"KNOWLEDGE, PROPERTY, AND SYSTEM DYNAMICS OF TECHNOLOGICAL CHANGE"

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Abstract

Technological change and its relationship to the growth of knowledge are considered here from a general system theoretic perspective. The traditional linear model that has influenced economic thinking and policy analysis suggests a unidirectional flow of causation, from exogenous, fundamental discoveries in science leading virtually to technological inventions, innovations, and the diffusion of new products production techniques. Scientific and technological advance should be approached, instead from a general viewpoint, as a phenomena of "organized complexity" that results in cumulative and irreversible transformation in knowledge and use of economic resources. This paper examines some of the system effects of various institutional solutions to the so-called appropriatbility problem affecting the production of information. It points out some of the science – technology interactions that have often been overlooked and discusses the implications of positive and negative feedbacks between the dynamics of innovation and diffusion. It concludes by considering what these may imply for discussion north-south differences over the policy of strengthening protection for intellectual property rights. Economic analysis needs to move to articulate the interdependence and interactions among the sub-processes in the overall system governing the production, distribution, and utilization of scientific and technological knowledge. The paper also tries to examine though an interesting coverage is already made regarding the experience of China and Japan in field of research and technology based on diffusion of information and acquisition methodologies applied to enhance economic growth.

Key Words : Knowledge, System dynamics, Codified and tacit knowledge, Property, Institutional solution, Diffusion, Localized solutions, Dissemination programs, Research System

Introduction

For a long time, most economists' conceptualizations of technological progress is to be recognized as an analytical approach that has dominated the discipline as a whole. There is a lot to be said for trying to understand the working of the system as complicated as an economy by examining the behavior of its component parts and trying to characterize the equilibrium states of the various subsystems that can be identified that what is considered in the neoclassical macroeconomics and related branches of economic analysis. We would like in this context to cover vital topics concerning the issues under discussion like the growth of scientific and technological knowledge, codified tacit knowledge and the properties of information as commodity feedback and interaction between advances in technology and science. Intellectual property and protective diffusion to be touching on a very critical aspect of appropriability problems and institutional arrangements for science and technologies.

I. Codified and Tacit Knowledge and Properties of Information as a Commodity

Knowledge can be gained though accidental discoveries, or it can emerge from systematic, national inquiry and observation, but in all cases knowledge products are distinctive rather that homogenous goods. In addition to being highly differentiated, knowledge is characterized by an extreme form of indivisibilities: it is sufficient, at least in principles, to acquire a specific piece of knowledge once. There is not social advantage to repeating the process of its acquisition; although the wheel does seem to have been invented on several occasions. The most important characteristic of knowledge is the possibility of its being possessed and enjoyed jointly even simultaneously – by different individuals. This property in a commodity may be referred to as "perfect expansibility" (Koch & Paden, 1972 : 629).

Knowledge is being expansible, displays one or two properties commonly associated with the general category of public goods. The other defining attribute of a public good – the "non-excludability" of individuals form its use- is not necessarily present in the case of knowledge because it remains quite possible to enforce exclusive use. Intellectual property rights are social contrivances that prevent non owners from using information (Eisentien,1980).

Their density at any point "it is suggested that expansible here as an alternative to the term non rival (Romen, 1990) to describe the possibility of a given piece of information being used concurrently by a number of independent users. Non rival, however, is a confusing term in this context because although it is intended to indicate that the nature of the good does not require competition among individuals for its possession, such individuals well may be economic rivals in the market and may therefore, compete for exclusive possession of the information in question for certain purposes even though they have gained possession of it.

Codification of Knowledge is a step in the process of reduction and conversion that renders the transmission, verification, storage, and reproduction of information especially easy. Codified information typically is organized and expressed in a format that is compact and standardized to facilitate and reduce the cost of such operation. The demand among any community for codification of knowledge in a given form will be influenced in part by recognizability of the encoding conventions employed. The degree of comprehensiveness, or sufficiency, of the codified communication also matters, as does the reliability of the source, and the availability of means of certifying the accuracy of the information.

On the supply side, whether or not knowledge is put into codified form is in part a question of how costly it is to do that and in part a matter of whether and to what extent there are rewards for the extra effort entailed. The forgoing discussion of codified knowledge should not create the impression that knowledge of all kinds can now be transmitted at negligibly small marginal cost or that the private and social costs of filtering, interpreting, and utilizing information are insignificant. In juxtaposition to position to codified knowledge, the concept of tacit knowledge refers to the common perception that we all are often generally aware of certain objects without being focused on them (Eisenstein, 1980; Palany,1966) that does not make them less important; they form the context in which focused perception becomes possible, understandable, and productive.

