THE ROLE OF TECHNOLOGY TRANSFER IN FOSTERING INTERNAL TECHNOLOGICAL CAPACITY: A CASE STUDY OF CHINA'S COMPUTER INDUSTRY

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To my wife and in memory of my mother

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THESIS

Presented to the Faculty of the Graduate School of

The University of Texas at El Paso

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

Department of Economics & Finance

THE UNIVERSITY OF TEXAS AT EL PASO

May 1990

ACKNOWLEDGEMENTS

I would definitely like to take this opportunity to express my gratitude to Dr. Dilmus D. James for his extensivedance and encouragement throughout the development of this thesis. A word of thanks also goes to his wife, Jan, for her generous assistance with editorial improvements. I am also grateful to Dr. Timothy P. Roth for his excellent and impressive teaching in his neoclassical theory courses and for his critical suggestions on my theory chapters of the thesis. An additional expression of gratitude goes to Dr. Joseph Chao for his service as a member of the thesis committee.

I am particularly indebted to Mrs. Joan Q. Osborne for her kindness in supporting my study at UTEP and for invaluable editorial assistance in both initial and final stages. Last, but certainly not least, I would like to thank Mr. J. Kevin Buchanan for his generous assistance in sharing significant bibliographical materials with me. Best wishes to him for the success of his thesis on the political dimensions of China's computer policy.

January 31, 1990

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Chapter 1

INTRODUCTION

China in the 1980s is launched on an ambitious program of economic and societal modernization. A crucial part of this program is the modernization of science and technology. Although China's current strategy of modernization differs in important ways from earlier strategies, a common theme running through Chinese modernization efforts since 1949 has been the central role of science and technology (S & T) in promoting economic development, national defense and cultural change. For example, a set of objectives can be inferred from current Chinese policy discussions on technological development by the year 2000. Two elements seem to be most relevant and significant to the discussion that follows. First, for her industrial sector in general, China hopes to upgrade the level of technology by the year 2000 to the levels of the advanced countries during the 1970s and 1980s. Second, China attaches special priority to selected areas of high technology--computers and electronics, biotechnology, materials, lasers, and robotics--which her leaders believe will be the basis for wealth and power in the 21st century. In these areas also, China hopes to approach the levels of the advanced countries by the year 2000 (Suttmeier: 1987). However, these developments require that more advanced technologies be made available to the general economy and each sector. "These are the main objectives of current technology policy. To meet them, the Chinese have embarked on a major program of reform of the economy and of the R & D system." Moreover, "they have begun aggressively to seek foreign technology and foreign investment, and show increasing interest in participating in the international economy and scientific community. These moves make a major change in China's S & T development strategy" (Ibid., 158).

In the theory of production, all of the myriad inputs into production can be classed under the "factors of production"--land, labor, physical capital, and, if management is separated out from other labor, management. Nevertheless, in most cases, the endowment of natural resources is the least important. Perhaps one of the most important factors in a country's output is technology, as well as technological innovation. It is, however, treated differently by various theoretical approaches in economics.

Neoclassical theory provides an elegant, narrowly defined approach dealing with technology, i.e., the available methods by which natural resources, or factors of production, may be combined into products (Pugel: 1981), and technological change. The prototypical model in this orthodoxy is one of full equilibrium under conditions of perfect and costless information (Nelson, Winter, and Schuette: 1976). In addition, technological innovation is not very much involved in the theory of production. For example, a production function that includes growth may be written:

$$Y = a + bR + cL + dK + eM + ft,$$

where Y = output, R = land, L = labor, K = capital, M = management, and t represents "the residual," all of the changes over time that bring an increase in output per unit of input, technological progress and increase in scale being the most conspicuous (Hagen: 1980). In contrast with this "ignorance," technological innovation is at the center of many approaches in the theory of growth. Among the most serious challenges to the neoclassical perspective are those that relate to its treatment of the processes of technological change. As the theory has progressed, the meaning assigned to "equilibrium" has become less restrictive (Nelson, Winter, and Schuette: 1976). The call for other explanations of technological change has resulted in several different theories. The perspectives of institutionalists and dissenting mainstream economists are, among others, more important approaches in the theory of growth and their framework are set forth in the following chapter, along with a description of the neoclassical point of view of the technological phenomenon. Since China is a country with a socialist economy, the Marxian perspective of technology is also mentioned in order to understand China's case more fully.

There is now almost universal recognition of the role of technology in the pursuit of profits, power, prestige, and prosperity; "technology transfer" (TT) has become a central concern of business and public policy everywhere (Blair: 1986). If a country's advance in technology continues long enough, it will probably reach a stage at which here and there, in one field or another, it develops techniques beyond those known in the most advanced countries. Until it reaches this stage, its technical advance will consist largely of adapting technologies already in use in technologically advanced countries. Then, the process can be described as the "transfer" of technology from the advanced countries (Hagen: 1980). In sum, technology transfer, from the neoclassical conception, would necessarily bring about enhanced internal technological capacity (ITC) in the recipient countries. However, in handling complicated cases in less developed countries (LDCs), the real world of technology transfer tends to be very different from what orthodox economics conceives it to be, since the assumptions on which the neoclassical theory is based often do not hold. The acquisition of internal technological capacity through technology transfer may result in much more complex consequences than is described in the "Harrod-Domar Growth Model."

Chapter 3 will detail the theoretical issue of the role of technology transfer and of the acquisition of internal technological capacity in LDCs. In this chapter, a brief look at the experience of a specific sector, namely the computer industry, in selected LDCs, including Brazil and Mexico in Latin America, and India, South Korea, and Taiwan in Asia, will be used to identify the policy issue involving technological progress in LDCs. An important issue of current development strategy in LDCs is the trade and industrial policy in the informatics sector, mainly the computer industry, defined to include automatic data processing equipment, peripherals, and software. For the LDCs, including China, policy in the sector has reflected a combination of economic, political, and security considerations. Prominent among them has been the fear of being left behind in a modern technological revolution due to lack of an independent national capacity in computer technology (Cline: 1987). The central issue for development is formulation of a strategy for transfer of computer technology that most successfully contributes to the development of the economy as a whole. A related goal is, therefore, the development of the countries' technological capacity. In broad terms, the alternative transfer strategies available may be seen in two dimensions: trade and foreign investment. Chapter 3 explains these considerations by means of a comparative examination of selected LDCs' policies and experiences related to their attempts to promote an indigenous computer industry.

Following the theoretical emphasis of Chapters 2 and 3, Chapters 4 and 5 set forth the institutional structure of the Chinese computer sector and the S & T policy evolution as it applies to technology transfer. The former summarizes China's centrally-planned system, while the latter exlores China's S & T policy evolution which largely reflects the Chinese expectations for, and perspectives on, the role of technology transfer.

Unless China is able to speed up her development of computer technology, either through her own R & D or by technology transfer, closing the gap between China and the industrialized countries is highly unlikely. With this in mind, what are the constraints and prospects for the acquisition of computer technology in the process of technology transfer to China? This is a central concern of this paper with particular emphasis on the economic aspects of the acquisition, assimilation, adaptation, innovation, and diffusion of computer technology in China's computer sector. This will be examined in Chapter 6, based upon the evaluation of computer policy and an analysis of the role of technology transfer in the acquisition of computer technology. The last chapter will be reserved for drawing theoretical conclusions and making policy recommendations regarding the development of Chinese computer technology.

Chapter 2

THEORETICAL REVIEW OF TECHNOLOGY AND TECHNOLOGICAL CHANGE

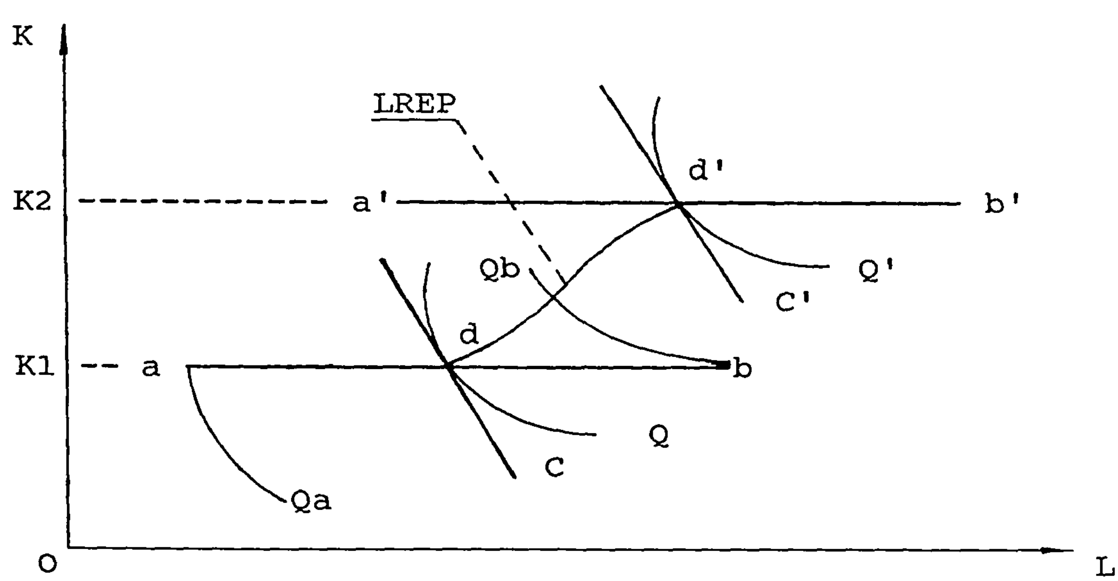
Preparatory to looking at technology transfer in general terms and the transfer of technology to China specifically, attention will be devoted to how several schools of economic thought incorporate technology and technological change into their economic schemas. The purpose is by no means to be definitive; rather the intent is to provide the reader with a feel for the main emphases and differences of various schools of thought. The first section introduces a pair of typical neoclassical models in which technology and technological change are treated in this elegant, narrowly defined approach. Although neoclassical economists are still making explicit efforts in developing the theory, several common features about technology and technological change remain more or less constant. The second section outlines the perspective of institutionalists, which differs from neoclassical theory in several important ways in terms of technology and technological change. There follows a section that involves mainstream dissent, featuring economists who try to break through neoclassical orthodoxy, while tending to stand firm on basic orthodox assumptions. In order to obtain a full appreciation of the Chinese perspective of technology and technological change, relevant Marxian thought is summarized in the fourth section. The last section provides a summary.

2.1. Neoclassical Perspective

Neoclassical or orthodox theory regarding technological change is based largely on the concept of a production function in a short-run situation. The available technology for the production of a particular good is usually summarized within a production function by technical coefficients. If the technology utilized by a specific firm changes in the sense that a new, higher level of technology is being employed, technological progress is then a change in, or the creation of, a production function(Pugel: 1981).

In a static model of production with only two inputs, K (a proxy for physical plant which embodies technology) and L (labor hours), a particular firm produces along a short-run expansion path (SREP), denoted by a-b as shown in Figure 2.1. The production function, a relationship between output and input, is fixed along the SREP in which an unchangeable technology is employed; K is, therefore, fixed at an initial stage K1. The isoquant curves denote different levels of output along the SREP from Qa to Qb. The output level increases as the only variable--input--increases from left to right. Qa and Qb, which are technically dependent upon the marginal rate of technological substitution (MRTS)--the ratio of the marginal product of L to the marginal product of K, represent the minimum-feasible and the plant-capacity outputs. When a

Figure 2.1. Technological Change at Equilibrium Stage

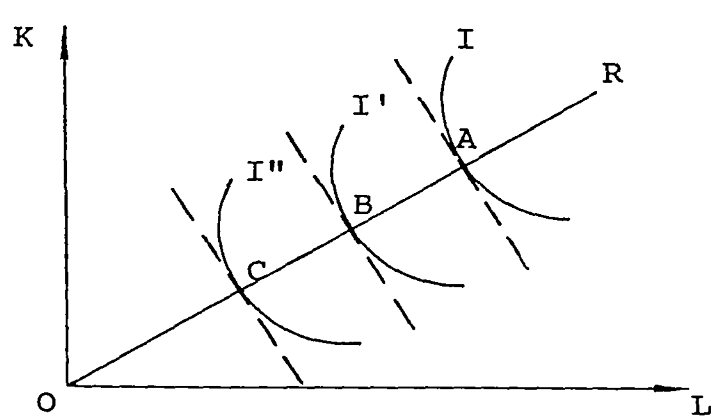


firm produces along a SREP, d is the only point at which output can be produced in the least-cost way because a decision rule of a profit-maximizing firm is satisfied, i.e., the MRTS is equal to the input price ratio (the price of L to the price of K). Graphically, C (cost of production) is tangent to Q (a specific level of output) at a point "d". A firm, however, can determine such a point as d only when assumptions for the short-run can be held. Technology is, among other factors, considered as being given and fixed in the short-run. Otherwise, if technology changes as K shifts up and down, the production function of a firm must change in the sense that production would not be accomplished along the initial SREP (a-b). Another SREP, a'-b' for instance, would occur as a sequential step as new, advanced technology, denoted by K2, is employed. As such a technological progress evolves, a long-run expansion path (LREP) is formed by a series of the least-cost points such as d and d', etc. Thus, a LREP connects all the least-cost points each of which is defined as the optimal choice for a profit-maximizing firm when it selects among technological alternatives.

Another rather typical model identifying technological progress within neoclassical theory is presented as follows

(Ferguson: 1966). Technological progress can be defined as capital-using, neutral, or labor-using,as the marginal rate of technological substitution of labor for capital (MRTS) diminishes, remains unchanged, or increases respectively, at the originally prevailing capital-labor ratio. In other wôrds, if technological change increases the marginal product of capital(MPK) more than the marginal product of labor(MPL)(at a given capital-labor ratio), progress is capital-using, because a firm now has an incentive to use more capital relative to labor since its (capital's) marginal product has increased relative to that of labor. The same type of statement holds, <u>mutatis mutandis</u>, for neutral and for labor-using technological progress.

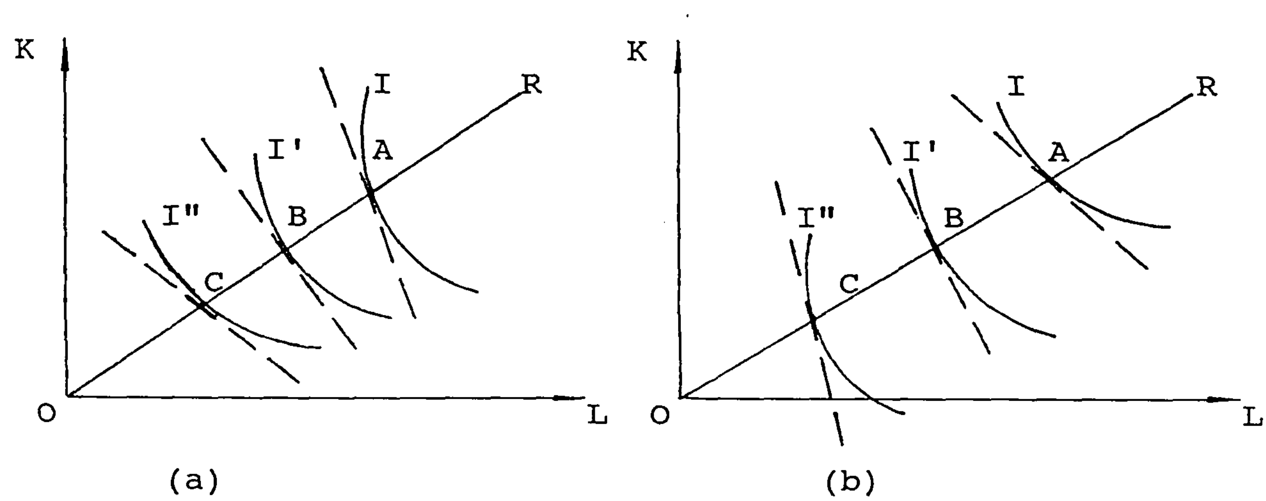
Figure 2.2. <u>Neutral Technological Progress</u>



Source: Ferguson, C.E. (1966: 150-152).

Basically, technological progress consists of any change (graphically, a shift vertically up or down) of the production function that either permits the same level of output to be produced with less input or the same level of inputs to be used to produce a greater level of output. The maps of isoquants (I, I', and I") in Figures 2.2 and 2.3 represent the combinations of inputs capable of producing a same level of output. OR is the ray whose slope gives a constant capital-labor ratio. A, B, and C show the points of production at a given capital-labor ratio as technological progress occurs as a shift of an isoquant in the

Figure 2.3. Biased Technological Progress



Source: Ibid.

direction of the origin. In Figure 2.2, all three isoquants--I, I', and I"--represent the same level of output. As technological progress takes place, I' shows that the same level of output can be produced by smaller quantities of inputs than at I. Similarly, as technological progress continues, I" shows that still smaller input combinations can produce the same level of output. Figure 2.2 illustrates neutral technological progress, i.e., a constant capital-labor ratio with the unchanging marginal rates of technological substitution (MRTS). At A, B, and C, the slope of the isoquant, the MRTS, is the same.

Figure 2.3 illustrates the other alternatives--capital-using and labor-using--in technological progress. Capital-using technological progress occurs when, at a constant capital-labor ratio, the MPK increases relative to the MPL. In other words, since the MRTS is the ratio of the MPL to the MPK, capital-using technological progress occurs when the MRTS declines along a constant capital-labor ray. As one moves from A to B to C in (a), the slope of the isoquant diminishes, representing a decline of the MRTS. By the same line of reasoning, (b) illustrates labor-using technological progress because the MRTS increases as one moves from A to B to C.

These illustrations of the neoclassical perspective demonstrate several well-known features about the orthodox treatment of technology and technological change. First, technology is viewed as being exogenously available to profit-maximizing firms. Intra-firm adaptations, improvements or innovations are usually not considered. At any time firms are viewed as facing a set of alternatives in technology regarding the input and output that they will procure and produce. All firms need to do is to choose among these alternatives so as to maximize profit or present value while operating in perfectly competitive markets. Perfect knowledge regarding technology, as well as other market conditions, are commonly assumed. Acquisition of technology is ordinarily seen as costless. Therefore, no firm can be driven out of the industry by virtue of inability, inefficiency or bad luck in acquiring techniques or technologies. It also implicitly implies that once firms start to employ a new vintage of capital equipment, they can simultaneously acquire the knowledge and technical skills associated with the efficient use of the technology embodied in the new capital good.

Second, the driving force for firms to allocate resources to producing new technical knowledge follows naturally from the profit motive. A decision rule for an individual firm to acquire technology and knowledge is determined by market conditions through comparison of the cost of scientific and technical input necessary to acquire knowledge and the magnitude of expected returns from using and marketing the results. This implies that technological progress is motivated by the pull of market inducements in which technological changes occur along an equilibrium path. Market conditions, especially relative factor prices, determine the pace and direction of technological advance in a fairly predictable manner. When orthodox economists do attempt to internalize technological change, they often see the technological frontier advancing because of the accumulation of a stock of capital in the form of R & D capabilities. Spending on R & D by a firm is motivated by the same profit-maximizing strategies applied to other types of investment (James: 1987).

In this brief discussion, it is not possible to do justice to the richness of the neoclassical treatment of technology. Illustratively, one might mention the insights into the problem of imperfect appropriability of technical knowledge, a condition which erodes the incentive for private firms to engage in R & D. Also, an entire literature arose around the difficulty of aggregating different vintages of technology, each with its own level of embodied technology. Suffice it to say, neoclassical economists are not satisfied with the rudimentary rendition presented above [1] and they are working on improving their dynamic analysis which incorporates technological change. The simple version is, however, satisfactory for serving as a basis for examining somewhat different points of view.

