) (CACM 1990). The ISO Open System Interconnect (OSI) standard has been promulgated to set standards of linking heterogeneous computer systems (IV) (ISO 1984). Broadly speaking, the varied efforts to establish the Unix operating system as a standard falls within this category. Over the past few years, several mainstream versions of the operating system have converged on a fairly well-defined set of features. Since 1988, two standard versions have emerged: the Unix International version backed by AT&T, Sun Microsystems and a number of other firms, and the Open Software Foundation version backed by IBM , Digital Equipment, Hewlett-Packard, and five other firms. Efforts to bring Unix International and OSF together to build the "final" version of Unix have thus far failed, but the potential for establishment of a single standard is widely recognized and awaited (Economist 1990; Bakos, King and Morgan 1990).

Standards appear as instruments for institutional intervention in innovation in several ways. They can be established to stimulate or speed up investment in innovation production (Cell III, Figure 1). For example, efforts to build data communication controllers can be stalled while different, decentralized actors try to figure out the structure of the connectors that go between the machines. Setting a standard for such connectors removes an obstacle to progress on the more complex and important problems in developing the controllers. A highly controversial arena for such standards involves High Definition Television (HDTV). Japan has adopted the Muse standard developed by several large Japanese electronics companies, and proclaimed the HDTV era "launched" in June of 1990. Whether this concerted effort will yield advantage remains to be seen, but in contrast, the lack of a terrestrial HDTV transmission standard, questions about the real importance of HDTV to the consumer electronics industry, and squabbles over whether the government should play any role in HDTV development have made it unlikely that HDTV broadcasting in the U.S. can begin before 1993 (Jurgen 1989). Standards are also established to promote the use of innovations after they have been developed (IV). Potential adopters are often concerned about future technical changes, and in particular about the residual value of their investments and the upgrade path for future procurement. They are reluctant to buy innovations that are "non-standard" because these will be hard to sell subsequently, and because any additional apparatus or protocols built around the innovation will be rendered useless in time.

An indirect but important kind of standard is that which establishes some minimum level of performance on a particular criterion that, to be reached, requires use of a particular innovation. For example, health regulations surrounding the sale of certain food products mandate pathogen or impurity counts below particular thresholds that can only be reached by use of innovations such as pasteurization in dairy products or batch retort autoclaving in canned goods. The standard itself does not mandate innovation, but provides an incentive to use innovations that meet the standard, and to produce new innovations that meet the standard more efficiently.

Standards are often called upon to help stabilize technological domains that confuse consumers in the belief that a certain world is preferable to a worrisome, uncertain world. However, premature settling on a standard can have the effect of stifling innovation in the future by locking innovation production onto a path that subsequently proves sub-optimal. Standards can therefore serve to constrain as well as enhance innovation. We believe, therefore, that *standards can be an important tool of institutional intervention in innovation production and* *diffusion of use in the area of IT, but standard-setting is a risky instrumentality that must be used with great care to avoid counterproductive consequences.*

Innovation Directive. The last category of actions is the innovation directive: a command to produce innovations or to use them. One form of directive is for the institution to produce its own innovations and/or use them (Cell I, Figure 1). This is best seen in the instance of a government agency or industry that is required to develop or use particular technologies. Another form of directive is the requirement that organizations invest given amounts of their resources in R&D activity presumed to lead to innovation (III). A third form of directive is a requirement that organizations use particular products or processes wherever they can be applied (IV).

In general, however, directive interventions have a mixed record in encouraging innovation production or diffusion in use. One reason, undoubtedly, is that institutions cannot easily force people to be creative. Invention is a form of human activity not well understood. Like art, it occurs when a complex and fuzzy set of capabilities, attitudes and incentives come together in an individual or, less often, a group. It is essentially impossible to "engineer" innovative processes. Another reason why directives about innovation do not usually succeed is that, to be effective in accomplishment of objectives, the directives must be targeted toward achieving specific innovative breakthroughs. This effectively places higher-level individuals who know relatively little about the intimate details of the problem in the position of directing lower-level individuals who do know the details. This produced the dilemma von Hayek (1945) characterized as the local/distant knowledge problem, in which those most empowered to act know the least about the problem at hand.

We note that in some circumstances, as in a state of war, conditions may require development or adoption of certain kinds of innovations if a country is to prevail. This is a highly unusual circumstance, in which many aspects of the social order are altered. For one thing, in the case of a war with broad public support, individuals often willingly sacrifice personal discretion to follow the directives of the national leadership. Private incentive, while necessary in some aspects of wartime activity, is generally reduced. Shared objectives become powerful motivators of individual action and striking results can be obtained. The technical progress made during the second world war in many areas (radar, rocketry, aviation, nuclear power) demonstrate that a kind of directive for innovation can produce dramatic effects. Again, this is an exceptional circumstance.