Like the knowledge that is codified and packaged as information, tacit knowledge can, in principle, be freely shared or exchanged. The transfer process usually involves demonstration, personal instruction, and the provision of expert services, (such as advice and consultations) by those who possess the knowledge that remain in an uncodified form. But the arrangements for effecting such transfers such as industrial and military technologies, health care, and the policy at large are various and remain to be studied more fully.

Recent discussion of the economics of R & D and technology transfers, however, recognize the significance of tacit components of technological knowledge. Complementary "know-how" is required, and to acquire will be after an expensive proposition (Arora, 1991; Pavitt,1987; Resenberg, 1990)

Thus, both codified and tacit knowledge are generated by scientific researchers, and both are used to produce further knowledge.

II. Appropriatbility Problems and Institutional Arrangements for Science and Technology "The Three Ps"

Non-vital possession (made possible by the "perfect expansibility" of ideas) low marginal cost of reproduction and distribution (making it more difficult to exclude others from access to information), and substantial fixed costs of original production are three properties generally associated with public goods.

And, as well-known, competitive markets cannot be relied on to perform well in allocating resources to the production of goods with those characteristics. Where prices are driven toward marginal costs, the revenues received by competitive suppliers will not even cover their full costs, much less approach the use-value of the goods to the consuming public.

Indeed, the attempt to make the beneficiaries pay for value received would so reduce demand as a result in an insufficiently low level of consumption. All this was appreciated by (Nelson 1959 and Arrow 1962) three decades ago on the "appropriatbilitiy problem" and the economics of R & D. From that time forward, the principal economic rationale offered for public policy interventions affecting R&D activities has been the putative failures of competitive markets. A) to elicit revelation of the actual demand for new scientific and technological knowledge and B) to provide private individuals and organizations with sufficient incentives to induce the socially optional amount of investment in the production of such information. In the literature of public finance economies, alternative allocative mechanisms have long been recognized as solutions to the public goods problem. (Pavitt, 1992)

There are three alternatives. One is that society should provide independent producers with "subsidies" financed by general taxation and should require that the goods be made available to the public of freely or at nominal charges. A second solution should have the state levy general taxes to finance its direct participation in the processes of production and distribution, contracting where necessary with private agents to do the work. The objective in this approach, again, is to supply the good without having to change a price that recovers its costs of production. The third solution is to create a publicly regulated "private monopoly" and to allow it to charge customers prices that will yield a nominal rate of profit. There is a striking correspondence between this set of solutions for the standard public goods problem and the main institutional arrangements that have been devised to cope with appropriatbility problem which arise when competitive markets are left to guide the production of knowledge and pure information goods.(Dasgupta & David,1988 ; David, 1992) The later arrangements are referred to as "The Three Ps": Patronage, Procurement, and Property. The term patronage stands for the system of awarding publicly financed prizes, research grant based on the submission of competitive proposals, and other subsidies to private individuals and organizations engaging in scientific discovery and invention, in exchange for public disclosure of their findings.

Patronage characterizes the pursuit of open scientific inquiry and is the dominant institutional and social mode of organization associated with the conduct of academic science research in democratic society of the west scientific performance in particular.

Procurement is associated with governmental intellectual work generally and for academic science in democratic societies of the west in research performance in particular. Scientifically whether the information produced will be disclosed for public use is an important policy issue or not.

This defense-related R&D typically carried on by government employees and private contractors under secrecy restrictions in secure facilities, whereas such public contract R&D and the scientific work of governmental experiments station is undertaken with the intention of disseminating the findings rapidly and widely.

The third institutional solution is for the society to grant private producers of new knowledge exclusive "private property" in the use of their creations, thereby forming conditions for the functioning of markets in which the originators will be able to collect (differential) fees for the use of their work by others. Here we come to the specific legal contrivances that define and institute intellectual property, patents, copyrights, and somewhat more problematically trade secrets. None among the three (Ps) provide a complete and perfect solution to the problem that they all address. Some field of useful employment has been formed for each type of institutional arrangements, but no one has emerged as clearly superior to the others in al contexts. (David, 1991b)

III. Public Policy and the Funding of Basic and Applied R & D

The argument generally offered for public policy interventions to enforce absence of governmental interventions, competitive markets would not provide private parties with sufficient inducements to undertake the socially optimal amount of investment in creating public goods in the form of new scientific and technological knowledge. This problem is especially acute, likely, in lines of research where the outcomes are contingent on developments in other, possibly remote, domains of knowledge.

Although fundamental, or basic, science research has these characteristics, it also has consequences for those seeking knowledge with more immediate and more predictable utilitarian implications, rather than being only an intellectual input into further research.