2.2. Institutionalist Dissent

Among the most serious challenges to the neoclassical perspective on matters related to technology and technological change are the views of the institutionalist school of thought, sometimes also referred to as "evolutionary" economics. Instead of defining technology as a stabilized productive method, as being exogenously available, and as being business or economic activity-related, institutionalists have placed technology, as well as technological change, at the heart of economic development. They employ a broad, interdisciplinary panorama within which technological advance occupies central stages.

Technology is broadly viewed by institutionalists as a part of culture which is the "stuff" of social behavior

(Ayres: 1944 and Lower: 1987). Technological change is also referred to as a social phenomenon, i.e., cultural change, by involving the nature of social evolution (Ranson: 1987). For example, Thorstein Veblen points out that technology as "knowledge" is always, in the last resort, a change in "habits of thoughts". Such a change occurs when "certain material ends" are affected by a given contrivance--a tool--and then the future growth of "habits of thoughts" is stimulated, too, followed by technological change (Lower: 1987). C.E. Ayres upholds this position by focusing on an interdependence between technological knowledge and mechanical contrivances (tools). Having incorporated Dewey's view that all knowledge is produced by use of tools, including conceptual tools, he distinguishes a point that only the skilled use of tools is the basis of technological development, a key point identifying the principle of "tool-combination" (Ibid.).

In his "tool-combination principle," Ayres (1944) explains that all culture derives from past experience. Since technology is objectified in physical tools and apparatus as well as in technical concepts, it is always capable of being progressively developed. This implies that every tool contains the possibility of being applied in a new situation, to different materials, and in different ways from its historic use. Thus, the principal characteristic of this process is the universal pattern of invention and discovery, i.e., all new devices are combinations of old ones, and so are all the discoveries of the scientists and all of the creations of the artists (Lower: 1987).

In the institutionalist perspective, technological progress is a tool-combination or tool-using process with an inherent dynamic nature in any specific institution. First, deriving from this new interpretation of technology, Milton D. Lower (1987, 1150) describes technological change as a cumulative "technological life process and evolving potential, not evolved technologies." The more tools there are, the greater is the number of potential combinations which leads to "contingent inevitability," i.e., one-way direction of the "cultural evolution" from the lower level toward the more advanced (Lower: 1987).

Second, there are many important science-technology push factors at work (James: 1987). Such a tendency for technological change, which is virtually ignored by the neoclassical model, renders institutions more permissive to further change because the "genetic material" of such a "cultural evolution" is believed to be a "mutational" function of technological change per se (Lower: 1987). Thus, "science-technology push is added to market-pull as an explanatory force" (James: 1987).

Third, the dynamic process of technological change does not operate in a vacuum. There is also a significant interaction between technology and institutions. In addition to firms' efforts to acquire technology and knowledge from market activities, technology is disseminated and improved largely through educational and research institutions. It is also applied through economic institutions; and thus, the decisions of public policy-making play an important role in the whole process. As a result, technology is "the stock of human know-how applicable to physical facts," a social character of technology (Ranson: 1987, 1267).

Started in a similar, but different manner, Thomas R. DeGregori claims that technology embodies the "cumulative experience" which encompasses the adaptation of the environment to the organism. Tool-using and tool-making have become "learned means" by which humans utilize the environment (DeGregori: 1985). Ayres (1944) believed that technological innovation played the decisive role in establishing the institutions of capitalism. The process of institutional adaptation to technological change is therefore tremendously important, as well as subtle and complicated; and special attention must therefore be given to it.

2.3. Mainstream Dissent

There are a number of mainstream economists [2] "who have become disenchanted with the neoclassical explanation of technological progress." They recognize that the whole progress is "far more diverse and complex than the neoclassical model admits" (James: 1987, 733). In the simplest neoclassical model, it is assumed that there is substitutability of labor and capital, and a wide variety of efficient techniques available to produce any given output. However, "the complex and perhaps insoluble problems of measurement of capital are ignored; labor is also assumed homogeneous and unambiguously measurable" (Stewart: 1972, 99).

Disregarding the inherent nature of exogenously available technology and the relatively static characteristic of technological progress in the neoclassical model, dissenting mainstream economists believe that in the real world the complexity of the progress itself may make internal technological improvement, as well as economic growth possible, even though a certain level of technology embodied in original capital equipment is given. For example, "there are kinds of productivity improvements, often individually small but cumulatively very large, that can be identified as a result of direct involvement in the productive process" (Rosenberg: 1982, 121).

Learning-by-using, referring to the feedback flow of information from users of capital equipment to producers of that good, is such an enterprise-level activity which could make a significant improvement in productivity, especially in "design-intensive" capital goods production. Thus, productivity can often be improved significantly without additional conventional investment in capital equipment.

The other two activities with internal dynamic natures, learning-by-doing and engineering innovations [3], are also the main topics of the mainstream dissenters. Through learning-by-doing, the repetition of certain activities, and accumulation of technical experience could lead to further improvement in technology because both the problems and opportunities could be perceived. Although engineering innovations are small or incremental, they routinely happen within a firm's operation. Not any significant effort, such as spending on R & D, is required for the innovations. This raises the possibility that at least part of the dynamic character of technological change can be viewed as an endogenous variable.

David C. Mowery and Nathan Rosenberg (1982, 234) point out another dynamic feature of technology and technological change in their claim that "the innovation process ... comprises an area of economic behavior in which uncertainty and complexity are absolutely central characteristics of the environment." For example, a common belief of institutionalists shared with the mainstream dissenters, is that market demand and factor prices are not the only powerful influences on the rate and direction of technical change (James: 1987). Although the existence of an adequate demand for the eventual product, "the demand-pull," is obviously important, there are, evidently, some factors going on that do not depend on the pull of relative factor prices. It is believed there is a complex and diverse set of supply-side mechanisms that are continually altering the structure of production costs and introducing entirely new products (Mowery and Rosenberg: 1982). This does not, of course, deny that factor prices are important, but evidently there are some supply push factors, which "are fundamental to the explanation of the timing of the innovation process" (Ibid., 231), operating within the scientific and technological processes and producing new technological knowledge.

With a focus on enhancing internal technological capacity (ITC) within the Third World, i.e., the process of the selection, acquisition, adaptation, and dissemination of technical knowledge, mainstream dissenters recognize that there are interrelationships between technical adaptation, the generation of new technical knowledge, and local learning (Fransman and King: 1984). In Jorge Katz's case of Latin American manufacturing plants, new technical knowledge was produced and absorbed regularly even though the basic conventional technology remained in use(James: 1987). Ordinarily, the whole production frontier is not known and it is costly to find out about it. The firm's assessment of it may depend only on its actual production experience which seems to be successful. In support of this idea, Richard R. Nelson and Sidney G. Winter (1977) claim that the sharp distinction between moving along a production function and shifting to a new one should be abandoned.

Furthermore, firms, especially in less developing countries, are seen as operating under a complex set of decision rules, while market forces no longer adequately serve the technological path (Mowery and Rosenberg: 1982). As a result, they are going along very different technological paths by following different guidelines instead of the traditional production function. This implies that some internal dynamics, partly independent of external market forces, are operative.

In dealing with externalities, it may be amazing to see that some of the mainstream dissenting economists appear to be moving far from the neoclassical position and toward another "extreme" of the institutionalists. For example, David C. Mowery and Nathan Rosenberg (1982) have proposed a number of policy measures designed to bolster the supply side of technological development, including a broader range of government funding of non-defense R & D and institutional changes designed to improve interactions between users and producers of technology and basic and applied research.

It is too soon, of course, to conclude that the perspective of the mainstream dissenting economists will converge completely with that of the institutionalists. In essence, the former are trying to improve and extend traditional neoclassical analysis by utilizing the existing methodology and the new theoretical approach for their work. Institutionalism is one avenue. As Eirik G. Furubotn and Rudolf Richter (1986) pointed out, however, institutionalism does not offer, or purport to offer a body of settled conclusions immediately applicable to policy. Therefore, a recent perspective, called new institutional economics (NIE), has surfaced, which focuses on analyzing government intervention in the market economy. They claim that a close study of existing institutional structures is essential to a valid assessment of the problems of industrial policy. This is important in evaluating the effectiveness of a government policy which affects the incentives and transaction costs within a system, and in contributing to orderly industrial readjustment and vigorous growth.

In summary, although through dissent the mainstream perspective is becoming broader than the old orthodox, neoclassical model, it still retains much of the orthodox essence. As a matter of fact, they are trying to provide a broader conception by seeing the neoclassical model as only one particular case (Nelson and Winter: 1974).

2.4. Marxian Point of View

Marx had an extraordinary view of technology and technological change in his theory of the evolution of capitalism. He was the first economist to fully realize the significance of technical change for economics and society (Heertje: 1973). However, he emphasized technological change as a lever for "paradoxes," as he saw them, which are embedded in capitalism. Having identified them, he stressed such "paradoxes" with the objective of predicting the "end" of capitalism.

There are at least two paradoxes upon which the Marxian's role of technology and technical change is based. First, human labor is the only source of "surplus value." Capitalists seek such "value" aided by a large army of unemployed which tends to hold down real wages. Second, there is a diminishing rate of profit which, in the long-run, is inconsistent with the interests of the capitalist class. The continuous accumulation of physical capital, due to the acquisitive spirit of the capitalist class, is the primary force, Marx believed, in causing profit rates to decline in the long-run. In this contradictory process, the role of technology and technical change is an intrinsic, logical link in his analysis. Three notions from his terminology are the keys for understanding his thought along these lines: surplus value, the rate of profit, and the organic composition of capital.

Surplus value is the same as profit in quantitative terms, but Marx asserted that surplus value is produced only by human labor. Human-labor work is regarded as the source of value through which the capitalists can reinvest and augment the stock of capital in pursuit of generating more surplus value. It has to be remembered that Marx assumed that capitalists pursue a maximum rate of return on capital(R) rather than an aggregate, absolute amount of profit. This is a basic factor determining capitalist behavior. However, R is dependent on the level of technology and the level of consumer spending. This means that technological progress is tantamount to the introduction of labor-saving devices, and so permits a given output to be produced with less labor. Since workers do most of the consuming, reducing labor costs of production will not necessarily raise profits. The output must be sold if profits are to be made (Higgins: 1968). In effect, Marx developed one of the earliest "underconsumption" theories.

The key concept for the whole story is the creation of the organic composition of capital in which Marx distinguished "variable capital," representing human labor, from "constant capital," the physical means of production such as machinery and raw materials. Marx maintained that technical change is accompanied by a decrease in the ratio of "variable" to "constant" capital. As mentioned above, in Marx's system, the investment decision, partly driven by continuous competition among capitalists, depends not merely on the size of their income, but on the rate of return on total capital. In the investment process, Marx saw technological innovation tending to be capital-absorbing and labor-saving which implies the generation of technological unemployment.

Therefore, Marx predicted that the increase in capital per worker must result in a fall in the rate of profit from which two paradoxes can consistently be derived. First, the capitalists will add the stock of capital due to investment partly driven by the pressure of competition. The accumulation of capital furthers the advance of technological progress which in turn reduces employment because of technology's labor-saving bias. Since human labor is the source of surplus value upon which capital accumulation depends, the reduction of employment results in the reduction of surplus value. This implies that the investment process will eventually cause its own demise.

Second, the reduction in employment will lead to a decline in consumption, and since the rate of return depends in part on consumer spending, the unsold output leads to a fall of the rate of return. In order to maintain R and to survive the competitve race, the capitalists must continually introduce improved technology in the process of production; such process will become more and more concentrated in "constant" capital.

For the purposes of this thesis, several observations are in order. First, technological change is the prime mover of the whole Marxist system. The technology of each era in a country's development determines not only the economic situation, but also the social and political configuration of the whole society. Furthermore, competition is viewed as one of the causes of technological progress because competition encourages the application of new inventions. As a consequence, some firms prosper while others flounder[4]. Moreover, technology is largely an endogenous variable since it is driven by an interaction between the increased mechanization of production and accumulation of capital. In addition to market power which also partly motivates technical change, mechanization leads to the acquisition of technical change through increasing specialization of labor, larger scales of production, and changes in the organization of production. Finally, technical change can lead to unemployment, which implies some policy issues for economic development even in the modern world.

2.5. Summary

Technology and technological change are typically treated as "given," "exogenously determined," or part of a "residual" in affecting economic growth in neoclassical theory. As we have seen above, other schools place technological change at or near the center of their theory. This distinction is significant to the theory and practice of technology transfer, which is the topic of the following chapter.

Notes:

1. There are several references for the critical assessment of the neoclassical short-run model, such as Furubotn (1962), Furubotn (1965), and Roth (1979).

2. They are referred to as those who rely predominantly on orthodox analytical tools for much of their work.

3. These two activities, as well as learning-by-using, will be discussed in detail in the following chapter.

4. Heertje(1973) points out that Marx was anticipating the concepts of oligopoly and monopolistic competition.

Chapter 3

TECHNOLOGY TRANSFER TO LESS DEVELOPED COUNTRIES: ------SELECTED CONSIDERATIONS

During the past 200 years technological innovations have been dominated by a handful of countries. As a study conducted by the Organization for Economic Cooperation and Development found in 1970, all of the 110 significant innovations in the twentieth century emanated from developed countries (DCs) (Stewart: 1981). Large groups of less developed countries (LDCs) currently lack adequate technological competence. For whatever reasons, they acquire advanced technology mainly from a few developed countries.

In addition to this, the universal recognition of the role of technology in the pursuit of profit, power, prestige, and prosperity has made "technology transfer" a central concern of business and public policy everywhere. However, faced with the perplexing, puzzling, and dynamic process of technology transfer from developed countries to less developed countries, the real effectiveness of regulatory and promotional policies designed to affect technology transfer should be fully explored. What general role does technology transfer and associated policies play in the economic development of LDCs? Exploring this question is the primary purpose of this chapter.

Section 3.1 reviews several traditional economic models dealing with international trade and technology transfer. Section 3.2 reveals the complexity and unexpected consequences of technology transfer to LDCs. The following section discusses the issue of internal technological capacity and its interaction with technology transfer. The last section examines experiences of several LDCs with regard to their attempts to acquire and master computer technology.

3.1. Literature Review

3.1.1. The "Harrod-Domar" Model of Technology Transfer.

The international transfer of technology takes place when technology in one country is made available to another country. Usually, LDCs acquire their technology from DCs. The acquisition of technology transfer can be conveniently inserted into a model of economic growth, known as "the Harrod-Domar growth model" (Todaro: 1985). The model assumes that (1) aggregate saving (S) is the principal source of capital stock(K), which in turn, is a fundamental determinant of economic growth; and (2) there is some direct economic relationship between the size of the total K and total GNP, or national income (Y), i.e., any net additions to K in the form of new investment will bring about corresponding increases in GNP. Saving is some proportion(s) of Y such that we have: S=s(Y), and, given a certain capital/output ratio (k=K/Y), incremental K--new investment--is equal to k times incremental Y such that we have: K = k * Y. Since S is equal to I (investment), we have:

$$\frac{\Delta Y}{Y} = \frac{s}{k},$$

where Δ Y represents economic growth. Δ Y can be obtained in two ways: (1) an increase in s; and (2) a decrease in k. A decrease in k also means an increase in productivity, which can be driven by technological improvement. In LDCs' situation, the rates of both saving and technological change are ordinarily lower than DCs. More foreign investment and technology imports from abroad would, therefore, seem to be very reasonable and efficient ways to reach a higher rate of economic growth.

3.1.2. The Law of Comparative Advantage.

David Ricardo's law of comparative advantage states that countries can benefit mutually if each specializes in the production and export of goods in which it is relatively more efficient. "Relatively" and "comparative" are important modifiers, because they mean that even a country that is more efficient in the production of all goods in an absolute sense will still find it advantageous to specialize and to engage in international trade.

In their neoclassical model which was built on Ricardian foundations, Eli Heckscher and Bertil Ohlin explained comparative advantage by differences in factor endowments among trading countries. A nation, other things being equal, tends to have comparative advantage in products that relies intensively on the factor of production that it possesses in relative abundance.

The relationship to the acquisition of technology by LDCs is rather straight forward. DCs, compared with LDCs, are blessed with relatively abundant, skilled scientific and technological manpower along with a supporting educational system and R & D infrastructure. Faced with choosing between buying or producing a particular technology, ordinarily it should be more efficient to buy. Thus, in effect, international trade in technology is incorporated into the general framework of comparative advantage. The current overall pattern of international technology flows between the First World and the Third World holds few surprises for the conventional economist.

LDCs, however, often complain about the type of technology available from DCs and they see this problem as being connected to high and rising rates of urban unemployment, the slow growth of employment in the manufacturing sector, and high and rising capital-labor (K/L) ratios in many LDCs (White: 1978). In addition, in the orthodox rendition, the dynamic nature and consequences of technology transfer may not receive as much attention as the issues of choice of technology and appropriate technology. The following section addresses these issues, as well as introducing other complicating factors.

3.2. Complexity of Technology Transfer

As opposed to most idealized models, the real process of technology transfer turns out to be complicated and sometimes ambivalent. This complexity is rooted in the conditions under which transfer occurs; the biases and fashions that influence decisions; the "players" and contents of the transfer; and the effects of the transactions. As an example, decision-makers in LDCs, especially at the firm level, often have a simple belief (or faith) that the latest vintage of technology is the best choice regardless of other considerations (Kuznets: 1966). Another kind of bias with technology transfer is what Celso Furtado has called the "Brazilian Model." Skewed income distribution favoring upper income groups creates a demand for "big ticket" luxury goods that tend to be produced by sophisticated, capital-intensive technologies. Consequently, even when local R & D efforts do generate viable technologies, there is still a strong tendency for these technologies to be rejected in favor of foreign sources (Stewart:1981). This tendency is reinforced by market advantages bestowed by foreign trademarks.

Furthermore, in practice, as technology transfer has been commercialized, the process itself has become more complex than the core technology itself (Stewart: 1981). In a typical technology transfer, there are usually different "players", each with different motives and perspectives. As indicated in the "theory of games" or "game-theory," a player would not be the "classical enterpreneur" but "many other individuals, such as ministry secretaries and department chiefs and financiers and possibly the head of state" (Enos: 1985, 50). The extent to which any player can influence the outcome will depend, in the real world, upon his power and the power of the others in the game. In the case of South Korea, for instance, John Enos examines the effect of the role of government in choosing petrochemical technology for the production of low-density polyethylene and vinylchloride monomer. Having found 15 suppliers of virtually identical core technology, the government then engaged in extensive negotiations over all sorts of issues, such as price of the technology, conservation of foreign exchange, managerial learning, worker training, service contracts, local autonomy over decisions, etc. (Enos: 1982). Technology transfer was enormously complex even though the technology was not in doubt from the outset.

Generally, technology transfer may involve an intricate set of arrangements for sharing access not only to products but also to persons and know-how, and for sharing repeated opportunities for learning-by-doing. Even in relatively simple industries, it may involve components of design, construction, engineering, procurement, assembly, start-up, operation, maintenance, marketing, management, and training (Blair: 1986). More importantly, in addition to effective communication of how to use the information, which may require the transfer of skills, managerial know-how and so on (Stewart: 1981), a major element in effective technology transfer is often the acquisition of appropriate marketing rights, e.g., the right to use trademarks, access to markets, and assured availability of inputs. International technology transfer, then, goes far beyond mere technical considerations.