We believe that, other than in the cases noted, *there is relatively little potential for innovation directives as useful institutional instruments for support of innovation production and diffusion of use in the area of IT.*

4. CONCLUSION

This review has placed the possible role of institutions in the international diffusion of IT into the context of existing theory about innovation. We conclude that both production and use must be considered as essential and linked components in any theory of innovation, and that neither can be understood without the other. Also, both supply-push and demand-pull forces must be taken into account in any assessment of possible institutional intervention. Finally, we note that institutions can and do play a critical role in innovation and that concerted institutional action can make the difference between progress and stagnation. Still, it should be clear that institutional intervention alone, without the broader contextual factors of economic conditions, will not produce innovation under directive.

We conclude with some observations on the role of government as an institution in the innovation process. Government entities are clearly among the most powerful institutional forces affecting innovation (Nelson and Soete 1988). Their effects come in several forms. Most obviously, deliberate interventions such as the U.S. government's military activities related to nuclear power, the Japanese government's stimulation of the electronics industry, and India's decision to dislodge multinational firms can all be seen as having direct and important consequences for innovation. Indeed, these direct interventions have become the subject of much heated inquiry as countries with extraordinary economic growth performance (notably Japan and South Korea) surge onto the international economic scene. The governments of both countries have intervened forcefully in economic development, especially in areas of innovation and technology, and the effects of these interventions have demonstrated that received economic wisdom about the inherent efficiency of markets and the evils of government intervention is flawed (Johnson 1982; Amsden 1989; Perez and Soete 1988). The desire of NICs to expand their production and use of high-technology, and of DCs to break into the game at any level, is ample testimony to the belief that government intervention *can* make a major difference in innovation success (Matley and Mcdannald 1987).

We should note, as well, that deliberate government decisions to refrain from intervening in innovative processes are themselves a form of policy. For the past decade the avowed policy in both the U.S. and the U.K. has been to withdraw from direct governmental support of innovation in spheres that, arguably, can be supported by commercial enterprise.[5] There is now considerable debate about whether this remains a wise course of action. For instance, Frank Land's fascinating account of recent debates in the House of Commons Select Committee on Trade and Industry regarding the government role in relation to innovation in IT reveals that the controversies are not limited to NICs and DCs (Land 1989).[6]

As we enter the decade of the 1990s, there is little doubt that IT innovations will continue to diffuse throughout the world. The warming of the East Bloc already signals a growing opportunity for the influx of these technologies where they previously have been, at best, weakly developed. The question remains as to the role of governments, and of institutions generally, in facilitating the successful production and diffusion of use of these innovations. There is substantial additional work to be done in determining the optimal mixes of institutional intervention, not only in terms of theoretical constructs, but in terms of actual demonstrated experience.

5. REFERENCES

Amsden, A. H. *Asia's Next Giant: South Korea and Late Industrialization*. New York: Oxford University Press, 1989.

Bakos, J.; King, J. L.; and Morgan, E. T. "The Unix Phenomenon: Technical, Economic, and Social Perspectives." Irvine, California: Department of Information and Computer Science Working Paper, 1990.

BDI, British Department of Industry. *A Programme for Advanced Technology: The Report of the Alvey Committee*. London: Her Majesty's Stationery Office, 1982.

Beniger, J. *The Control Revolution*. Cambridge: Harvard University Press, 1986.

Boyer, R. "Formalizing Growth Regimes." In G. Dosi et al. (eds.), *Technical Change and Economic Theory*. New York: Pinter Publishers, 1988a, pp. 608-630.

Boyer, R. "Technical Change and the Theory of 'Regulation'." In G. Dosi et al. (eds.), *Technical Change and Economic Theory*. New York: Pinter Publishers, 1988b, pp. 67-94.

CACM. "EC Commission Communication on Establishing an Information Services Market." *Communications of the ACM*, April, 1990, pp. 426-432.

Carter, C. F., and Williams, B. R. *Industry and Technical Progress: Factors Governing the Speed of Application of Science to Industry*. London: Oxford University Press, 1957.

Cheng, K. C. "Country Report: The Republic of China." In *Information Technology-Led Development*. Tokyo: Asia Productivity Organization, 1990, pp. 137-151.

Chesnais, F. "Multinational Enterprises and the International Diffusion of Technology." In G. Dosi et al. (eds.), *Technical Change and Economic Theory*. New York: Pinter Publishers, 1988, pp. 496-527.