Basic research may, of course, yield unexpected discoveries that have immediate practical uses, some of which will be extremely valuable as has been in the cases of lasers and enzyme restriction techniques in the field of biotechnology. These are, however, a rare exception. More typically, the important economic payoffs from basic research come in the form of higher rates of return on expenditures allocated for applied research form the societal perspective, basic and applied research should be viewed as complementary activities. The problem is that by investing in applied R & D, firms and nations can reap much of the benefits of prior basis research to what they may have contributed nothing. The existence of this manifestation of the familiar appropriability problem, and the linkage between applied and basic R&D, however, do not imply that the best remedy is to institute some new and strongly protected private rights in intellectual creation that take the form of fundamental scientific discoveries.

Intellectual property rights generate concurrent areas of excess and deficient investment in R&D, thus, falling rather short of allocative efficiency. Unfortunately the situation is not much improved by the possibilities of privately appropriating the benefits of inventions and discoveries in production methods that can be protected as trade secrets.

The most reliable mode of private appropriation entails being first to exploit the namely acquired knowledge by establishing cost advantage in actual production operations- having potential competitors to be farthest down the learning line for the new activity.

Industrial enterprises may support open science by funding basic science research because they recognize the potential advantage of gaining access to the stores of codified and tacit knowledge that are made available to scientists through their membership in invisible colleges and specialized networks for information exchange. Mowery (1983) and Cohen and Lenithal (1989) have called attention to firms' monitoring of external technological change through their conduct of in-house R & D, which is often overlooked in the emphasis usually placed on the internal generation of innovations through the performance of R & D. Rosenberg (1990) suggests that both the monitoring function and the development of capabilities for absorbing scientific knowledge may be important motives for company-financed "basic" research.

IV. Dynamic Feedbacks Between Innovation and Diffusion

The dynamics of technology adoption (Diffusion) processes are closely interwined with the dynamics of technology development resulting form endogenous, incremental innovation – rather than belonging to the separate departments assigned to them (David 1986; Stoneman and Davis 1987). This point is distinct from and, in the significance of its implications, goes well beyond the more widely acknowledged linkage between innovations and diffusion that was examined in the preceding section. There it was noted although R & D performance and the generation of innovations might be stimulated by instituting strong protection for intellectual property, such a policy would adversely affect diffusion by raising the costs of access to the protected new technologies. Thus, an impulse promoting a new technology's adoption leads to the quickening of a rate at which it undergoes further improvements; that, in turn, promotes the technologies diffusion, and so forth, until it has displaced rivals and saturated the market. But, the same structure that is capable of generating virtuous circles: early failure of an innovation can also leads to the establishment of vicious circles and upward spirals can also lead to vicious circles: early failure of an innovation to penetrate the market can deprive it of opportunities to undergo subsequent improvements that would remedy its initial defects, thereby blocking its eventual diffusion. (David & Olsen, 1986,1991)

V. The New Microeconomics of Technology Diffusion

The objective of economic of economic environment was one in which the only consequential change taking place was the gradual dissemination of information about the benefits of the new technology. This might occur as a "contagious" – through the contact between adopters and non-adopters by doing in the supply of a capital good embodying the new technology and under conditions in which there are heterogeneities among firms that are all fully informed and have consistent expectations which the dynamics of the system fulfills. Thus, regarded, the gradual increase in the extent of an innovation's application across economy has the appearance of an adjustment process, which eventually approaches the restoration of equilibrium.

Firms considering a new production technology embodied in fixed equipment may face different raw materials costs, energy prices, and transport charges; they may differ in the makeup of technically related product arrays produces using joint facilities; they may operate in different labor market and have different implicit or explicit contractual commitments to their employees; and they may encounter different terms for borrowing. Furthermore, such firms are likely already to possess some durable capital equipment of varying ages and vintages, which they would have to retire, were they to adopt the new technology.

The existence of these sources of positive feedback as we have seen already brought about by the irreversible, dynamic, decreasing cost effects of diffusion of new technology implies that small initial advantages and disadvantages (and seemingly transient impulses including policy shocks experienced at an early stage of a new technology's history) can cumulate readily into large advantages or disadvantages in comparison with alternative technologies. A particular product design, process technology, or organizational system thus can become "Locked in" while vital technologies are "Locked out" through the workings of decentralized competitive market processes.

VI. Intellectual Property Protection, Innovation, and Diffusion

Many of the recent technology- gap models of international trade serve to reinforce the view that under conditions of free trade the economic interests of developing countries are identified with conditions in which it is easy and inexpensive to borrow or copy new technologies (Grassman and Helpman 1990) i.e. in these models the interests of the North are seen as bound up almost exclusively with the generation of innovations, in other words, the industrial countries are pictured as operating in the first four compartments of the traditional linear model. They do fundamental and applied science, invention and innovation, whereas the developing nations are occupied with imitation and technology diffusion.