Moreover, technologies can be proprietal or in the public domain; they can represent levels ranging from traditional through intermediate, conventional and newly emerging; and they may be relatively disembodied and easily inserted into prevailing modes of production, free-standing turnkey types, or anywhere between these extremes (James: 1989). Frances Stewart (1981) makes a distinction between formal and informal transfers. Informal technology transfer refers such activities as reading technical books, journals, etc.; personal contacts in meetings and conferences; skilled labor and professionals shifting from one firm or industry to another; and so on. Formal technology transfer, a main topic in this paper, is concerned with most economic activities which bear a specified monetary cost. Direct forms of formal technology transfer include direct contracting of individual experts and consultant companies, engaging engineering design and plant construction enterprises, training nationals for specific production projects, technical information activities and transfer of the process technology embodied in capital goods by importation of equipment purchased directly from machine manufacturers (Cooper and Sercovich: 1971). Indirect forms of transfer range contractually from investment overseas in a wholly-owned subsidiary, joint-ventures, turnkey arrangements, and license and management contracts between independent parties (Stewart: 1981).

Finally, the contents and consequences of technology transfer are also influenced by the degree of monopoly or competition in the market involved, the relative bargaining strength of participants, and the nature of the recipient and supplier firms; the type of product involved (basic, intermediate, or final) and the maturity of the product or process in the "product life cycle"; economic, engineering, and managerial objectives; the degree to which the technology can be "packaged" or "unpackaged"; and the specifics of government policy (Blair: 1986).

Besides all of the above, the nature of technology transfer varies among countries, among economic sectors, and overtime. Furthermore, there may be other political, social, cultural, and historical conditions, which make technology transfer more unpredictable than stark economic models imply. Finally, an issue to which we turn in the following section is how technology transfer relates to internal technological capacity (ITC). Surely technology transfer, if it is to be effective, should mean something more than just technology relocation.

3.3. Acquisition of Internal Technological Capacity

3.3.1. Technology Transfer and ITC: Substitution and Complementary Relationships.

Technology transfer does not necessarily bring about enhanced ITC. As Miguel S. Wionczek observed, incorporation of technology imported in the productive structure and its positive impact on the social organization of the recipient country depends almost exclusively upon, not the volume of technology transferred, but the host country's ability to establish its own capacity to (1) absorb the technological knowledge offered in accordance with the priorities set by its development model and (2) use this knowledge to produce more advanced or appropriate technology of its own (Wionczek: 1986).

Wionczek's thoughts are consonant with Simon Teitel's distinction between technological change and technological development. As we know, technology can be defined as "methods" and "knowledge" used in the production process. Technological change is commonly used to refer to all modifications of such "information" (Teitel: 1981). As an extension of this definition, the acquisition of ITC through importing technology from abroad and then adapting it to local conditions is nothing more than technological change. Technological development, however, goes far beyond this. It has not only led to the acquisition of technological capacity to absorb imported technologies but also resulted in the local development of new products, new processes, and an array of scientific and technological capacities. Technological development, therefore, represents a mature stage in acquiring ITC in a developing country which can both adapt and create industrial technology.

It is the recognition of these points that explains why the accumulation of ITC has now become a primary objective of technological development among LDCs. A number of reasons explain this shift in emphasis. First, financial constraints motivate LDCs to seek new approaches for acquiring technology. Scarcity of foreign currency is a major problem for many developing nations that would like to purchase technology from abroad by following the traditional pattern. The debt problem, shared by most LDCs, has contributed to the paucity of foreign exchange. In essence, it has spawned an import substitution attitude toward technology, an attitude that stresses the substitution effects between technology imports and ITC [1].

In spite of the shortage of foreign currency, why should LDCs not base their acquisition of technology on Ricardian trade doctrine and not simply purchase it through market channels from industrialized countries that have a comparative advantage in technology? Perhaps the simplest reason is that the technology does not exist in DCs, or that the technology exists, but is not for sale. As an example of the former, Peru has taken the lead in microbial leaching of copper and other metals, partly because the techniques needed were not known in DCs. As an example of the latter, Abdus Salam, Nobel laureate in physics, tells of his brother and associates rediscovering penicillin in India because the technology was not for sale. Similarly, some technology cannot be bought or sold because of its peculiar nature. There is an irreducible component of know-how, often firm-specific, that can only be acquired by operating experience (Murnane and Nelson: 1984). Even in the conventional production set the "boundary" of technical knowledge is the abyss of the unknown and the impossible (Nelson and Winter: 1980). The difference between what is "known" and what is "technically possible," requires further examination (Katz: 1982). The accumulation of such "tacit knowledge" is, therefore, crucial for the technological progress at the enterprise level [2].

Another motivation may come from monopoly power of technology sellers. Technology sellers are often large multinational corporations with superior bargaining power due to their size, superior knowledge of the technology and their ability to segment the market by countries (and sometimes by industry or firms). The costs to the buyer can be through an outright excessive price, transfer pricing, restrictive clauses in a contractual agreement (Vaitsos: 1974), or through inferior or obsolete technology. If these costs become unbearable, local development of the technology may be economically feasible.

Besides these economic and technical considerations, others such as political and national security may also become the raison d'etre for LDCs to develop their own ITC. Indeed, these motivations seem to loom large in such undertakings as Brazil's ethanol project, Argentina's development of nuclear power and China's computer program.

The decision to produce or to import technology is not the whole story, however. Important complementary interaction between technology transfer and the acquisition of ITC is being increasingly appreciated by the literature. First, imported technology almost always has to be adapted to local conditions, a process which involves a good deal of technical learning. Furthermore, although the buyer cannot know everything about a technology[3], those "players" in the "game," such as scientists, technicians, managers, and government officials, who participate in R & D and innovative undertakings, are likely to be capable of having a better grasp of current and potential capabilities of a given technology, as well as more accurate information on suitable technical substitutes and alternative sources. Moreover, indigenous R & D and innovation, up to some point, could complement the process of acquiring technology from abroad through enhancing bargaining skills and reducing the duration and expense of adapting imported technology. The greater the threat of the LDC's generating the needed technology at home, the greater their bargaining power with the seller. Once those "players" get access to the basic principles or so called "know-why" on which a technology is found, they could be apt to be less awed by sales pitches touting purported technical marvels, be more prone to ask the right questions, and be more capable of gauging the amount and nature of adaptation required for getting the technology operational under local conditions (James: 1988). Finally, increased internal R & D opportunities might cut down on the number of scientific and technical people leaving home, i.e., the brain drain, which is not likely to be properly reflected by market signals.

3.3.2. ITC at the Enterprise Level.

1. Know-How and Know-Why.

As was mentioned earlier, technology transfer has now become a central concern of business and public policy with a recognition of the role of technology in the pursuit of profit, power, prestige, and prosperity. A related goal is the acquisition of internal technological capacity, either in conjunction with technology transfer, or through domestic generation of new technical knowledge. With regard to ITC, it is common to differentiate "know-how" from "know-why," a distinction first made popular by Sanjaya Lall. Figure 3.1 shows one rendition on this theme by Don Scott-Kemmis and Martin Bell (1985). Stream A, denoting technical services and capital goods imported, will augment only the production capacity of a technology importing firm. Stream B, consisting of skills and know-how, encompasses the flow of various types of knowledge and technical skills required to augment those already accumulated by the technology importing firm. Although A plus B comprise a wide range of different types of knowledge, e.g., knowledge about products, processes and methods, materials and components, etc., quite little is revealed about how the basic scientific and technological principles work (Scott-Kemmis and Bell: 1985). By definition, stream C, which includes knowledge and expertise which are required to design and to create modified production systems, is the only stream that can significantly increase the host country's ITC. Such knowledge and expertise for generating and managing technological change extend the firm's capacities beyond that necessary to operate a given production system. It includes knowledge about the principles underlying the production systems (or elements of the system). Much of this technical knowledge may be highly system-specific, and, importantly, will involve particular types of expertise required to apply those principles in designing and implementing technological change, and to organize technological programs.

Another way of making this important distinction is through viewing the enterprise's acquisition of ITC as a

Figure 3.1. The Technological Contents of Technology Transfer

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 EXPORTING FIRMS                                IMPORTING FIRMS
________________                               ________________
|               |                              |               |
|               |  A    Technical              |               |
|               |====>  Services &      ====>  |      New      |
| Technological |       Capital Goods          |               |
|               |                              |   Production  |
|               |  B                           |               |
|               |====>  Skills &        ====>  |    Capacity   |
|               |       Know-How               |               |
|   Capacity    |                              |_______________|
|               |                              ________________
|               |  C                           |               |
|               |====>  Know-Why        ====>  | Technological |
|               |                              |   Capacity    |
|_______________|                              |_______________|
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Source: Scott-Kemmis and Bell (1985: 1993).

"ladder," involving sequential steps: (1) having a growing talent for spotting a problem or opportunity with a technological dimension; (2) learning to search, screen, select, and bargain for technology; (3) acquiring the ability to modify imported equipment and production procedures to fit local conditions; (4) developing the capabilities for making further innovative alternations of technology in response to changes in the economic environment; (5) being able to produce and act upon enterprise-generated designs leading to major equipment modifications or new products; and (6) instigating organized R & D activities (James: 1988). Steps 5 and 6 contribute to the acquisition of "know-why." Jumping from rung 4 to rung 5 usually involves a considerable challenge and requires a conscious decision to commit resources to risky undertakings in training, hiring, or R & D.

2. Routine-Learning Experiences.

"Learning," as used here, refers to the acquisition of additional technical skills and knowledge by individuals and, through them, by enterprises (Bell: 1984). "Learning-by-doing" occurs when the technological progress depends largely or entirely upon production experience. The routine execution of production tasks often generates a flow of information about, and understanding of, problems encountered and/or opportunities perceived, which leads to improved productivity.

Learning-by-doing happens routinely, and usually involves activities that tend to be passive (occur without conscious effort) and costless in terms of being a by-product of normal procedures (James: 1988). However, given all of these merits, doing-based learning does not seem to be sufficient to ensure continued technological progress. These types of productivity gains tend to be exhausted rather quickly (Bell: 1984). As F.C. Sercovich (1980) points out, the relatively passive doing may be a slow and ineffective means of accumulating certain types of technological capacity since the cost and risk of inefficient doing may be very high.

Unlike learning-by-doing, "learning-by-using," refers to the accumulation of technical knowledge through use of a new product. It is a more or less market-driven phenomenon, which involves a flow of information from product users back to the producers. It is an extremely important external economy to producers of "design-intensive" capital goods. Learning-by-using pertains particularly to some specific industry such as electronics, where many products manufactured and processes used are too complex to be designed perfectly the first time around; only after extended use can they be improved (Khanna: 1986). In Rosenberg's case of software technology, successful software development is predicated on close interaction with the users, even for application packages sold over the counter (Rosenberg: 1982). For personal computer technology, the feedback from the users is no less important in the design and engineering of new products than in semiconductor technology (Khanna: 1986).

3. Engineering Innovations.

There are generally three major in-plant engineering activities, i.e., product design, process engineering, and industrial organization, which can routinely generate technical knowledge. For example, in a reasonably competitive situation, some effort must be devoted to product specifications for product-differentiation and/or cost-reduction. As a result, incremental information is generated when the original product design is upgraded, improved or modified. In process engineering, it is a daily job to register and to interpret technical parameters which describe the behavior of the production process under different operative circumstances. The capacity per se is the result of accumulation of technical information and skills associated with the understanding of the production process (Katz: 1982).

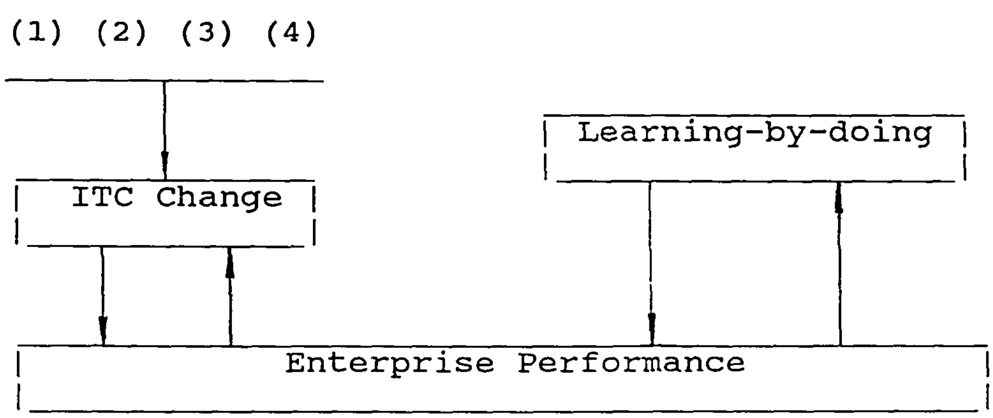
These routine activities of ITC acquisitions, however, can behave differently depending on whether continuous-flow or discontinuous "batch" processes are utilized. Other things being equal, use of discontinuous processes producing a heterogeneous product will probably lead to more ITC acquisition in the firm's routine engineering than will employing a continuous technology and producing a homogeneous product (Katz: 1982).

4. Non-Routine Efforts.

Referring again to the aforementioned "ladder" by which firms acquire ITC, getting from rungs 1 - 4 to rungs 5 and 6 is not ordinarily routine, cheap and relatively riskless. It usually takes a deliberate, conscious decision, requiring significant resources; and there is no guarantee that the training, hiring, R & D, or whatever strategy used will work.

As Martin Bell (1984) contended, the effectiveness of all of these mechanisms, i.e., training, hiring, searching, R & D, and system performance feedback, which are possible discontinuities in the ITC acquisition "ladder", is non-routinely determined (See Figure 3.2). For example, the information flow about a firm's systematic performance, which is knowledge and understanding about the technology itself, is so far from being passive or automatic that some firms often run for years without any technical consciousness or technical information gleaned about their own production performance that would inspire technological innovation. Moreover, the effectiveness of such a flow on

Figure 3.2. Different Learning Mechanisms Involved in Infant Enterprise Maturation



(1) = Training; (2) = Hiring; (3) = Searching; (4) = R & D

Source: Bell, Martin (1984: 191).

the firm's capacity to change technically depends on the _prior_ availability of skills and knowledge to analyze and interpret the information generated (Dahlman and Fonseca: 1978). In short, advantages of early learners tend to become cumulative.

Whether a firm is capable of hiring technologically-embodied manpower, ready-made technological capacity, can be a factor in determining the "step-jumps" in ITC acquisition, although such a resource may not instantly bring about the required technological change in the hiring firm (Bell: 1984). Nor are such ITC acquiring measures as hiring technically competent manpower, training, and engaging in R & D routinely. On the contrary, they require conscious, active efforts by firms to gain from disembodied technical knowledge. This can apply to technology transferred from abroad as well as purely domestic activity. In this regard, access to specific services, training, consulting, and help with installation, etc., and start up operations are often essential ingredients for a successful technology transfer project.

3.3.3. Sectoral and National Levels.

1. Capital Goods and Technology Exports (TE).

Countries like Brazil, South Korea, Mexico, and Taiwan are currently grouped as newly industrialized countries (NICs) because, among other things, the evidence shows that they are able to accomplish capital goods production and to export technology to other LDCs or even DCs (Lall: 1984). The production of capital goods and technology exports (TE) are viewed currently as two crude indicators of acquisition of ITC (James: 1988), indicating the current status of technological development. For capital goods production, as Dilmus D. James (1989) notes, a tremendous variety of worker skills and demands on managerial abilities are associated with the wide range of products that characterize the industry. In addition, many of such skills and techniques are in demand throughout the industrial sectors, labor, and management circulation. As a result, improvements in capital goods spread productivity increases and concomitant technical change to manufacturing in general. Meanwhile, production of capital goods requires a sophisticated level of design capacities that must be sporadically or continuously upgraded as material and technical inputs change and user specifications are altered. For TE, these NICs have shown an impressive record in not only the production and export of locally developed technologies, but also an incipient flow of foreign investment abroad and in the sale of licenses, consulting services, and turn-key plants (Teitel: 1981). The next section will elaborate on this increasing technical capacity of NICs.

2. Continuous and Discontinuous Production Processes.

Continuous-flow, highly-automated technologies characterize the most current production processes in firms and industries in DCs. Continuous-flow production methods are generally product-specific, i.e., their "layout" is organized along a sequence or order imposed by the various technical transformations that have to be carried out to produce a given product. Since the sequence of technical transformation is always the same, the "layout" is rigidly determined in a high rate of mass production. Consequently, (1) the pre-production planning of the "line" is extremely detailed and complete, meaning that there is low *ex post* flexibility in both the product design and the production process; (2) the product tends to be highly normalized and most of the equipment is designed to fulfill specific tasks; and (3) there is relatively little "on-the-job-decision-making." Clearly, under these conditions, there is less opportunity for a broad-based exposure of the work force and technical personnel to the learning experience.

In contrast, discontinuous processes, entailing varying but relatively low degrees of automation, dominate the manufacturing sectors of LDCs (Katz: 1982). These processes, usually using more general purpose equipment and often producing more heterogeneous products (sometimes customer-designed), are far more flexible in terms of work scheduling, choice of production techniques, and plant layouts. Much more decision-making on the part of workers, technical personnel and supervisors is required.

With regard to technology transfer, it is usually questioned whether continuous-flow technology imported from DCs could act as a vehicle for fostering the type of learning needed in LDCs. Indeed, on a more macro-level, Gustav Ranis has drawn attention to the truncated learning in Latin America, in contrast to South East Asian countries, because the former "skipped" the production of labor-intensive consumer goods in her import-substitution-industrialization (ISI) process and went directly to capital-intensive, heavy industry. Naturally, whether continuous-flow production is preferred to the discontinuous process, is determined by a number of factors other than technological ones, e.g., factor prices, market size, availability of skills,dependability of delivery schedules.

3. Controversy Over Infant Industry Protection.

According to the infant industry argument, a new manufacturing industry may not enjoy a "static" comparative advantage judged at today's relative cost. However, it may have a potentially "dynamic" comparative advantage which can lead to a prosperous status in the future (Cline: 1987). But, the initial development of such an industry in LDCs may be retarded by two difficulties: (1) the lack of a set of financial institutions and (2) incurring "start-up" costs of adapting technology to local conditions or of opening new markets (Krugman and Obstfeld: 1988). In order to help this industry survive its initial period of high cost production and grow strong enough to meet international competition, government intervention in terms of protecting the infant industry through tariffs and/or subsidies can be judged as a second-best policy option [4].

In addition to several common problems, such as the uncertainties in guessing at future comparative advantages and the inappropriate uses of protection, there is still another difficulty. This issue is referred to as a "moving target" problem [5]. An important condition for successful infant industry development along product life cycle lines would appear to be a relatively stable technology, such as in steel or automobiles, in which the principal technologies in the industry could be in place for several decades (Cline: 1987). This consideration must be kept in mind as the discussion turns to the controversy regarding computer technology in LDCs.