Chiarodo, R., and Mussehl, J. "The Semiconductor Market in the European Community." *Communications of the ACM*, April, 1990, pp. 417-423.

David, P. A. *Technical Choice, Innovation and Economic Growth*. Cambridge: Cambridge University Press, 1975.

Easterlin, R. A. "A Note on the Evidence of History." In C. A. Anderson and M. J. Bowman (eds.), *Education and Economic Development*. Chicago: Aldine, 1965, pp. 425-427.

EC Commission. *Proposal for a Council Decision Adopting the First European Strategic Programme for Research and Development in Information Technologies (ESPRIT)*. Brussels: EEC, 1983.

Economist. "Computer Standards: Too Much Togetherness?" *The Economist*, May 5, 1990, p. 83.

Encarnation, D. J. *Dislodging Multinationals: India's Strategy in Comparative Perspective*. Ithaca: Cornell University Press, 1989.

Feigenbaum, E., and McCorduck, P. *The Fifth Generation*. London: Pan Books, 1984.

Flamm, K. *Creating the Computer*. Washington, DC: Brookings Institution, 1985.

Flamm, K. *Targeting the Computer*. Washington, DC: Brookings Institution, 1987.

Freeman, C. "Evolution, Technology and Institutions: A Wider Framework for Economic Analysis." In G. Dosi et al. (eds.), *Technical Change and Economic Theory*. New York: Pinter Publishers, 1988, pp. 1-12.

Freeman, C., and Perez, C. "Structural Crises of Adjustment: Business Cycles and Investment Behavior. In G. Dosi et al. (eds.), *Technical Change and Economic Theory*. New York: Pinter Publishers, 1988, pp. 38-66.

Gilpin, R. *Technology, Economic Growth, and International Competitiveness*. Washington, DC: Government Printing Office, 1975.

Habakkuk, H. *American and British Technology in the 19th Century*. Cambridge: Cambridge University Press, 1962.

Henderson, J. W. *The Globalization of High Technology Production: Society, Space, and Semiconductors in the Restructuring of the Modern World*. New York: Routledge, 1989.

Hicks, J. *Theory of Wages*. New York: McMillan, 1932.

Hughes, E. C. "Institutions." In R. E. Park (ed.), *An Outline of the Principles of Sociology*. New York: Barnes and Noble, 1939, pp. 283-346.

ISO, International Standards Organization. *Basic Reference Model for Open Systems Interconnection*. ISO 7498, 1984.

Jae, B. L. "Country Report: Republic of Korea." In *Information-Led Development*. Tokyo: Asian Productivity Organization, 1990, pp. 197-205.

Johnson, C. *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975*. Stanford, California: Stanford University Press, 1982.

Jurgen, R. K. "Chasing Japan in the HTDV Races." *IEEE Spectrum*, October, 1989, pp. 26-30.

Kimberly, J. R. "Issues in the Creation of Organizations: Initiation, Innovation and Institutionalization." *Academy of Management Journal*, Volume 22, 1979, pp. 437-457.

Land, F. "The Government Role in Relation to Information Technology." Working Paper, London Business School, 1989.

Landes, D. *The Unbound Prometheus*. Cambridge: Cambridge University Press, 1969.

Mathias, P. *Science and Society, 1600-1900*. Cambridge: Cambridge University Press, 1972.

Matley, B. G., and Mcdannald, T. A. *National Computer Policies*. Washington: IEEE Computer Society Press, 1987.

Mowery, D. C., and Rosenberg, N. "Technical Change in the Commercial Aircraft Industry, 1925-1975." *Technological Forecasting and Social Change*, Volume 20, 1981, pp. 347-358.

Mowery, D. C., and Rosenberg, N. "The Influence of Market Demand Upon Innovation: A Critical Review of Some Recent Empirical Studies." *Research Policy*, April, 1979, pp. 103-153.

Nelson, R. "Institutions Supporting Technical Change in the United States." In G. Dosi et al. (eds.), *Technical Change and Economic Theory*. New York: Pinter Publishers, 1988, pp. 312-329.

Nelson, R., and Soete, L. "Policy Conclusions." In G. Dosi et al. (eds.), *Technical Change and Economic Theory*. New York: Pinter Publishers, 1988, pp. 631-636.

Pavitt, K. *The Conditions for Success in Technological Innovation*. Paris: OECD, 1971.

Perez, C., and Soete, L. "Catching Up in Technology: Entry Barriers and Windows of Opportunity." In G. Dosi et al. (eds.), *Technical Change and Economic Theory*. New York: Pinter Publishers, 1988, pp. 458-479.