Information asymmetries and monitoring difficulties make it virtually impossible to write efficient contracts specifying the transfer of tacit knowledge. It is nevertheless possible to design contracts for the successful implementation of technologies by bundling the provision assistance (conveying tacit knowledge) together with the licensing of the use of codified information such as patents and copyrights (Arora 1991). But if protection for such property rights is weak in the borrowing country, and if transferees cannot be bound effectively to preserve trade secrets, the originating firm is unlikely to enter such contracts.

The implication is that the tacit knowledge components are vital and remain unavailable domestically, would be borrowers of technology have an interest in a regime of stronger protection for intellectual property. Such protection could take the form of statutory measures or judicial enforcement of trade secrecy rights. This conclusion is distinct form, not at odds with the argument as already referred to in Chi and Glossma (1990) because the focus is on the successful transfer of codified and tacit information regarding innovations that already have been made in the North (developed countries), both regions the South (developing countries) and the North, the foregoing analysis shows that the south could gain even when there was no incremental innovation- inducement effect of extending intellectual property protection into south markets.

VII Science and Technology for Development: Lessons learned from China and Japan, in the field of Research and Technology.

In today's economy, knowledge has become an increasingly important factor. As World's Bank data show, a strong correlation is to be found between the percentage GDP spent on research and development and GDP per capita. Science and technology (S&T) are critical for development ignoring their importance is short-sighted, it only makes the gap between developed and developing world larger. There are signs the S&T are increasingly part of the agenda of both international community and policy makers in developing countries. Some of the developing countries have already started to use S&T for development. From the newly industrialized economies (NIEs) such as South Korea, Singapore and Hong Kong to the recently emerging countries such as China, Malaysia, and India all have aggressively pursued a policy of development technological capabilities. Malaysia whose world competitiveness was ranked as no. (4) in 2003 has shown to the rest of the developing world how S&T (Science and Technology) can spur economic growth. (Peilei Fan, September 2, 2004)

UNU-IAS has analyzed the spectacular economic growth in Japan (1960-1990) and China (1980-2000) in order to assess the role played by technology policies and identify lessons learned that can help policy makers in developing countries make evidence- based decision about the most appropriate strategies to develop science and technology program. For example, let us take the case of China in particular. On the technology front, China's R&D effect is only (0.7%) of GDP, which is low by international standards, and basely (1%) of global R&D. Its output in terms of international patenting is negligible. China thus, needs to develop a broader innovation strategy that not only focuses on high technology and R&D, but also improve its productivity and increase its overall competitiveness.

Therefore, the key issues that were recommended toward the enhancement research in science and technology were as follows:
1. Role of government is given good priority in the dynamity of the process.
2. Finding localized solution
3. Focusing on foreign vs. indigenous technology.
4. Giving special role to be played by private sector.
5. Concentrating on the Information and Communications Technology (ICT).

Both the Japanese and Chinese governments played a major role in enhancing the respectable industrial capability which contributes considerably to the economic growth of the nations. The Japanese government started much earlier than the Chinese government since the early Meji period (1888-1890). Its post World War II involvement through the Ministry of International Trade and Industry (MITI), subsequently renamed (METI) covers a large range of activities, with specific focus on key sectors during various decades.

The Chinese government started the national innovation system reform in 1980s. It took the government several tries to find relatively successful approach to reform R&D system. The government has also implemented two large-scale national S&T program (the 863 program and the Torch program which aim to foster the high quality fundamental research and to facilitate the commercialization of technology. States' Council Decision on Accelerating S&T development in 1995 has boosted the country's R&D spending and as a consequence, technological progress has contributed significantly to the nation's economic growth in the second half of 1990s.

Conclusion and Recommendations

The paper has investigated elusively the various elements brought up in the predicate to cope with the challenges brought about by knowledge revolution and increased international competitiveness as well as the various implications of the massive restructuring that developing countries especially those with the ambition to follow the model of China and Japan and will be undergoing such vital changes in the structures of knowledge, technology diffusion, a knowledge-based rather than the current factor-based strategy is needed. This knowledge based strategy as a quite dynamic system of operations, consists of making more effective use of new and existing knowledge and technology throughout the whole economy. There are four key pillars to this knowledge-based strategy.

- An economic and institutional regime that provides incentives for the efficient use of existing knowledge and the creation of new knowledge and entrepreneurship.
- An educated and skilled population that can create and use knowledge.

• A dynamic informative infrastructure that can facilitate the effective communication, dissemination, and processing of information.
• An effective innovation system where enterprises, research centers, universities and other organization interact effectively to create and diffuse technologies using growing stock of domestic and global knowledge.

As for policy recommendations, the following could be investigated and to be applied where possible:

• Improving the broader framework through:
- Upgrading the legal and regulatory environment
- Explaining the information and telecommunication infrastructure
- Investing in higher education and training.

• Redirecting the innovation system through:
- Expanding technology dissemination programs
- Benefiting from global knowledge and technology
- Strengthening the research system

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