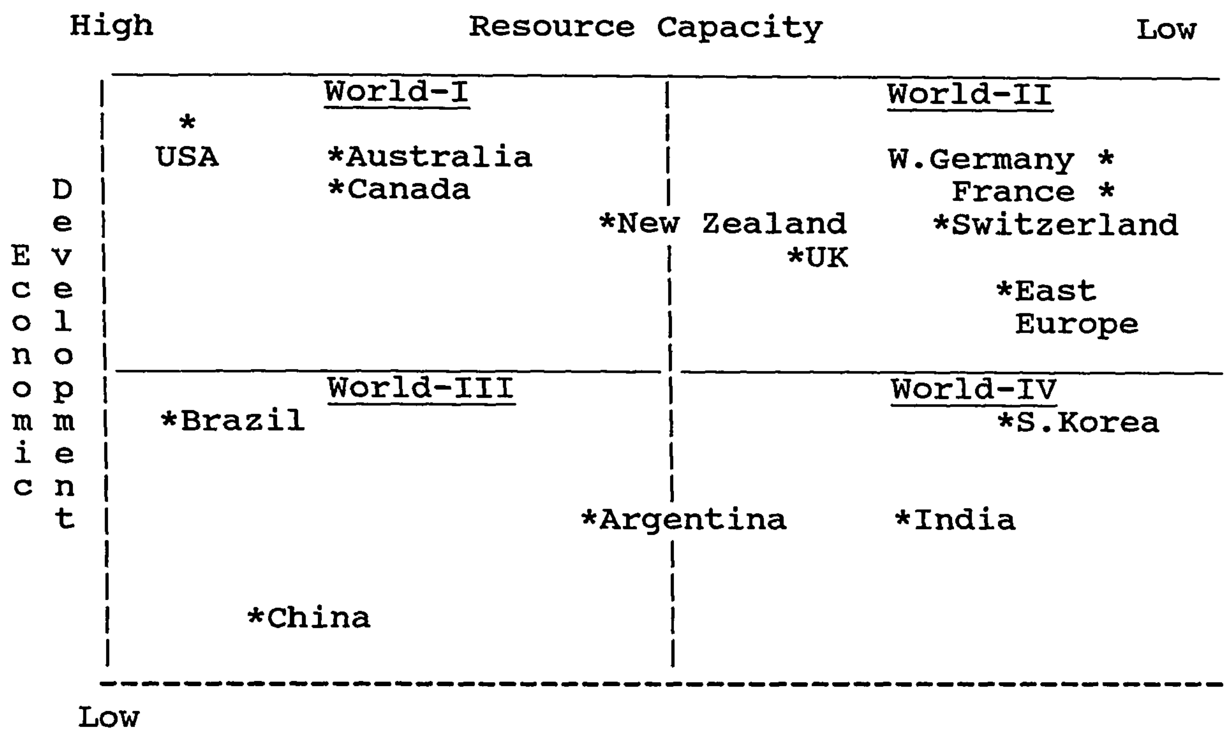
3.4. Experience of Some LDCs: Computer Sector Strategy

3.4.1. Strategy Options.

The selected LDCs that will be discussed have lower levels of general economic development than the industrialized countries, although some, such as Brazil and China, possess high-rank levels of resource capacity, mainly natural resources such as land, minerals, etc. In Figure 3.3, the horizontal axis shows the potential resource capacity (rising from right to left), while the vertical axis indicates the level of economic development (rising from bottom to top). As Table 3.1 shows, most of these developing countries have made tremendous progress in economic and industrial growth since the mid-1960s [6].

At a national level, a common feature for the economic and industrial growth in LDCs is that a specific industrial

Figure 3.3. Classification of the Plant



Source: King, Alexander, (1980: 22).

Table 3.1. Economic Growth in China and Selected Countries (1965-1980)

Country	Population (million) mid-1985	GNP per capita ($) 1985	Average annual growth rate (%) GNP	Industry	Manf.
China	1,040.3	310	6.4	10.0	9.5
S.Korea	41.1	2,150	9.5	16.6	18.8
India	765.1	270	3.8	4.1	4.4
Brazil	135.6	1,640	9.0	10.0	9.8
Mexico	78.8	2,080	6.5	7.6	7.4
Argentina	30.5	2,130	3.3	3.3	2.7

Source: World Bank Report, 1985.

strategy is usually pursued under state intervention and policy regulations. The computer sector, for example, is currently accorded high priority in many LDCs. The experience of the LDCs can serve as the basis for an evaluation of technology transfer policies for several reasons. Broadly speaking, technology can be transferred through importing it or by hosting direct foreign investment. In each dimension, the strategy may incline to be relatively open or closed: relatively high or low protection on imports; and prohibition of investment and production by foreign firms or active cooperation with the multinationals. Second, although national laboratories and private companies in the United States, Japan, and Western Europe are today taking the lead in computer technology, the potential role of the technology is equally great for improving productivity and for changing the industrial and economic structure in LDCs. Finally, in traditional industrial sectors such as steel, the effectiveness of the strategy may be complemented by the slow pace of technological innovation. Computer technology, however, is being developed at a very fast pace. A life cycle for a technology-intensive product can now be as short as two to four years [7]. Thus, an effective strategy requires an appropriate estimation of the role of technology transfer.

In the 1950s and early 1960s, the dominant development strategy in Latin America and many countries in Asia and Africa was import substitution industrialization (ISI), an important extension of the infant industry argument. An essential idea involved in the ISI pattern is that a LDC could develop industries oriented toward the domestic market by limiting imports of manufactured goods (Krugman and Obstfeld: 1988). Today most LDCs have renounced the early, broad umbrella promotion of the entire industrial sector, in favor of more targeted promotion of specific industries. Very often, in the more advanced LDCs, the computer industry is among those selected for special treatment.

In the computer sector, Argentina formerly granted the sector a partial isolation, especially in electronics capital goods, while all the other sectors in the economy were structured on stronger protection maintained during the mid-1970s (Nochteff: 1985). However, before the 1985 re-regulation, a drastic reduction in tariffs, as well as other restrictions, was a major component of Argentina's industrial policy, which resulted in a series of unexpected happenings. For example, dependence on external technology was reinforced and the possibilities for adapting the technology to local conditions were reduced (Ibid.). After 1985, high tariffs, 100 % for instance, on imported computer technology, have become the policy option of protecting the domestic sector while foreign investment is still allowed if it can expand market size and the technological frontier in Argentina (Cline: 1987).

In Mexico, the primary objectives in regulating the computer sector were to increase exports, to provide support to domestic companies, to control imports, to regulate the technology transfer and foreign investment, and to increase employment (Nochteff: 1985). However, the ISI strategy was eventually carried out in a very moderate mode because of the common border with the United States. The case of smuggling renders a policy of very high protection ineffective.

Driven by an incentive of "national security," i.e., reducing dependence in the military field on foreign suppliers (Nochteff: 1985), the Brazilian government adopted "market reserve," the closure of both trade and foreign investment in small computers such as micros and minis (Cline: 1987). While the development of mainframe computers still relies on multinationals, compared with the experience of Mexico, the Brazilian policy represented the extreme in terms of high protection.

A notable distinction between Brazil and Mexico, as well as Argentina, is Brazil's remarkable exports of data processing equipment (DP) (See Table 3.2). A critical difficulty with the ISI pattern is, however, that industrial plants are more often built to standard size but operate at only a fraction of capacity. The domestic market frequently tends to be too small to accommodate to optimal scale of production. Argentina lags behind other selected LDCs in both economic growth(See Table 3.1) and DP export seemingly because of this (See Table 3.2).

However, having taken advantage of the product life cycle in the computer sector, a developing country under the ISI strategy will inevitably be shooting at a moving target of constant technological advance and declining international prices. Although Brazil seems to be successful in her technological development, the domestically produced, sophisticated micro-computers turn out to be more expensive than at the international price level. In contrast, Mexico's products are quite close to that level due to the relatively open policy in trade and foreign investment (Cline: 1987).

Unlike the ISI pattern, experiences of South Korea and

Taiwan provide another case of infant industry development in terms of "export orientation" strategy. Their experiences also proved to be successful in terms of economic efficiency. A key feature in policy evaluation in all of the cases above is the attainment of economies of scale (Cline: 1987). Apparently, an open policy leads more easily to attainment of economically efficient scales of production. The matter of economic efficiency through economies of scale will be broached again in Chapter 6 when the focus is on China.

3.4.2. Critiques on the Strategy: TE and Comments.

Technology exports (TE) by NICs are on the rise, thus indicating their growing technological competence and their exploitation of comparative advantage. But industrial performance[8], when examined by individual strategy, turns out to be complicated. Taiwan, for instance, adopted an export orientation in development. However, in terms of technology exports, the evidence shows that her specialization comprises only the narrowest range of the least advanced technology. On the contrary, although India has experienced protection of domestic production, her technology exports in terms of industrial projects are prominent among other NICs. India is also leading the others in terms of diversity and sophistication of technology exports (Lall: 1984). South Korea stays in a middle position in technology exports, while Brazil fits into a weak situation in all forms of industrial technology export [9].

In the computer sector, however, the case is somewhat different. As shown in Table 3.2, Brazil was the most successful among LDCs in exporting automatic data processing equipment in the period of 1977 to 1981 despite continuing problems of attaining optimal economies of scale. Although South Korea took a leading position in Asia (excluding Japan), she fell behind Brazil, at least during

Table 3.2. Exports of Automatic Data Processing Equipment in Selected Countries: 1977-1981 (US$ millions)

	1977	1979	1981
World Market	4,338.3	9,325.9	11,775.2
U.S.A.	1,271.3	3,441.7	5,042.9
W.Germany	786.7	1,107.3	1,433.2
Japan	153.5	n.a.	878.0
Asia	13.9	23.2	82.8
S.Korea	4.1	6.1	14.8
Latin America	88.0	104.2	199.5
Brazil	63.0	79.1	198.9
Argetina	24.0	24.7	n.a.
Mexico	0.4	n.a.	n.a.

Source: Partly adopted from O'Connor (1985: 318-319).

the period shown in Table 3.2 (O'Connor: 1985); but she succeeded in producing competitively priced microcomputers as well as peripherals (Cline: 1987). A significant fact behind such a lag between the two countries was that Brazil has spent about in excess of $ 1 billion on R & D in informatics in 1978, compared to only $359 million by South Korea in 1979 (O'Connor: 1985).

Another case presented by M. Urrutia (1988) is that of Mexico. After having suffered from technology export stagnation in the computer sector in the early 1980s, Mexico has improved significantly in terms of both economic efficiency and technology exports since 1984. As evidence, she exported DP worth $85 million in that year, a big jump compared with the earlier data in Table 3.2.

Some students of these diverse computer strategies suggest that there is a need for longer-term strategies that place computer sector development at the service of the entire economy. To ensure that the computer sector, initially protected as an "infant industry," eventually reaches maturity, William Cline is convinced that the only way is a clear commitment to the reduction of protection and the opening of the sector to international competition over a specific timetable such as 5 to 10 years (Cline:

1987). He believes that technology isolation is costly and can set back the general state of technology in a country. H. Pack and L.E. Westphal (1986) make similar observations from their study of South Korea. South Korea's governmental authority intervenes in selective industries to help them gain dynamic comparative advantage. She has discriminated in her treatment between established, internationally competitive industries and new, infant industries that were deemed worthy of promotion. In the former sectors, which have already had static comparative advantages, market forces operating in response to largely neutral incentives prevail; in the latter sectors, which have not gained comparative advantages, market forces are influenced by selectively promotional incentive policies and are supplemented by instruments of direct control and allocation. It should be noted that only those industries thought to be reasonably close to the threshold of international competitiveness are promoted.

David C. O'Connor (1985) also advocates selective and temporary protection. He warns that it is not realistic for every LDC government to seek to promote a local computer industry. Before developing a computer industry, a number of conditions must be met, such as market size, R & D infrastructure, technical personnel, foreign exchange availability, and sufficient flexibility in policy.

Furthermore, a LDC must carefully select the appropriate point of entry. Few, if any, LDCs can ever expect to become broad-line producers of all size classes of computers. Moreover, any LDC government with serious ambitions to develop a local computer industry must recognize the indispensability of a strong technological base to support such an industry.

Finally, government must assume the role, in many countries, as risk bearer or risk sharer with regard to investment both in R & D and in the commercialization of the output of the R & D establishment. Prior to involvement in financing all of these, the government must devote attention and resources to the elaboration of an institutional framework to support effective R & D activities in the computer sector.

Notes:
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1. One should note, however, there are powerful complementary effects as well.

2. Unlike orthodox factors of production, technical knowledge is frequently incompletely specified, i.e., it

leaves room for ad hoc solutions and unforeseen procedures not completely described ex ante (Katz: 1982). As a consequence, it cannot be entirely duplicated, nor can it be costlessly transferred. Knowledge accumulated through experience becomes an important part of the technological information package in any specific technology. Only local experience can lead to the acquisition of those elements involved in a given technology package.

3. As Kenneth Arrow pointed out in his "fundamental paradox of knowledge," a buyer is unlikely to know exactly what is being purchased. This is once called by Charles Cooper, the "pig in the poke" problem (James: 1988).

4. In dealing with the two problems, which are also known as an "imperfect capital market" and inadequate powers of "appropriability," the first-best answer is to create a better capital market and to compensate firms for their intangible contribution to pioneering a new area (Krugman and Obstfeld: 1988).

5. See Cline (1987).

6. As illustration of how dynamic a growth path can be, one might note that South Korea's real output per capita grew only 2.1 percent from 1955 to 1960 (Krugman and Obstfeld: 1988).

7. Denis F. Simon and Detlef Rehn (1987) mention the case of integrated circuits (ICs). For example, the era of the very large-scale ICs started in 1979 when 64K random access memory (RAM) was developed. By 1983, successful development of a 256K RAM was announced; mass production and sales started in 1984. In 1985, one year later, the technology for 1 megabit chip was introduced. The 4 megabit chip will be, in all likelihood, developed by the end of this decade.

8. Such performance is in terms of technology export or ITC acquisition.

9. Technology exports can be classed into two groups: industrial and non-industrial. The former involves industrial projects exports, direct investment, and licensing, consultancy and technical services, etc. The latter mainly includes civil construction project exports(See Lall:1984).

Chapter 4

CHINA'S ECONOMY: TECHNOLOGICAL ACHIEVEMENT AND FAILURE

Since the inception of communism, China has experienced about forty years of industrial growth. On entering the post-Mao era in 1977, China initiated ambitious S & T programs, and as a consequence, has enjoyed many impressive achievements, particularly in S & T as it applies to national security. While the achievements of Chinese S & T policies are notable, so are the failures. Among other problems, Chinese strategies for S & T development have been unable to create the conditions for effective linkage of R & D and production (Suttmeier: 1987)[1]. While there is no doubt that a substantial technological and scientific base has been established, particularly through learning-by-doing, the general lack of adequate contact with the industrialized world, coupled with the upheavals of the Cultural Revolution (which is almost always blamed as a major cause of technology stagnation) has resulted in significant weakness in the civilian sectors (Khanna: 1986). Thus, since the 1950s, China's ability to achieve "intensive" economic growth through productivity gains and innovations has been disappointing.

Nevertheless, China has now promulgated an extremely ambitious goal of economic growth for the rest of the century: a quadrupling of the 1980's industrial and agricultural output by the year 2000 (OTA: 1987). Clearly, the contribution of new technology and technological innovation to this goal, a growth rate of 7 % per year in real terms, will be increasingly important in the following years if the goal is to be reached. A number of other economic objectives are also vital, e.g., efficiency in using resources (materials, energy, etc.), improvement of production processes, achieving economies of scale, improvement of product quality, increased diversity of product types, and so on. All of these objectives would very likely benefit from an infusion of new technology and technological innovation.

The first section of this chapter outlines China's centrally-planned economy (CPE) and summarizes the major economic achievements realized under this planning. The following section presents the current status of China's technological development in terms of productivity. Special emphasis is given to a long-term problem, i.e., technology stagnation. The last section explores the institutional environment in which a number of causes may be systematically responsible for technology stagnation.

4.1. Technological Achievement and the Centrally Planned Economy

The China of 1949 was impoverished and in economic disarray with hyperinflation after years of foreign invasion and civil war. Building an industrial economy with a full spectrum of industries and achieving an average GNP growth rate of 6 % for thirty years were major accomplishments. In addition, China raised the average life expectancy of her population from 36 to 67 years and feeds 22 % of the world's population with only 7 % of the world's arable land (OTA: 1987). China had also made considerable progress in providing the infrastructure for R & D, and now has an extensive network of research institutes. For example, China has built and launched her own experimental communication satellites and has offered to launch foreign satellites, indicating her scientific and technological capacity (Lin and Wu: 1984), especially in defense-oriented areas. China's machine-building industry is capable of designing and manufacturing almost all types of foreign precomputerization-machines. Still, this sector remains under-developed, particularly compared with the most up-to-date technologies of the 1980s in the West (Ishikawa: 1988).

Although China is not a typical planned economy [2], since the 1950s she has relied mainly on central planning which resembled a Soviet-style economic system. Many of the features of a centrally-planned economy (CPE) are still prominent in China. There are three defining characteristics for a CPE: (1) Most of the means of production (especially in industry) are owned either by the state or by collectives, which traditionally have been largely controlled by the state. (2) The allocation of resources is accomplished mainly by the decisions of central planners. And (3) prices therefore play the least important role in resource allocation and have been largely restricted because of price controls over a long period (OTA: 1987).

In a model of CPE, a planning authority, consisting of a group of economic planners, plays a central role in economic activities, in which all factors of production, as well as technological change, are controlled by the economic plans. It is believed that government direction can achieve economies of scale through rationalizing the range of products and the division of labor and other resources. Also it is held that the contradiction between technological change and economic growth in the Marxian context can be resolved. Technological change, it is thought, can be geared to the maximization of social welfare instead of the pursuit of "surplus value". Increments in productivity can be sustained by economic development plans and the political consciousness of the workers.

Under CPE, China has been able to concentrate her limited resources (natural resources, physical capital, skilled personnel, etc.) on some selected developing projects which would normally require a longer term to be fulfilled without the CPE approach. In the early 1950s, the country had to recover from a war-torn economy while providing for basic needs of about 500 million people. Heavy industry, in keeping with the Soviet model, received first priority in obtaining physical capital, raw material, and skilled labor. As a result, the priority of developing heavy industry led to sacrificing the development of agriculture and light industry in terms of (1) more taxes being drawn from the latter and being reinvested in heavy industry; and (2) less scarce resources being allocated to the low priority sectors.

In China's economic development, both "respectable but not spectacular" achievements and "some serious failures" have been experienced. As would be expected, the emphasis on heavy industry entailed postponement of technological change in the light industry and agricultural sectors (Dean: 1972), consequently leading to imbalanced development in the economy as a whole. China now is still a low income country with a very large agricultural sector of low productivity. Production of other consumer goods show a very slow rate of growth. The greatest anomaly is the service sector, which is relatively smaller than that of almost any other country (OTA: 1987).

Furthermore, inefficiency and waste is rife in the Chinese economy and has persisted over a long period. For example, one-third of state owned firms produce at a loss; returns on investment were one-third of those in Japan; energy consumption per unit of output was as much as five times greater than in the advanced countries (OTA: 1987). Other factors(political interests, national security, etc.) often seem to distort economic considerations and result in seriously inefficient use, or even outright waste, of resources. The expenditure of around 200 billion-yuans (Chinese currency unit) in the wild, the "third-front areas," without encouraging results economically, is illustrative of this problem in the Chinese CPE (Economist: 1987) [3]. Finally, the biggest failure of the Chinese CPE perhaps is technology stagnation within the industrial sector since the early 1950s. Before economic reform in 1978, GNP growth was bolstered mainly by rising resource inputs, while technology and technological change were only moderately effective. The discussion now turns to this extremely central issue of technology stagnation.