Raman, K. S. "IT Applications and Their Impacts in Singapore and Other Asian NIEs." In C. Y. Kuo, C. M. Loh, and K. S. Raman (eds.), *Information Technology and Singapore Society: Trends, Policies and Applications*. Singapore: National University of Singapore, 1990.

Rosenberg, N. *Inside the Black Box: Technology and Economics*. Cambridge: Cambridge University Press, 1982.

Schumpeter, J. "Analysis of Economic Change." *The Review of Economics and Statistics*, May, 1935.

Schumpeter, J. *Business Cycles*. New York: McGraw Hill, 1939.

Schumpeter, J. *Capitalism, Socialism and Democracy*. New York: Harper and Row, 1942.

Schumpeter, J. "The Instability of Capitalism." Economic Journal, September, 1928.

Tornatzky, L. G.; Eveland, J. D.; Boylan, M. G.; Hetzner, W. A.; Johnson, E. C.; Roitman, D.; and Schneider, J. *The Process of Technological Innovation: Reviewing the Literature*. Washington, DC: National Science Foundation, 1983.

Utterback, J. M. "Innovation in Industry and the Diffusion of Technology." *Science*, February, 1974.

Vernon, R. *Sovereignty at Bay*. Cambridge: Harvard University Press, 1971.

Vernon, R. *Storm Over the Multinationals: The Real Issues*. Cambridge: Harvard University Press, 1977.

Von Hayek, F. "The Uses of Knowledge in Society." *American Economic Review*, Volume 35, 1945, pp. 515-530.

White. L. *The Science of Culture*. New York: Farrar, Straus, and Giroux, 1949.

Willinger, M., and Luschovitch, E. "Towards the Economics of Information-Intensive Production Systems; The Case of Advanced Materials." In G. Dosi et al. (eds.), *Technical Change and Economic Theory*. New York: Pinter Publishers, 1988, pp. 432-457.

6. ENDNOTES

1. This paper is from the project "Government Policy and Information Technology in Asia/Pacific Nations," conducted by the authors, with support from the University of California Pacific Rim Research Initiative, the University of California, Irvine, the National University of Singapore, and the Harvard Business School.

2. Tornatzky et al. (1983) provide the best review of this literature currently available.

3. Boyer's characterization of regulation is drawn from the so-called French School of regulatory economics that has arisen since the early 1970s. It's essential logic is expressed through the idea of the "regime of accumulation," which sets the terms under which wealth can be created and accumulated over time. This view is especially useful for considering the institutional role in innovation, because it embraces both the implicit incentive operators explored by Schumpeter (1928, 1935, 1939, 1942) and Hicks (1932), but also the contextual factors that make incentive-based action sufficiently safe to encourage innovators. Formal explication of these notions can be found in Boyer (1988a).

4. Although our study deals specifically with government policy and information technology, the broad construction of the study includes all major institutional actors that *might* play a significant role. Without understanding the role of these other institutions, it will be impossible to attribute particular outcomes wholly or in part to government action. The conceptual inclusion of this array of institutions does not imply that empirical study of all institutions is equally feasible. In fact, our experience thus far is that the activities of a broad range of institutions can be investigated in developed countries, but institutional activity in the NICs and DCs is seen mainly in actions of the central government, and to a lesser extent international agencies and multinational corporations.

5. This assessment, while generally valid, has some limitations especially in the case of the United States. As Mowery and Rosenberg (1979) note, the U.S. government's support of R&D in the commercial aircraft sector fell off sharply during the late 1960s, and the later generations of commercial aircraft were developed largely with non-government sources. In contrast, during this period the European Airbus Industries consortium gathered momentum and launched its first fleet of commercially successful passenger jets, with very substantial amounts of government subsidy. The Reagan and Thatcher administrations in the U.S. and U.K., respectively took stands quite strongly against government support in any case where private investment might be sufficient, though in some areas this ideological position was not maintained. For example, in the U.S. during the 1980s, defense R&D spending grew much more rapidly than civilian R&D spending, and the overall share of government spending devoted to development as opposed to basic research increased substantially as well.

6. The argument of the Committee was that government should take an active role on both the supply side and demand side of innovation in information technology, but the Thatcher government firmly refused to do more than help "stimulate" demand and nurture innovative use of information technology, in keeping with the notion that government's job is to help markets work well. It is significant that the debate was framed in terms of two "models": the "Japanese model," in which both supply and demand are targeted; and the "Thatcher model," in which only demand is targeted.