4.2. Technology Stagnation

The level of technology in China's most developed sectors at the beginning of the People's Republic period may have been equivalent to the level achieved in the West in the 1930s. However, after more than thirty years, i.e., by the mid-1980s, China has only mastered the technology of the 1950s and early 1960s of the Western machine-building industry (Ishikawa: 1988). This twenty-year gap between China and the developed countries has not been closed, despite S & T achievements. Regarding the highly automated and computerized technologies developed in the 1960s and 1970s, China is only capable of operating the imported turn-key plants incorporating these technologies (Ibid.).

In a very pessimistic assessment, Zhixian Lin and Mingyu Wu (1984) assert that the protracted lag of two or three centuries in China's industrial and technological capacities has hampered her ability to manufacture complete sets of industrial equipment. This resulted in great gaps in productivity, technological innovation and management of enterprises, as well as in many other relevant areas. In sum, China's technology development is still at a stage of learning and trying to master advanced technical achievements already accomplished elsewhere in many parts of the world.

China has not gained productivity benefits from investment that other countries have realized. Productivity of labor is only one-tenth of the Japanese level (OTA: 1987). This at least implies that the previous economic growth rate, namely 6% over 30 years, has largely been achieved by (1) the high rate of investment in fixed capital, with little endogenous technological improvement, and (2) growth in the labor force over the years rather than productivity improvement. Comparative rates of investment in the two countries, as well as comparative rates of labor productivity, would need to be examined in order to confirm the conclusion that China is lagging in dynamic terms. However, Table 4.1, which quantitatively

Table 4.1. Sources of China's Economic Growth (Annual %)

Period	Growth Rate of NMP* (1980 price) (Gy)	Gains from Increase in Capital (Wk*Gk)	Gains from increase in Labor (WL*GL)	Gains from Productivity Increase (a)
1953-57	6.61	0.84	1.67	4.10
1957-65	2.09	1.87	1.63	-1.41
1965-76	5.11	2.81	1.68	0.62
1976-85	8.78	3.30	1.69	3.79

Source: Dwight H. Perkins (1988: 628).
* NMP--net material product.
Methodology: These figures are derived from aggregate production converted into the standard growth accounting form:

$$Gy = a + (Wk*Gk) + (WL*GL)$$

where G = the growth rate of the variable in question
y = net material product referred by Western economists or national income defined by Chinese
k = the capital stock
L = the total labor force
Wk = elasticity of output with respect to capital
WL = elasticity of output with respect to labor
a = productivity growth or the residual derived by subtracting the contribution of labor and capital inputs.

expresses the contribution of total factor productivity to national income, effectively establishes this important point. Throughout the 19 years prior to 1977, the contribution of productivity growth was zero or even slightly negative!

As a result of high rates of investment, consumption remained low. As Table 4.2 shows, China took a large portion of national income (Y) [4] per year to sustain a high rate of capital accumulation (K). In the 1970s, for instance, the Chinese gross domestic capital formation rate was around 30 percent of national income, an extremely high rate for a poor country. The contribution of incremental capital to NMP has been kept at an increasing rate since the 1953-1957 period (See Table 4.1).

Another regression analysis, by Gregory C. Chow(1985), concludes that in the 1952-1980 period the combined effect of the increase in labor and capital is an exponential annual growth rate of .1025 in aggregate output. The contribution from capital is .07608, which is almost three times the contribution from labor, i.e., .02644. Thus, capital contributed three-quarters and labor only contributed one-quarter of the growth in industrial output. Chow also estimates that the output-capital ratio was .1435. The interpretation is that although China has invested 30 % of her national income, the increase in average annual output per dollar of increase in capital stock, is only 14 cents. Capital is thus not very productive; it requires more capital, together with other

Table 4.2. China's National Income and Capital Accumulation (in billions)

Year	Y	K	% of Y	Year	Y	K	% of Y
1952	58.9	13.0	22.1	1967	148.7	30.4	20.4
1953	67.5	16.8	24.9	1968	141.5	29.8	21.2
1954	71.4	19.5	27.3	1969	161.7	35.7	22.1
1955	75.4	18.5	24.5	1970	192.6	61.8	32.1
1956	84.8	21.7	25.6	1971	208.2	68.4	32.9
1957	90.8	23.3	25.7	1972	214.0	64.8	30.3
1958	111.8	37.9	33.9	1973	232.6	74.1	31.9
1959	122.2	55.8	45.7	1974	235.1	74.1	31.5
1960	122.0	50.1	41.1	1975	250.5	83.0	33.1
1961	99.6	19.5	19.6	1976	243.5	75.6	31.0
1962	92.4	9.9	10.7	1977	265.9	83.2	31.3
1963	100.0	18.3	18.3	1978	301.0	108.8	36.1
1964	116.6	26.3	22.6	1979	335.0	116.1	34.7
1965	138.7	36.5	26.3	1980	366.7	116.5	31.8
1966	158.6	47.0	29.6	1981	388.7	109.0	28.0

Source: Partly adapted from Gregory C. Chow (1985: 199).

inputs, to produce a unit of output compared with developed countries such as the United States (Chow: 1985, 204-205).

These studies indicate that economic growth in China, especially industrial growth, has followed a resource-driven pattern instead of a technology-based model. Whether or not the Chinese policy makers were aware of this, technology stagnation has been inherent in the Chinese growth pattern. This inherent problem became even worse due to a number of systematic characteristics of the Chinese CPE.

4.3. Institutional Environment

Technological innovation in China is influenced by many extra-market relationships. In the West, technological innovations are a function of economies of scale in research or production, cost advantages associated with factory input and capital, or product differentiation(Simon and Rehn: 1988). The stimuli underlying innovation in the market-driven system is mainly demand-pull in terms of expected returns from R & D expenditures. In addition, technological trajectories can be supported and sustained by supply-push, i.e., advances in the technological frontier. Thirdly, according to institutionalists, the rate and direction of technological change is determined by an interactive, iterative process in which technological and social institutions dominate.

4.3.1. Demand-Pull.

Individual enterprises in China have not been provided with significant incentives for innovations. First, the introduction of new technologies to industries and enterprises was decided by the central government, mostly through the authorization of their capital construction investment plans, which included new technology, as well as choice of technologies (Ishikawa: 1988).

Furthermore, a major objective of the typical firm's management is not to maximize profits but to meet the production target set up by the planning authority; thus, there is a lack of incentive for management to increase output in order to reduce unit costs. As a result, it is not a priority for a firm to pursue innovation and technological change.

Moreover, due to the allocation of inputs, firms had little incentive to economize on the use of resources. Resource scarcity at a national level may, nonetheless, become resource abundant at a firm level. A firm is much more likely to be penalized if the output target cannot be met, rather than to suffer because of wasted resources. Firms do not worry about bearing the cost of extra inputs.

Finally, under the frozen-price system, prices do not serve as an indicator of true scarcities, either for short run fluctuations or for a long term situation. A high-cost project in a market-regulated situation may turn out to be cheap in the CPE environment. Meanwhile, firms using scarce but cheaper resources as inputs may believe that they still operate efficiently in the sense that their pseudo-cost of production is low and that their pseudo-rate of return is high. They perceive little reason to take risks by replacing the technology currently employed.

4.3.2. Supply-Push.

"In situations where the market is either absent or immature, technology push may be the more common force behind innovation" (Simon and Rehn: 1988, 3). However, under the Chinese CPE, the separation of a firm from consumers or product users may lead not only to the absence of market disciplines, but also to the lack of ITC accumulation through learning-by-using. As discussed in Chapter 3, the development of electronics technology requires user-producer interaction as a condition for healthy technological development, due to its novel, design-intensive, and "intangible" nature. Secondly, most of China's modern industries were set up by and under China's CPE. By 1956, virtually all modern industries and large-scale commerce had been socialized (Perkins: 1988). Among them, few could afford to spend more than 1 % of their output value on R & D, a meager amount compared to 5-10 % spent by many firms in DCs (Baark: 1987a). Thirdly, only 27 % of large- and medium-sized firms had their own R & D departments (Ibid.).

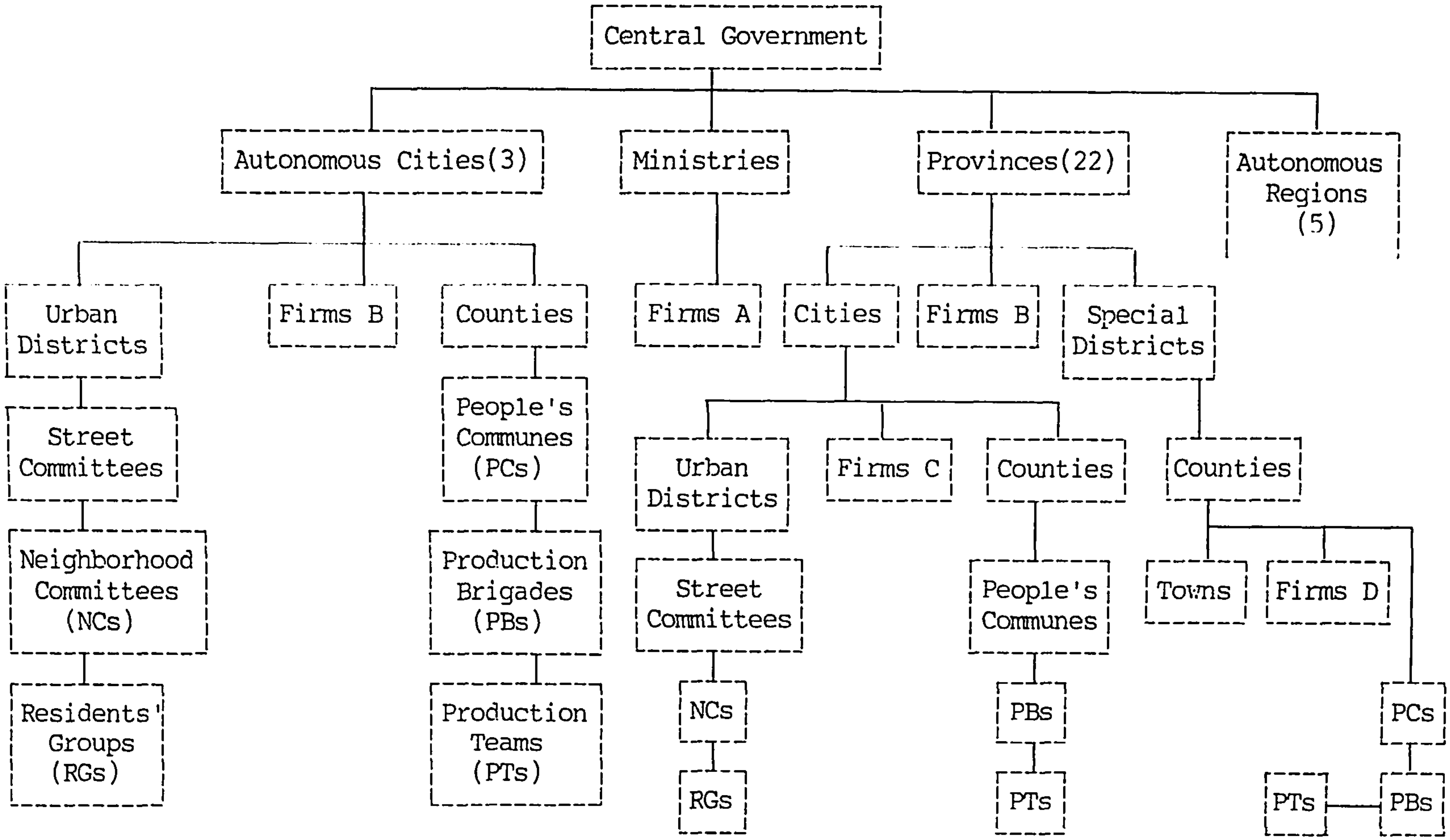
4.3.3. Rigid Planning Authority.

In China, the force behind domestic technology diffusion is usually an administrative decision. Technology and technological knowledge are not treated as commodities but rather as public goods, belonging to society and being acquired costlessly (Simon and Rehn: 1987). Furthermore, for a central planning authority to assign production quotas and to provide proper amounts of inputs as well as appropriate technology for millions of firms, it not only must possess all information about their economic conditions--technology level, productivity of labor, capacity of equipment, etc.--but also must accurately estimate future changes in all of these conditions. It is not surprising that neither China's CPE, nor other planning economies, have met these heroic stipulations (OTA: 1987). Moreover, the planning authority can only determine production processes quantitatively rather than qualitatively; technological content in terms of product quality and diversity has been explicitly excluded from the economic plan. Finally, technological innovation may involve various forms of organizational change and adaptation, which may be either the cause or the result of the innovation process (Simon and Rehn: 1988). This interdependence, very much in harmony with both orthodox and institutionalist thoughts, is likely to be managed poorly in a rigid CPE framework.

4.3.4. Economies of Scale.

Not all of the state-owned firms are under the control of central government ministries. As Figure 4.1 indicates, only the large- and part of the medium-sized firms(Firms A) have been under the guidance of the state. Many sizable firms (most of Firms B) have been under municipal control, or a joint central-local control. A number of small-sized firms (Firms C), as well as some of Firms B, have been controlled by provincial authorities or other local entities. A tremendous amount of small-sized firms (Firms D) have been controlled by counties or urban districts, etc. Although small-sized firms compose more than 90 % in number, their total factor productivity is much lower than large-sized firms (Perkins: 1988). Regardless of their small scale and low productivity, they provide local income and job opportunities; therefore they are protected by local authorities.

Figure 4.1. <u>China's Administrative-Political Structure</u>



Source: Sigurdson, Jon (1977): "Transfer of Technology to the Rural and Collective Sectors in China." In <u>Science and Technology in the People's Republic of China</u>. Ed. Organization for Economic Co-Operation and Development, 173. Paris: OECD.

4.3.5. Education and Manpower.

China's population constitutes 22 % of the world's population. Only 23 % of the nation's population are illiterate, but the number of scientific and technological personnel is far from sufficient--only 0.3 percent of the nation's population (Lin and Wu: 1984). Meanwhile, due to China's international isolation as well as the ideological prejudice that prevailed until the late 1970s, scientific and technical manpower was, in fact,qualitatively deficient (Ishikawa: 1988). In general, the lack of in-house engineering skills may be overcome by the use of external consultants, but as Anupam Khanna (1986) points out, the engineering consultancy service sector in China is still in an embryonic stage. In China, employment in state-owned enterprises tends to be permanent and governed by administrative rather than market rules (Perkins: 1988). The lack of labor mobility implicitly increases the cost of internal technology diffusion.

4.3.6. Barriers to Internal Technology Diffusion.

Technological progress can promote economic and social development, but the development of technology must enjoy the necessary support from the economy and society. In China's CPE, more and more evidence indicates that institutional arrangements are more likely to be an impediment rather than an impetus to technological development. In support of this view, Lin and Wu (1984) point out that previous achievements are (1) scattered and piecemeal and not likely to lead to a new production line or a technological process or project and (2) they are often merely prototypes and samples for exhibition rather than commercial commodities.

In addition to the barrier between producers and users discussed previously, there are a number of other deficient linkages prevailing in China's economy. First, China possesses about 5,000 R & D institutions, which make up the core of the science and technology system. However, they are operated by such diverse agencies as ministries, provinces, municipalities, the Chinese Academy of Science (CAS), and the defense sector. Clearly, there is a potential problem as to how R & D activities can be coordinated. As a matter of fact, each of the individual branches tends to behave in a very insular fashion, with limited mechanisms for horizontal interaction with their counterparts (Simon and Rehn: 1988). Consequently, although

ITC activities such as learning-by-doing did take place, these isolated learning experiences could not transform themselves into a more general social learning (Khanna: 1986). Meanwhile, because of vertical gaps in user-producer linkages, combined with departmental isolation and regional geographic barriers, technology users commonly produce special equipment in-house, and perform repairs and maintenance for their equipment (Ibid.).

Second, a serious vertical gulf between R & D activities and application of newly produced technologies in production has already become a major policy concern. In short, Chinese scientific research has achieved much which could be applied to other fields, but which remain confined to laboratories (Lin and Wu: 1984). For example, China developed the research on semiconductors at about the same time as the Japanese and succeeded in the experimental production of a transistorized computer before the Japanese. However, after several years, they found that they have fallen far behind international standards. Many reasons explain the disarticulation between R & D and application/production. One explanation is that the research institutes were directed by higher government authorities instead of manufacturing firms. Their research funds were also provided irrespective of their performance. As a result, the researchers have little incentive to worry about the practical applications of their work in industry and other fields. Another is that under CPE both industrial ministries and firms tended to maximize current output rather than the quality and novelty of products. Thus, industrial innovation received a relatively low priority (Simon and Rehn: 1988).

Third, China has established a considerable foundation in the field of defense science and technology. Most significant technological achievements and successful applications of R & D are found in this sector. However, China has been unsuccessful, thus far, in reaping the advantages of those achievements in the civilian sector (Lin and Wu: 1984).

The analysis above constitutes a strong case that China must pay a high cost for her acquisition of technology whether imported or indigenously generated. The cost goes beyond monetary terms and must take into account political, psychological, and cultural disutilities in achieving the necessary economic cum institutional transformation. Taking all of these economic and extra-economic factors into account, China's S & T goals may be impractical; and technology that is imported may not necessarily be efficacious in enhancing her ITC. However, the enormous growth of R & D resources since the end of the Second World War has been spectacular and economic growth has been, since 1976, strongly nourished by the fruits of this research. A country's economic success ordinarily comes from its indigenous research, combined with product and process innovations imported from abroad. Japan is the archetype of a country which has relied with great success on imported technology. Newly industrialized countries, such as Brazil, South Korea, and Taiwan, are also examples in which technology transfer plays an important role in developing their own domestic technological capabilities. With this in mind, the focus now shifts to how technology transfer affects China's internal technological capabilities and what strategies China should pursue in acquiring such capacities.

Notes:

1. This is a problem that seems quite common to many developing countries. See Williams Silveira (1985).

2. The Chinese economy can be divided into two types: the planned economy, which is "fundamental and predominant";

and the market-regulated economy, which is "supplementary and secondary" (Perkins: 1988, 614).

3. In 1964, within weeks of the Gulf of Tonkin incident, when China decided that it was about to be invaded by America, Chairman Mao overruled the cautious advice of his prime minister, Zhou Enlai, and gave orders for a so-called "third-front strategy," which attempted to turn remote inland areas of China into industrial fortresses. The scale of this endeavor was immense and so was the waste. Two-thirds of all industrial investment in 1966-70 went to "third-front" areas. So much money was being tied up in these projects so that by the mid-1970s it was usually taking at least ten years to complete any large or medium-sized project, while the inefficiencies of the third-front factories are still haunting the country.

4. What the Chinese call national income is usually referred to by Western economists as net material product (NMP). NMP differs from GNP because it excludes a large part of the services sector.

Chapter 5

SCIENCE AND TECHNOLOGY POLICY AND TECHNOLOGY TRANSFER

China is an enormous country with the largest population in the world. Natural resources, accumulated physical capital, and skilled labor, as well as educated personnel, are relatively scarce with respect to the population. The utilization of advanced technology, along with the upgrading of conventional and traditional technology, is essential to economic growth in China. For whatever reasons, and the Chinese CPE not withstanding, China's S & T development has not shown sufficient dynamism; it is not too much to say that technological advance in the civilian sector has been stagnant. This condition has not been lost on Chinese leaders and explains the attitude of the Chinese toward technology transfer. Technology transfer has been literally regarded as most essential for both economic development and the Four Modernizations.

China actually has twin attitudes toward technology transfer. On the one hand, she is opening up the door for all advanced technology; on the other hand, she has been explicitly or implicitly pushing technological "self-reliance". Whether such a policy mix can be effectively combined is a question that will be treated in the next chapter. In this chapter, the first section traces China's economic development strategies. The following section explores the evolution of S & T policy along with each development phase. The third section focuses on the shift in technology transfer policy in modern China. The emphasis of the fourth section is on current reform of S & T and technology transfer policies. The last section is devoted to discussing policy tendencies toward developing an efficient technology transfer process.

5.1. China's Economic Development Phases

Soon after the government of the People's Republic of China was founded in 1949, it formally expressed the view that the development of science and technology would be a central priority of the new regime (Suttmeier: 1987). Although S & T has been at the center of national policy considerations over the past 40 years, whether national policy has actually fostered S & T is subject to interpretation. It is important to recognize that in many important respects there has not been a single "model" of economic development (Barnett: 1977); nor has there been one coherent, consistent strategy for S & T development. The evolution of Chinese strategy from 1949 to the present has been marked by several major shifts; the same can be said for China's S & T policy stance toward technology transfer. Table 5.1 depicts six major periods associated with important alternatives in the direction of policy.

5.1.1. Reconstruction (1949-1952).

In 1949, the Communists inherited a badly disrupted and underdeveloped economy. Their primary initial objective was simply to restore agricultural and industrial production to their previous levels. Long-term, sustained development was not a major consideration at this time. To achieve earlier levels of output, they began, for the first time in modern Chinese history, to practice strong centralization and "taut" planning to assure the coordination of the economy (Suttmeier: 1987). As a result, by the early 1950s, China had completed the basic construction of her national economy in such respects as establishing nation-wide transportation and communication

Table 5.1. China's Economic Development Phases: 1949 - the present

Period	Features	TT* Policy	S & T Policy	Management	Performance
1949-52 Reconstruction	Rehabilitation of a war-torn economy	The Soviet as a main source	Facilitate TT & industrialization	Centralization and "taut" planning	Economy recovery
1953-57 First Five-Year Plan	Establishment of an industrial base	Massive Soviet aid and dependency	Same as above	Same as above	PTY** at 4.1 %; An unprecedented rate of K*** formulation
1958-60 Great Leap Forward	Mass mobilization & balance of growth	From dependent to self-reliant	Walk-on-two-legs	Decentralization	PTY at -1.4 %; NMP**** declined
1961-65 Readjustment	Readjusting strategy	Self-reliance & diversity of importation	Developing own R & D and local design capacity	Recentralization	The economy recovered
1966-76 Cultural Revolution	Political movement	Radical self-reliance & pragmatism	Worker-innovation	Decentralization on fiscal system	PTY at 0.6 %; Tension between central & local
1977-now Four Modernization	Priority on S & T and TT; "open-door"	Vigorous TT; from import to pragmatic self-reliance	Locally technological innovation	Decentralization and centralization	PTY at 3.7 %; Drastic increase in importation

References: Barnett (1977), Lang (1984), Dean (1972), Suttmeier (1987), and Table 4.1.
* TT--technology transfer; ** PTY--productivity; *** K--fixed capital;
**** NMP--net material product (See Table 4.1)

facilities, bringing inflation under control, and restoring fiscal and monetary stability (Barnett: 1977). More importantly, she attained prior peak levels in many major production fields. At this point, she was ready to formulate and implement a long-term economic plan.

5.1.2. The First Five-Year Plan (the 1st F.Y.P.) (1953-1957).

The fundamental task of the 1st F.Y.P. was to concentrate efforts on industrial construction which comprised 694 scaled construction projects. Among these were 156 key projects which the Soviet Union was designing for China as the preliminary groundwork for socialist industrialization (Lang: 1984), in which the priority was placed on investment in heavy industry (Ishikawa: 1972). Such an emphasis reflected a strategy of selective growth under conditions of austerity, i.e., resources were channeled through a centralized planning authority primarily into capital-intensive heavy industry. These favored large-scale manufacturing activities were expected to stimulate other sectors and led to rapid economic growth. This strategy proved to be partly successful. China built a new and much more diversified industrial base in only a few years(Barnett:1977), and with Soviet assistance, expanded production of heavy industry from 1952 to 1959 at an annual rate of about 18 % (Lang: 1984). Such a massive influx of equipment and technical assistance was to provide China with a necessary technological infrastructure for developing a modern industrial economy. Finally, the contribution of increased productivity to net material product (NMP) during this period explained a large portion (4.1 %) of the NMP growth rate of 6.6 % (See Table 4.1.).

However, Chinese policy makers soon began to realize that the extremely ambitious program for heavy industry was leading to needs in other unsatisfied economic sectors. Also, aside from the problem of sectoral balance, there was the question of how to sustain the rapid rate of growth. Since the early development loans from the Soviets were used up and no further long-term credits were forthcoming, there was serious doubt created about the new regime's ability to continue purchasing sizable quantities of capital goods from abroad to sustain the build-up of large-scale modern industry (Barnett: 1977). Finally, the relative neglect of agricultural development resulted in a reduction of agricultural production. Food and fiber production could not meet domestic requirements, nor could it provide farm exports for repayment of the Soviet loans (Lang: 1984).

5.1.3. Great Leap Forward (1958-1960).

To balance the sectorally-biased economic development and to seek new resources which could compensate for the lack of long-term capital loans, a political compaign was launched to emphasize mass mobilization of the rural labor force. The idea was to increase agricultural production and to enhance the development of small-scale indigenous industries throughout the countryside. This new economic policy called upon the Chinese to "walk on two legs," i.e., simultaneous development of both industry and agriculture, in both foreign and indigenous technologies, of both large- and small-scales of production, and in both centrally and locally controlled enterprises(Lang: 1984, and Dean: 1972). The strategy was implemented by a far-reaching decentralization (Barnett: 1977), which emphasized the role of local authorities in accomplishing economic goals. For the first time, China's S & T policy was characterized by both continuous importation of industrial raw materials, capital equipment, and complete plants from abroad, mainly from the Soviet Union, and the nurturing of "self-reliance"

(Lang: 1984).

Several external forces hampered the movement [1], but essentially, it failed quickly due to exhausted enthusiasm, wide-spread resentment, and passive resistance. For the first time, the country had to face drastic declines in the growth rate of NMP and productivity gains (See Table 4.1.).

5.1.4. Readjustment (1961-1965).

The new economic strategy in this period stressed agricultural development; light industry received second priority, with heavy industry coming last. Quality of output, instead of quantity and the growth rate, was surfacing as an important dimension of the economic scheme (Lang: 1984). Consequently, under the restructuring, industrial management was rationalized; many unsuccessful small-scale firms were closed down; and attention was again given to efficiency, technological innovation, and "experts," as well as professional managers (Barnett: 1977). In foreign trade, importation from non-communist countries replaced dependency on the Soviet Union. Self-reliance was pragmatically carried out in harmony with increased trade with a diverse range of trading partners. In sum, more liberal economic policies were introduced, and the economy was rapidly restored to significantly increased levels of both agricultural and industrial production (Chow: 1985).

5.1.5. Cultural Revolution (1966-1976).

This five-year encouraging period of economic progress was interrupted by a long-term disturbance in which both mass mobilization and self-reliance were radically practiced. During the "Cultural Revolution," political struggle and chaos dominated the country's life. Economic development was not given priority, especially at the beginning of the period. "Worker-innovations" in the framework of mass mobilization was stressed again at the expense of professional knowledge and expertise. Local authorities were given more power over their own financial matters (Suttmeier: 1987). Small-scale production, favored by local authorities, was spreading throughout the country. As a consequence, however, economic efficiency suffered drastically (See Table 4.1.). The technology lag between China and the industrialized countries grew even larger (Barnett: 1977). Policy makers quickly realized the danger of economic failure and began, on an impressive scale, importation of complete plants in the early 1970s (Ibid.). They were also beginning to realize that closing the technological gap requires not only pragmatic measures in foreign trade, restoration of economic order and rebuilding of leadership and institutions, but also a long-term program instead of the trial-and-error-like strategy in the past. This recognition led to the promulgation of another ambitious program in 1974, although it was not carried out until several years later.

5.1.6. Four Modernizations (1977-the present).

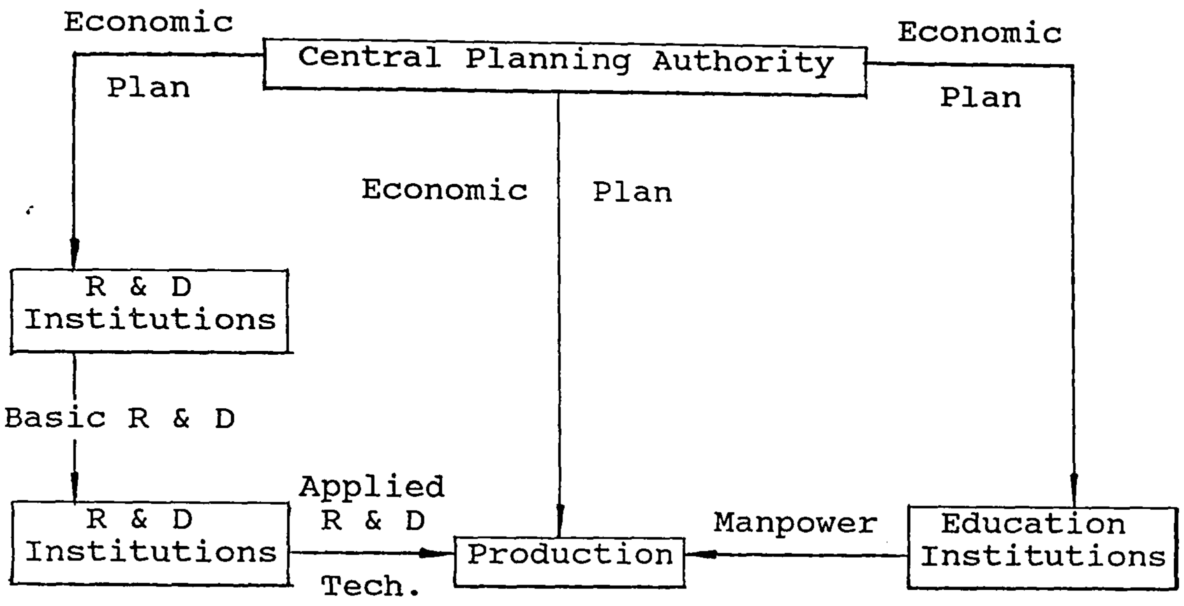
Long-term technological stagnation in the civilian sector led policy makers to regard S & T as one of the priorities of economic development in the late 1970s. During this period, there was a restoration of productivity gains (See Table 4.1.); however, the formulation of policy proved to be difficult (Ye: 1987). Recurrent policy shifts, or even policy splits, characterized this period. For example, there was a "bouncing ball" between centralization and decentralization. As a consequence, much rhetoric was devoted to technological innovation, but to a large extent, it lacked substance (Ibid.). The following sections elaborate on this problem.

5.2. S & T Policy Formulation Prior to Economic Reform

5.2.1. The Soviet-Type S & T Development Strategy.

The Soviet model dominated Chinese S & T policy, especially during Reconstruction, the 1st F.Y.P., and Readjustment. This domination was particularly pronounced in the defense sector. Although one objective of economic reform is to eliminate vestiges of the Soviet pattern, it still remains influential. The main characteristic of this model is the organizational centralization of S & T (Suttmeier: 1987). In Figure 5.1, the sectors of research, education, and production are supposedly coordinated through the planning authority by using economic plans. Production is the center of the system, which implies that technological innovation in the production of enterprises is "supply-driven" by the outcomes of the R & D institutions, and by the technologies made available to enterprises by planners (Ibid.). Significantly, in China, the innovation process is formally split into basic R & D or "scientific research" and activities to transform scientific results into new products and processes (Simon and Rehn: 1987). The China Academy of Science (CAS), for instance, can command the highest quality human resources

Figure 5.1. China's Structure of S & T and Production under the Soviet-Type Planning Model



available in the country and acts as a premier agency for performing basic research. The industrial R & D institutions, which are also centralized under the control of associated production ministries, are each assigned an industry to which it is supposed to supply applied R & D results and technologies.

Research in universities has a decidedly secondary role in this S & T system (Suttmeier: 1987). In fact, much of the higher education infrastructure consists of specialized training institutions, often administered by production ministries, which view these universities as suppliers of manpower for their subordinate enterprises.

Under this system, S & T policy priority was naturally influenced by the overall economic policy in each period. For example, during Reconstruction and the 1st F.Y.P., S & T policy was intended to implement the development of heavy industry by mobilizing human and material resources and to facilitate the use of imported technologies. In the 12-year science development plan, which was first introduced in 1956, most of the scientific projects, including electronics, were located in industrial areas (Suttmeier: 1987) [2]. During these periods, however, most technologies used in production were embodied in capital equipment imported from the Soviet Union (Dean: 1972). Instead of developing and fostering R & D, the function of the S & T policy was essentially to channel imported technologies into new industries in accordance with the central economic plan (Ibid.). Although such a policy could accelerate the growth rate of industrial expansion, it virtually assured a strong dependency on external sources of technology. Since the emphasis was on the quick expansion of industrial capacity, the possibility of absorbing and diffusing the imported technologies in other sectors was reduced. It was not until the 1960s that Chinese policy makers realized the importance of technological improvement to existing capital plant and equipment.

In the early 1960s, the Chinese scientific research apparatus was suddenly asked to become an immediate source of technological innovation, because of the failure of the Great Leap Forward compaign and the sudden withdrawal of Soviet assistance. "Worker-innovation" in the Great Leap Forward was replaced by specialized and formal professional engineering disciplines. All of the R & D institutions in the CAS, in the industrial ministries, and in the universities were being required to accommodate to this policy adjustment, i.e., developing China's own technological capabilities to sustain industrial production. In the period of Readjustment, the S & T policy was intended to encourage all R & D institutions to devote the major part of their activities to applied research and experimental development linked to technological needs in the capital good industries (Dean: 1977). The researchers were then encouraged to take responsibility for developing their laboratory prototypes and research results into practicable technologies. These measures, in effect, opened the factories to the R & D institutions, allowing them access to production facilities for trial-production and experimental development purposes.

By the mid-1960s, such a commitment led to a large percentage of successful "innovations", i.e., technically successful prototypes. Computer technology was one of the areas showing some technological achievements after intensive independent development by indigenous Chinese R & D. This will be explored in detail in the following chapter. However, the main problem seemed to be that, under this Soviet-type S & T model, research and trial-production plans were not always adequately coordinated with the factories' production schedules. One reason was factory managers' desire to meet their output quotas, leading them to resist the diversion of production facilities to "non-productive," experimental uses. Meanwhile, they also preferred to use imported technologies, in which the risks and costs of experimental development had already been incurred, rather than to jeopardize production by using new and untried innovations(Dean: 1977). At the national level, serious separation of R & D and application and production still remained; bureaucratic "red tape" continually worsened; and the demand-side factors [3] were systematically neglected by the "supply-push" S & T system. The result was that the Chinese were plagued for almost 30 years by a system in which the outcomes of R & D, often significant ones, did not find their way into production.

5.2.2. Mass Mobilization Model.

The new regime resorted to the policy of mass mobilization, which failed for whatever reasons. This strategy, however, was significant in several respects. First, it was intended to break with the Soviet model of S & T development by moving forward decentralization. In order to create a closer linkage between R & D and production, research and technical service facilities were established at the local government level. Furthermore, Chinese S & T development has considerable experience in many distinctive learning activities such as mass-oriented innovation; small-scale, labor-absorbing technologies; problem-solving approaches; and learning-by-doing activities. Finally, in stressing self-reliance, it was made clear that the Chinese people's wisdom and capabilities were to be the main underpinnings of S & T development (Suttmeier: 1987).

Although these considerations reflected good intentions, ironically the movement *per se* held expertise in low esteem, which in turn led to attacks on experts. The very technical knowledge which China required was seriously devalued. Although "worker or peasant innovations" did provide some innovations which served the Chinese needs for a time, they were usually crude and of no enduring value to the general upgrading of industrial technological capacity (Suttmeier: 1987). Significantly, after each radical practice of "self-reliance," the lag between the domestic technological level and that of the industrialized countries had been widening, not closing. There followed immediately, as discussed above, an influx of foreign technology.

5.2.3. National Security Model.

In the late 1950s, one of the priorities of S & T policy under the Chinese CPE was that a very large share of resources, both material and manpower, were to be devoted to R & D for national defense purposes. Accordingly, a large portion of the work of the institutions of the CAS and some of various universities were commited to military related R & D (Suttmeier: 1987). The successful explosion of a nuclear device in 1964 was the first positive evidence of important scientific and technological achievements made within the defense sector. There followed a satellite launching in the 1970s. In addition, China's computer technology was developed rapidly under this new approach.

The defense sector was the major user of computers prior to the 1980s. It was, and still is quite common for all R & D, production, and application to be closely controlled within a single defense-oriented enterprise. In short, sometimes the computer technology developers may also be the users. Chapter 6 will provide a more detailed discussion concerning computer technology in the defense sector. It is notable, however, that R & D development under the defense sector has incurred enormous costs. Whether technology developed under this model can be applicable to the needs of civilian sector remains to be seen.

5.3. The Evolution of Technology Transfer Policy

Dependency or "self-reliance," in terms of liberal importation vs. import restrictions, is an issue capturing much attention in China, both in terms of general trade strategy and policies affecting technology transfer. Regardless of the political and ideological debates over the issue, actual Chinese technology transfer policy has experienced a shift from importing complete plant and equipment ("turn-key plants") to importing more pure technology and technological knowledge.

From the early 1950s to the late 1970s (excluding the surge in imports which began in 1978), the Chinese expended approximately $12.9 billion on technology importation, a relatively small amount in relation to the size of the country's economy. But a very high percentage, 93 %, of this expenditure went for whole plant and equipment. As shown in Table 5.2, in addition to the influx of plant and equipment in the early 1950s, some types of know-how in terms of blueprints, advisory services, and training accompanied the Soviet aid. This may have held some possibility for fostering the China's future ability to enhance her own ITC. However, China's subsequent approaches to technology acquisition in the 1960s and 1970s were more "arm length," focusing on importation of complete plants and sets of equipment without due attention given to the software, training, and advisory services(Suttmeier: 1987).

By 1979, the Chinese came to the conclusion that the "arms length" mode of transfer both was too costly and did not yield the know-how they had expected. A big shift in technology transfer policy was implemented in the early 1980s. The new policy discourages the acquisition of complete plant and equipment and has stressed the acquisition of know-how. In addition, the emphasis has been

Table 5.2. The Contents of Technology Transfer (1950-1985)

Period	No.of Major Projects & Contracts	Million ($)	Major Areas	Major Types
50-60	156 projects& 400 items of technology	2,660	metallurgy, machine building, trucks, coal mining, electric power, petroleum	whole plant & equip., blueprints, advisory,& training
60-66	84 contracts	280	metallury, chemicals & chemical fibers, synthetic texitiles	complete plant*
70-78	300 contracts**	9,900	steel, petro-chemicals, & chemicals	complete plant
79-85	n.a.	9,700	n.a.	products, components, technology, & know-how

Reference: Suttmeier (1987: 176-179).

* See Dean: 1972, 70.
** Many of the contracts were concluded in great haste in late 1978 and subsequently were cancelled or postponed (Suttmeier: 1987).

on technologies to be used in upgrading or renovating existing enterprises instead of supporting the establishment of new ones (Suttmeier: 1987). However, the new procedures have not developed evenly since the new policy was launched, as the following discussion will indicate.

5.4. The Current Reforms and Problems

5.4.1. Initiatives and Their Implications.

In the late 1970s, China started to reform her economic system. One proximate cause for the reform was the concern that the development of China's science and technology was not serving the country's production; and as a result, the economy was not realizing sufficient gains in productivity (Suttmeier: 1987). As the post-Mao leadership finally began to coalesce by the end of the decade, there was an explosion of interest in Western science and technology, and China initiated a new "open door" policy to try to benefit from foreign S & T.

In the early 1980s, a coherent set of objectives for technology was beginning to take shape. First, Chinese industry was to reach at least the present Western level of technology by the year 2000. Second, modern technologies were to be diffused to China's rural areas. Third, priority was to be given to technologies supporting the development of natural resource industries. Finally, the Chinese have identified a number of technologies that they believe will be the basis for new high-technology industries--electronics and computers (including advanced software applications such as CAD/CAM), biotechnology, new materials, robotics, lasers, and space and ocean technologies (OTA: 1987). The Chinese expect that these technologies will lead to major industrial advances and have targeted them for special attention in the hope of eventually becoming competitive in world markets.

The achievement of these goals, as the policy makers know, will require the modernization of the domestic R & D system. They also realize that this cannot be achieved without the transfer of foreign technology to China (OTA: 1987), since the economy as a whole has not enjoyed significant breakthroughs from her own R & D system, except for several achievements made in the defense sector. China's past industrial growth appeared to have depended on a sporadic, but fairly large-scale, infusion of foreign technology and capital goods (Barnett: 1977). Thus, the formulation of an appropriate strategy for fostering her own ITC is still a central challenge for the current reforms.

5.4.2. New Focus in Technology Transfer Policy.

Since late 1985, the principal focus of China's technology transfer has broadened significantly to include industrial property rights, proprietary technology, technical services, documentation, know-how, and management and marketing expertise, instead of merely importing plant and equipment (Chwang and Thurstont: 1987). China hopes that she will be able to import advanced technology and adopt what is best in foreign countries; to develop foreign trade by being able to support imports by selling competitive export goods; to utilize foreign investment; and to expand foreign economic cooperation and technological exchange (Ren: 1981). Instead of purchasing complete equipment from abroad, China intends to import advanced technology and techniques for making basic components and basic materials, and for boosting the country's technological level and productivity. Infrastructure and natural resource industries are especially targeted (Ibid.). However, China's expectations may be overly ambitious since the acquisition of so much technology may prove to be beyond her capacity to assimilate quickly and comprehensively (Chwang and Thurstont: 1987). The problem of "absorption capacity" is well recognized and documented among development economists.

Part of the problem, at least in the short-run,is that there has been a change in the locus of decision making on technology transfer in China. It is no longer the central ministries and a single foreign trade corporation which are the principal actors. Instead, many other players have become active, including enterprises, local governments and other authorities not tied to centralized contacts (Suttmeier: 1987). But many local firms and provincial or municipal import-export corporations, as evidence shows, were inexperienced and ill-equipped to make decisions regarding technology imports. This shortcoming led to the purchase of overly expensive, and perhaps even worse, inappropriate technology (Ibid.). By early 1985, imported equipment lays idle throughout the country simply because the importing firms did not know how to operate and repair it (Davenport: 1987). A return to centralization, which followed in the same year, was implemented to regulate project approval in the form of foreign exchange allotment controlled by upper-level or central authorities. But the process proved to be too time consuming and too bureaucratically inefficient (Ibid.)[4]. Without appropriate reform of this institutional environment, the effective absorption of foreign technology is almost sure to suffer.

5.4.3. Current Trends in S & T policy.

There are two major current trends in Chinese S & T policy: (1) organizational rationalization and (2) commercialization. In attempting to rationalize the administrative apparatus, the issue of the proper balance between centralization and decentralization is perhaps the most important. First, the management of R & D in China has suffered from a rigid state administration, dominating all activities of the S & T system. For example, research topics and funding were "handed down" from the authorities, who also were to be primarily responsible for popularizing and diffusing the R & D outcomes (Baark: 1987b). After reform, there has been a blend of decentralization and centralization. On the one hand, individual research units are being given more autonomy with respect to funding, personnel, and the choice of research topics. On the other hand, strengthened central coordination resulted in the establishment of the Science and Technology Leading Group in 1982, headed by Premier Zhao Ziyang (Suttmeier: 1987). In essence, key national projects will remain under the control of the central planning authority.

Secondly, in the past most research institutions were not attached to enterprises. They are so called "independent research institutes," and their autonomy has been impeding cooperation between research, design, training, and production. Currently, an emphasis has been on creating various forms of partnership between research units and enterprises, and on integrating defense R & D and civilian industry (Baark: 1987b).

Finally, heretofore it was difficult to facilitate the development and motivation of the most talented people involved in R & D and to provide appropriate rewards for their efforts. The current policy is aimed at increasing the mobility of researchers by breaking the pattern of "unit's ownership," or life employment, by enterprises (Baark: 1987b). If successful, this should promote ITC through a more robust circulation of technical people, as well as produce more incentives for technical personnel who are enticed to new enterprises by more attractive rewards. However, the reform of the personnel system is among the most politically sensitive objectives and change is likely to come slowly (Suttmeier: 1987).

Another trend in the S & T policy effort is "commercialization of technology," which is intended to create the links between R & D and production. For example, by 1985, one third of all China's research institutes had experience with contractual R & D. In 1986, 10 % of central-level research institutes became economically independent by selling technology and services. This was due to an attempt in 1985 to cut fixed state subsidies for most research institutes engaged in industrial R & D by 10 % of their operating expenses. A final goal seeks to abolish all fixed funds for these institutes by 1990 (Baark: 1987a).

Furthermore, the introduction of a "technology market," as it is called by the Chinese, has seemingly been an important stimulus to internal technology transfer. As evidence, the involvement of the defense sector in the civilian economy is geared to making defense R & D and production more efficient by subjecting it to more market competition (Suttmeier: 1987). Finally, current policy is marked by a change in the attitude and philosophy regarding technology, which represents a break with the traditional perspective that technology is a free public good.

There is, however, a serious question about the prospects for these reforms. The complex reform programs have been plagued by difficulties at every step and have been very slow to take effect(Ye: 1987). They may also encounter many unexpected problems, some of which are inherent in the nature of the system of government. For example, many departments and regions are still pursuing the old strategy that focuses on increasing quantity of output through building new production capacity (Chwang and Thurstont: 1987). This problem, and many others which will be considered in the next chapter, could largely dilute any effectiveness of China's new policy.

5.5. Evolutionary Tendencies of China's Policy

The current status of China's science and technology, after nearly forty years, is still at the stage of learning and mastering advanced achievements already accomplished elsewhere in the world (Lin and Wu: 1984). Accordingly, a proper technology transfer policy will take this into consideration. However,throughout the new regime's history, there has not been a reasonably stable policy in developing S & T and importing technology. Some policy changes have been the results of a natural process of trial and error. Others, however, have been the consequence of serious differences among Chinese leaders, rooted in ideological and political outlooks (Barnett: 1977). To facilitate the discussion, some policy tendencies or trends, which may still exert influence on contemporary and future progress, are identified.

First, several ambitious programs were launched in 1956, 1974, and in the early 1980s with the intent of catching up with, and surpassing, the world's level of S & T within a relatively short period. Such a goal, as the failed program in the 1950s suggests, drastically underestimated the gap between China's S & T level and that of the industrialized countries, especially in the field of high technology. Moreover, their estimations failed to take into account both the pace of the other countries' development and the resistance of the domestic social and economic institutions. In assessing an appropriate program, not only an accurate estimation of the gap and the tendency of the outside is required, but also consideratios of China's current economic and other institutional factors are necessary for success (Lin and Wu:1984).

Specifically, China must take into account a number of elements which, if ignored, could seriously limit her ability to absorb imported technology and to apply it efficiently, such as (1) efficiency of allocating and using natural and manpower resources, as well as certain technologies; (2) infrastructure for absorbing and disseminating technology; (3) ability of translating experimental, laboratory or small-scale production successes into broader gains; (4) lack of management skills, training, discipline, and problem-solving expertise; (5) scarcity of qualified scientific, engineering, and technical personnel; (6) shortage of foreign currency and ability to generate foreign exchange through exports: and (7) lack of uniform dissemination and/or enforcement of laws, rules, and regulations (Chwang and Thurstont: 1987).

Secondly, technological progress in China has essentially revolved around the expansion of production capacity. For example, prior to the 1980s policy emphasized importing less sophisticated foreign technology in the form of turn-key plants in order to expand production capacity quickly (Ishikawa: 1988). This policy tendency could be a major reason why China's technology level is now so far behind that of other countries (Yang: 1987). If this development path is followed in the future, the technology gap between China and the outside cannot be closed.

Thirdly, the majority of S & T policy reforms still tend to be geared toward supplying technology. However, in many cases,the most serious problems appear to be connected with stimulating the demand for technology (Baark: 1987b).

Finally, one cannot fail to note China's policy swings between centralization and decentralization; dependency and "self-reliance;" indigenous technologies and the most advanced foreign technologies; and importation of complete turn-key plant and buying know-how from abroad. Evolutionary change is to be expected, and indeed is desirable, as policy measures are adjusted due to learning from experience and in response to structural changes in the economic environment, but "pillar to post" shifts cannot be a productive approach. Taking these four tendencies into account, the following chapter attempts to make economic evaluations and technical assessments of specific policies regarding computer technology and the computer policy of China.

Notes:
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1. There were several external factors responsible for the end of this period, including (1) a succession of national disasters led to bad harvests in 1959 and 1960, resulting in food shortages and mulnutrition; and (2) the sudden withdrawl of Soviet assistance in the summer of 1960 aggravated China's economic crisis (Lang: 1984).

2. In addition to electronics, these priority areas also include atomic energy, jet propulsion, automation and remote control, petroleum and scarce mineral exploration, metallurgy, fuel technology, power equipment and heavy

machinery. Only a few, however, are related to agriculture, such as chemical fertilizers and agricultural mechanization.

3. These demand factors are risks and incentives, prices, supplies needed, and trained manpower, etc. All of them constitute the environment of innovation.

4. In the case of Nanjing, as Alice Davenport (1987) reported, local authority must wait until central and upper (provincial) authorities have determined its foreign exchange allotment before assigning funds to local projects. Sometimes, the length is incredibly long because of the proposal-approving procedure. As a consequence, it is normally beyond mid-summer, or even until the end of year before cities' authorities have a clear idea of their calendar year allotments.

Chapter 6

EVALUATION OF THE CHINESE COMPUTER POLICY: THE ROLE OF TECHNOLOGY TRANSFER

Several reasons led to the selection of China's computer sector as a case for evaluating S & T and technology transfer policies and their relation to the acquisition of ITC. First, although the electronics industry in China has come a long way since the 1950s (Khanna: 1986), China still falls far behind international standards in this area. This fact implies a great deal about Chinese policies in developing technology. Second, in traditional industrial sectors such as steel, the benefits of technology transfer can be enhanced by the slow pace of technological innovation. For these sectors, China has finally established an infrastructure for capital goods production and has even been able to export some manufactured products. However, computer technology is being developed at a very fast pace. Taking this fact into account, an effective computer policy requires an appropriate estimation of the role of technology transfer.

Finally, the Chinese computer sector, among others, is one that has suffered least from technology stagnation.

The first section is devoted to the historical development of Chinese computer technology, computer policy, and associated problems. The second section discusses current policy issues in computer technology development. A systematic evaluation of computer policy in terms of technology transfer and ITC is a main task of the third section. In addition, China's strategies and policy results are compared with those of selected LDCs in order to enrich the discussion. The last section summarizes the chapter and sets the stage for conclusions and policy recommendations in the final chapter.

6.1. Development of the Computer Industry

6.1.1. Historical Development

Development of an indigenous Chinese electronics industry, including the computer sector, started in the mid-1950s. As Table 6.1 shows, through concentrating critical resources on a few projects and through relying heavily on Soviet technology, the first computer was assembled in 1958, only one year after Japan (Simon and Rehn:

Table 6.1. Development of China's Computer Technology and COmparison with USSR and USA

Period	Achievement	Model (year)	Tech.	Policy	Parameter (ops)	USSR (year)	USA (year)
1958-63	First G* First digital computer First application on project	August 1 (58) DJS-1 DJS-2 (58-63)	Vacuum tube	The Soviet assistance	2 K 1.8 K 10 K	URAL-1 (51) 12 K	IBM-701 (47-51) 20 K
1964-67	Second G	DJS-6 (65) 109 C	Transistors	Self-made but the Soviet model	100 K 105 K	M-20 (59-60) 50 K BESEM-6 1 M	120 K 850 K
1970-82	Third G First IC computer DJS-100 (mini)	111 DJS-11 (mini) 013 HD-59	IC**	Self-made but Western model	100 K 1 M 2 M 5 M	NAIRI-3 (68-73) 1.5 M RIAD-1060 1.5 M BESEM (80) 10.6 M	CDC-7600 (69-74) ILLIAC-IV 100 M
1983-	Fourth G	757 Galaxy	IC	Self-made but Western model and imported components	10 M 100 M		GRAY-1 200 M CYBER-205 200 M

References: Witzell and Smith (1989), and Lin (1987).
* G--generation; ** IC--integrated circuit.

1988). However, research on computers was not begun until the late 1950s, driven by strategic considerations for developing China's defense sector(IPM, IE, and RPIUL:1986).

During the late 1950s and the early 1960s, the country's annual average investment in the electronics industry increased significantly, by 47 % compared to that in the 1953-1957 period (See Table 6.2). As a result, in 1965, the second generation computer, the first that was transistor-based, was developed with semi-conductor technology introduced previously from the Soviet Union. In the 1960s, China was able to import computers from some Western countries and to imitate some of their technology when these countries relaxed their export control restrictions on strategic materials to China (Lin: 1987).

Table 6.2. State Investment in the Electronics Industry

Period	Yearly Average Investment (in billion Yuan)	%*
1953-1957	0.1110	--
1958-1965	0.1632	47
1966-1976	0.2468	51
1981-1985	0.4600	86

Source: Adapted from IPM, IE, and RPIUL (1986: 12).
* Based on the previous period.

In the early 1970s, the Chinese came out with the DJS-11, a third generation IC computer capable of 1 M ops (operations per second) while the Soviet model NAIRI 3 was of 1.5 M ops. By 1977, the model 013 was developed and capable of 2 M ops, as compared to the 1976 RIAD-1060 of the Soviet, which was only capable of 1.5 M ops(Witzell and Smith: 1989). On the surface, the gap had closed and the Chinese had gone ahead of the Soviets after several years of imitation of both the Soviet Union and the West [1].

During the 1980s, production of computers has been roaring at an incredible pace. In 1980, China produced 100 minicomputers, 250 microcomputers and 1,390 single-board microcomputers. As Table 6.3 shows, computer output increased even faster after 1982 when vigorous efforts were taken to develop microcomputers. It was then estimated that China would be able to produce 10,000 microcomputers in 1984 alone, and that the number could reach 30,000 in 1985 (Lin: 1987). It should be remembered that the first microcomputer arrived on the United States market only ten years before this time (Stepanek: 1984). In November 1983, the University of Defense Science and Technology developed the first supercomputer, Galaxy, which ushered in the fourth generation of China's computer technology and was capable of 100 M ops.

Table 6.3. An Estimate of China's Output of Computers

Year	Large-, Medium-, and Small-Scale Computers	Micro-Computers	Single-Board Micro-Computers
1956-79	2,310	400	50
1980	100	250	1,390
1981	137	380	1,500
1982	241	1,487	5,701
1983	360	5,436	10,499
1984	381	10,000	15,911
1985	700	30,000	n.a.

Source: Lin (1987: 66).

Setting aside the existing technology gap which will be discussed in the following sections, China's computer technology followed the international technological frontier more closely than did most other industries. Even during the Cultural Revolution, China's computer sector was little affected by the political turmoil (Lin: 1987). One of the main reasons is that the development of computer technology is defense-driven, which associated the sector with a top national priority and sheltered it from unfavorable treatment.

6.1.2. Policy History and Problems in Development.

As mentioned in the previous chapter, few Chinese firms could spend more than 1 % of their output value on R & D. At a national level, the resources going to R & D for electronics is currently about 3 % of the production value of the sector against an estimated 10 % of the sales value in Japan, the United States, and Western Europe (IPM, IE, and RPIUL: 1986). Because China cannot afford enough investment in production facilities and research, and since technology can ordinarily be obtained cheaper abroad than producing it domestically, technology transfer is necessary for the country to develop computer technology and to close the gap.

Prior to the 1980s, the policy for developing computer technology was characterized by the principle of "first concentration and then distribution" (first-and-then). This meant that only a limited number of research institutions and enterprises were selected by the planning authority to import advanced technology and equipment from abroad. They then copied them in order to create their own technological capabilities for self-reliance (IPM, IE, and RPIUL: 1986). Resources required to accomplish this task were directed only into these units. Furthermore, having done the absorption, assimilation, and adaptation, these units were expected to disseminate the prototype products to appropriate using enterprises.

Before the 1980s, however, most computers were used for military purposes and for scientific calculation (Lin: 1987). Since the defense sector received priority in S & T development, the development of computer technology has naturally been affected by this bias. First, the emphasis was on stand-alone machines for scientific calculations and the processing of large quantities of numbers so that operational speed and memory size were regarded as the most important technology parameters. Consequently, development of software and peripherals, which is more popular in the West, has lagged very far behind (Simon and Rehn: 1988). Most observers believe that China's comprehensive technological level, i.e., technical indicators, quality, reliability, peripherals, software, etc., lags behind Western countries by ten to fifteen years, or even more (Khanna: 1986; Lin: 1987; and Stepanek: 1984).

Second, because the development of the computer sector has been protected and nurtured by the defense sector, considerations of cost and efficiency were frequently subordinated to meeting defense requirements and standards. Since a significant proportion of defense production was highly specialized, automated, and small-scale in terms of quantities of output (Simon and Rehn: 1988), remaining faithful to strategic considerations has been at the expense of civilian goals and has resulted in a slower pace of computer development and application in the civilian sector (Witzell and Smith: 1989). As a result, there has been a widespread lack of civilian research and production facilities.

Third, the electronics industry, including the computer sector, is not only a part of the national defense S & T (Lin: 1987), but also a part of a highly compartmentalized, bureaucratic apparatus, which has few incentives or mechanisms for cross-fertilization and interaction (Simon and Rehn: 1988). Therefore, defense-oriented computer technology has been developed with a lack of horizontal technology transfer from the defense sector to the civilian sector.

In spite of technological achievements, made mainly within the defense sector, development of computer technology, as well as its application within the civilian sector, has been impeded by China's poor overall industrial performance: namely, the lack of serial production, the lack of services and infrastructure (which involve broad areas such as application programming, operator training, and routine maintenance) and small scales of production.

Having become dissatisfied with the performance of domestic computers and, being bolstered by the popularization of computers through a policy encouraging the modernization of science and technology [2], for a while imports of microcomputers were rising very rapidly. In this 1984-1985 "computer fever," as shown in Table 6.4, inventory went up drastically. For example, China's inventory of only 8-bit and 16-bit computers could have reached 57,000 by the end of 1985, equivalent to about 2 % of the total number of installed microcomputers worldwide. However, one serious problem was that a significant percentage of their microcomputers was not properly used or was even idle (Stepanek: 1984). It was estimated that only about one-third of the computers were being used properly while the rest were subject to a severe shortage of good software and peripherals, and to erratic performance of power supplies (Witzell and Smith: 1989).

This is a powerful indication that China has not increased her ITC along with importation. More accurately,

Table 6.4. China's Current Computer Inventory

Year	Large, Medium, and Small	Micros
1980	2,600	n.a.
1981	3,945	10,000
1982	4,000	10,000
1986	7,000	130,000

Source: Adapted from Witzell and Smith (1989: 28).

the problem may be that progress has been too rapid for China to follow in terms of absorbing, assimilating, adapting, and diffusing the imported technology. This constitutes a formidable challenge. If China cannot benefit from technology by following the "first-and-then" principle, each passing year China, as James Stepanek (1984) observed, might find herself further and further behind.

6.2. The Current Policy

Having realized that S & T is one of the most important of the Four Modernizations (Fang: 1978) along with the importance of a number of new high-technologies, including computer technology, which are expected to lead to a major industrial advance (OTA: 1987), China launched an eight-year plan (1978-1985) for the development of S & T in early 1978. As Fang Yi (1978) emphasized, China urgently needed to make a great new advance in computer science and technology. Thus, a broad-based top priority was given to the entire Chinese computer sector. For example, a series of objectives were listed in the plan, including producing large-scale ICs, developing the technology for ultra-large-scale ICs, turning out giant ultra-high-speed computers, achieving serial production for a range of computers, developing peripherals and software, making strides in applied mathematics, and popularizing the application of computers (Witzell and Smith: 1989).

Still, there is no concensus as to what the real problems are. As D. O'Connor (1984) pointed out, there are basically two sets of questions that the Chinese government must seek to address. The first set has to do with the "preferred avenues" of international technology transfer; the second with the absorption capacity of the Chinese industry and the adaptability of foreign technology to local conditions. Clearly, the first question addresses the apparently unresolved question of the balance between domestic production and foreign imports (Witzell and Smith: 1989). The second one, which is closer to the topic of this thesis, is about how to accomplish absorption, assimilation, adaptation, and diffusion of computer technology, whether domestically developed or imported.

Addressing the first issue, two major controversial extremes can be identified. One group advocates that China adopt the world's most popular models and copy them in domestic plants. The second approach adamantly insists that China must carry out her own independent development since it would allow China much more freedom in the choice of technology and in the choice of components and products (Witzell and Smith: 1989). For example, Li Peng (1986), a Vice Premier in 1986, stated that the most important task for the computer sector was to utilize domestic components and products. As a matter of fact, a policy shift has indeed occurred in terms of restricting importation of computers which can be produced domestically. Importation must be approved according to critical needs and the lack of availability of domestic products (Brown: 1983). Definition of critical needs becomes involved with strategic defense considerations and optimizing the use of resources for importing the most advanced components and systems (Witzell and Smith: 1989). For example, as Chinese 8-bit micro-system production expands, approvals will be increasingly limited to those types of 8-bit systems with essential features not found in China (Brown: 1983).

There has also been a traditional policy split on the second issue, the balance between the stage of absorption, assimilation, and adaptation, and that of diffusion. At the first stage, the transferred technology is intended to be "digested, developed, and created" (IPM, IE, and RPIUL: 1986). Current emphasis is placed on modernizing existing facilities through selected modifications and imported equipment rather than constructing numerous new projects (Simon and Rehn: 1987). Following the first stage, those adapted outcomes could, it is hoped, be disseminated throughout the sector. For example, this includes the hope that China's priority defense sector can spill over and stimulate civilian production (Witzell and Smith: 1989).

Apparently, with regard to the "trickle-down" approach and the "first-and-then" principle, the chanllenging issue is whether China can effectively and efficiently assimilate imported technology and, after appropriate adaptation, disseminate the outcomes throughout the entire computer sector. In addition, as the global technological frontier advances, China faces a "moving-target" problem that might render her new program questionable in terms of acquisition of ITC through technology transfer. The next section is devoted to these issues.

6.3. Evaluation and Comparison

Since China cannot import all of the most advanced technologies, an appropriate policy regarding selectivity is critical in determining whether imported technology can be assimilated and diffused effectively and efficiently.

6.3.1. Institutional Environment.

1. Decision Making.

Since the Ministry of Electronic Industry (MEI) was founded in 1963, approximately 21 provinces and cities have established electronics industries (IPM, IE, and RPIUL: 1986). Currently, the electronics industry, including the computer sector, possesses more than 3,000 enterprises with a total employment of 1.4 million people (Khanna: 1986). However, since there have been overlapping jurisdictions and a lack of clearcut lines of decision-making, it is often difficult to know who has authority or responsibility for making the various decisions. Table 6.5 gives an example of multiple ministerial-level organizations which have the same interest in the research, production, and application of electronics technology, components or equipment (Simon and Rehn: 1987).

In addition to this vertically-oriented administrative structure, a number of key enterprises, including those that are mainly defense-oriented, are jointly administered

Table 6.5. Key Ministries in China's Electronics Industry

Name	Primary Interest		
	R & D	Production	Application
Min of Electronics Industry	*	*	*
Min of Space Industry	*	*	*
Min of Machine-Building	*	*	*
Min of Posts & Telecom	*	*	*
Min of Railways			*
Min of Public Security			*
People's Bank			*
Min of Metallurgy	*		*
Min of Transport			*
Min of Water Resources	*		*
Min of Ordnance	*		*
Min of Light Industry			*

Source: Simon and Rehn (1987: 262).

by central and local authorities, following the principle of "dual leadership" (Simon and Rehn: 1987). Furthermore, most major provinces and cities have their own electronics and computer corporations (Stepanek: 1984). Consequently, at times, these organizations have engaged in intense rivalry and competition. Each respective ministry and locality wants its own infrastructure for meeting or exceeding output quotas. Moreover, with each ministerial, local, or joint authority regarding its own research and production as the most essential, often within the entire sector quality and novelty are sacrificed. Finally, such departmental barriers can impede inter-agency cooperation and coordination and tend to isolate scientific activity from manufacturing activity (Simon and Rehn: 1987).

To overcome these barriers, in 1984 China established The Leading Group for the Invigoration of the Electronics Industry under the State Council. It is designed to ameliorate the problems of coordination within the sector by involving a number of high-level agents from the leading government commissions, such as the State Planning Commission (SPC) and the State Scientific and Technological Commission (SSTC), and key ministries, such as MEI. On the other hand, a circular was published by the State Council in early 1986 that stressed the separation of government administration and enterprise-level management. The intent was to create extensive horizontal relations by giving the firms more autonomy in decision-making. For example, almost all of the enterprises under MEI (161 of 172) will no longer be controlled by the ministry. However, the effectiveness of the reform remains to be seen since most of these firms [3] are located in the interior, known as "the third-front" areas and many of them are engaged in defense production (IPM, IE, and RPIUL: 1986).

2. Funding Problems.

Generally speaking, the authority for overseeing innovation of plans and projects, including transferring technology, is split between the Science and Technology Commission (STC) and the Economic Commission (EC). The former is responsible for R & D; the latter for production. Once an item reaches the production stage, it is the State Economic Commission (SEC) or local ECs that takes the lead. There are, however, two serious shortcomings inherent in this organizational structure.

First, although the SSTC or local STCs might be best in selecting, initiating, and financing "supply-push" R & D outcomes, the lack of a more holistic approach combining research and production often leads to the appearance of many prototypes that never make it to the stage of mass production. The R & D activity, which may start at the initial research stage, is likely to end at the second production stage due to the reluctance of these authorities to fund large scale output. After making prototypes available to manufacturing firms, research institutions can also find there is no further R & D funding available.

Second, at the production stage, it is the SEC or local ECs who provide funds for the purposes of "technical transformation" and plant innovation which are supposed to modernize existing factories and research facilities by taking advantage of R & D and technological innovation (Simon and Rehn: 1987). Importation of computer technology is also controlled by the SEC and local ECs (Witzell and Smith: 1989). However, the primary goal of the SEC and local ECs is to attain full use of existing production capacity, and afterward to sustain production expansion. As a result, they see importation of technology as a "quick fix" for transforming production capacity, rather than an avenue for attaining mastery over the transferred technology and thereby enhancing internal capability.

3. Manpower.

It is estimated that only 50,000 out of 1.4 million employed in China's electronics industry are advanced scientific and technical personnel (Khanna: 1986). It is also predicted that in 1980-1990 the computer sector could absorb productively 400,000 more personnel (not including software engineering manpower). However, without drastic changes, only 20,000 can be trained during this period! Despite this enormous deficit, the manpower problem is further complicated by the fact that many of the technical and scientific persons working in the computer area are much older persons who obtained their training abroad and returned to China in the 1950s (Witzell and Smith: 1989). The problem associated with the anemic circulation of technical personnel among R & D and production enterprises, and the attendant loss of diffusion of technical knowledge, has already been mentioned.

Aside from basic educational capacity, another factor limiting China's training of applied engineers has its roots in her past economic system when enterprises were not responsible for sales of their products. They had little incentive which subjected their product to appied engineering in order to promote sales. As was mentioned earlier, in theory, the lack of in-house engineering skills can be overcome by the use of external consultants; however, in China these services are in an embryonic stage of development (Khanna: 1986). Although the current reforms encouraging commercialization could stimulate enterprises to participate in competition, given the residue from a rigid system of developing and allocating manpower, it is doubtful that an adequate provision and utilization of engineering skills will be attained without an explicit effort by the authorities.

6.3.2. Enterprise level.

1. R & D Activity.

Significant expenditure on R & D is usually required to enhance an enterprise's ITC or achieve "technical transformation." After the current reforms, Chinese enterprises have access to more funds for their own R & D activity. For example, Simon and Rehn (1987), in a case study of a leading semiconductor firm in Shanghai, the largest city in China, found that about 8-10 % of the enterprise's sales was reinvested in research for new products, technical transformation, and development for new production equipment. Although it is not a typical case[4], it does represent a current trend in Chinese firms' spending on R & D and other forms of technological upgrading.

Technical progress will not, however, necessarily lead to a prosperous firm due to a myriad of other influences within the traditional economic system. By virtue of traditional production-oriented goals, and the lack of a mature S & T infrastructure such as technical consultancy services, a firm can rarely justify concentrating its limited resources on R & D. Instead, it probably engages in developing, improving, and producing a large part of its own production equipment (Khanna: 1986). In dealing with transferred technology, it may focus on setting up a repair shop or other type of in-house maintenance services so that imported equipment can be operated. As a result, the firm's R & D activity is likely to be limited to learning-by-doing or other similar routine activities without any significant ITC acquisition. Furthermore, in many cases, results from R & D processes, including those of firms and research institutions, are subject to a certification meeting comprised of various experts drawn from various agencies who state their views about the performance of the new item(s) (Simon and Rehn: 1987). Frequently, the new product or process never gets translated into production, primarily because the potential end-user, who is often within the same unit [5], was never intimately involved in the design process. Finally, the weak links between enterprises, particularly if under the jurisdiction of different bureaus, ministries, provinces, or cities, prevent close inter-enterprise interaction and communication regarding R & D activities (Khanna: 1986). In sum, any national benefit from firm-level R & D can be overwhelmed by high-unit costs due to small-scales of production, enterprise-level duplication of R & D effort, and weak horizontal diffusion to other enterprises.

2. Firms-Level Engineering.

In the Chinese electronics industry, only 600 of the 3,000 firms have fairly advanced production capabilities. Technical transformation of the existing firms through importation of technology is necessarily important. However, the largest weakness in the technology delivery system, which could be defined as the firm's "digestive" ability, lies in applied engineering [6], which is qualitatively different from research or applied research (Khanna: 1986). In addition, even though subsequent efforts [7] were made to combine R & D with production, many of the "newly established institutes" were actually design departments, existing within enterprises, which were merely renamed without any fundamental change of personnel or mission

(Simon and Rehn: 1987). Moreover, China has been making extensive use of reverse-engineering to acquire technological know-how and still seems to believe this is a successful path for enhancing ITC through transferred technology. However, as a means of acquiring firm-level production and technical know-how, it is probably too slow, too expensive, and too risky [8] (Khanna: 1986). Finally, since many of the electronics enterprises were, or still are, defense-oriented, the computer designs often cannot complement civilian uses nor promote the popularization of computers within the general economy(Simon and Rehn: 1987).

3. Learning Activity.

As mentioned earlier, China's universities have traditionally played a secondary role in R & D, and it was not feasible for institutions of higher education to turn out professional graduates capable of doing productive work at the initial stage of developing new technology (IPM, IE, and RPIUL:1986). Consequently, learning-by-doing has been a cornerstone of China's strategy for acquiring technological capabilitites. However, unlike learning-by-doing, learning-by-using is an area plagued by systematic constraints to the development of industrial technology in China. This lack of feedback from users to capital goods producers, including new computer systems, may be profound, and a shortcoming should deserve explicit policy attention by Chinese authorities (Khanna: 1986).

6.3.3. Sectoral Level and Demand-Side Factors.

1. Market Size and Scales of Production.

Few doubt that China can be regarded as a sizable and potential computer market, especially comparing to other LDCs (Lin: 1987) [9]. However, considering deficiencies in software, peripherals, manpower, services, and even electricity supplies, it is by no means certain that the demand for computers will be promising in the short term. Furthermore, the Chinese policy generally confines major thrusts to a few strategic areas (often defense-related) requiring a very large-scale effort. This could gear China's computer production to smaller, specialized markets. Moreover, individual demand for personal computers is thought to be unrealistic, even for a long-term horizon. If prices range from $2,500 for an Apple II to $30,000 for an IBM PC, when the annual income of a Chinese worker is less than 1,000 Yuan (Witzell and Smith: 1989) [10], it is obvious that a "cheap" microcomputer, by developed country standards, is <u>extremely</u> expensive for a family in China. Clearly, this does not take into consideration about any expense of housing and maintaining the computer, the cost of software, and the explicit outlays or foregone earnings incurred while learning to use a computer. Either Chinese incomes must rise relative to the cost of personal computers, sharing of PCs must be encouraged, or the government must absorb some of the costs of PC proliferation, if PC use is to grow appreciably.

In addition to the limited market size, regional jurisdiction results in a large number of small factories, many of which are not only poorly equipped for production, but also operate at below optimum scales of production (Khanna: 1986). Since 1977, the electronics industry has spread over almost all of China. Nearly 28 out of 30 provinces possess their own electronics manufacturing firms (IPM, IE, and RPIUL: 1986) and all are attempting to "hop onto" the electronics bandwagon (Khanna: 1986). As Table 6.6 demonstrates, however, only seven of them, which comprise less than 22 % of total enterprises in the sector, operate at a scale of production exceeding 5 million Yuan per factory [11].

As computer technology develops, especially in IC

Table 6.6. Number of Electronics Factories and Electronics Production by Province: Total and Share (1983) (million Yuan)

Province	Factories		Production		Output value
	No.	%	Total	%	per factory
Beijing	130	3.4	1,310	8.5	10.1
Shanghai	348	9.0	3,210	20.8	9.2
Gansu	20	0.5	160	1.0	8.0
Shaanxi	76	2.0	580	3.8	7.6
Tianjin	117	3.0	780	5.0	6.7
Guizhou	21	0.5	130	0.8	6.2
Sichuan	136	3.5	770	5.0	5.7
Guangdong	263	6.8	1,169	7.5	4.4
Fujian	117	3.0	460	3.0	3.9
Guangxi	37	1.0	140	0.9	3.8
Hubei	146	3.8	500	3.2	3.4
Jiangxi	88	2.3	300	1.9	3.4
Jinagsu	785	20.3	2,480	16.1	3.2
Liaoning	274	7.0	860	5.6	3.1
Henan	86	2.2	260	1.7	3.0
Shangdong	180	4.6	480	3.1	2.7
Jilin	91	2.3	220	1.4	2.4
Anhui	74	1.9	170	1.1	2.3
Yunnan	27	0.7	60	0.4	2.2
Hunan	135	3.4	250	1.6	1.9
Neimonggo	31	0.8	60	0.4	1.9
Zhejiang	383	9.9	640	4.1	1.7
Hebei	112	2.9	190	1.2	1.7
Qinghai	6	0.2	10	< 0.1	1.7
Xinjiang	6	0.2	10	< 0.1	1.7
Shanxi	74	1.9	100	0.6	1.4
Ningxia	10	0.3	10	< 0.1	1.0
Tibet	---	---	---	---	---
Hainan*	n.a.	n.a.	n.a.	n.a.	n.a.
Total	3,873	100	15,450	100	

Source: IPM, IE, and RPIUL (1986: 21).
* A new province established in 1988.

production, it is difficult for a firm with a small scale of production to survive. Given the high investment cost in R & D or innovation, only a considerable scale of production permits a significant decrease in the unit cost of components (IPM, IE, and RPIUL: 1986).

2. Demand-Side Factors.

In the West, strong interrelationships exist between producers and end-users. New technological development in the computer sector can lead to new applications and the creation of new markets. Furthermore, the needs of end-users exert strong influence on the direction of the innovational process through learning-by-using (Simon and Rehn: 1987). In China, however, the whole user-friendly notion has, heretofore, been totally absent. In the case of Shanghai computer factories, customers had to come to the factroy to learn how to operate their purchased machines. It is also reported that a lot of Chinese computer operators frequently have to write their own software (Stepanek: 1984). Therefore, it is not surprising that around 1,500 organizations reportedly have generated their own in-house hardware application and maintenance, and software development personnel (Witzell and Smith: 1989).

In China, the significant barrier between producer and user has been the rule, rather than the exception.

Over the last several years, the locus of project initiation has shifted from the central to the local level. Meanwhile, the market has come to play an increasing role in stimulating firms' innovation through allowing profit retention, a material incentive for developing and producing new products (Simon and Rehn: 1987). However, despite a strong influence from the central government[12], as Simon and Rehn (1987) found in the case of the Shanghai semiconductor industry, there are still several systematic constraints preventing enterprises from being fully market-driven. First, the firms are now placed directly under the control of the municipal EC, which still emphasizes current production instead of R & D projects. Second, despite the new system of production responsibility, technological innovation continues to be primarily driven by the supply-push vagueries of technological opportunity. Technologies are provided by the EC, partly owing to a desire for prestige, rather than end-user demand.

Of obvious interest to users is the improvement in product quality, which, if it is occurring, is not readily reflected in production statistics (Khanna: 1986). In

Shanghai, even though domestic components are subsidized to compete with considerably lower-priced foreign ones, few managers want to be risk-takers who introduce a new component. Domestic components are thus to fall short of the high quality and reliability of foreign counterparts (Simon and Rehn: 1987). This refutes a popular belief among Chinese policy makers that China would have a comparative advantage in production because of an abundance of cheap skilled labor. As a matter of fact, non-price factors such as reliability, serviceability, efficiency, durability, weight, functional versatility, and design are extremely critical in the market for computer products. They often overshadow price considerations (Khanna: 1986).

3. Application.

One of the most serious difficulties in China's computer development has been in applying the technology. Many reasons are responsible. Life-term employment in China seriously erodes any labor-saving application of computers in many areas of the economy. Also, after decentralization, enterprises and local institutions have been jointly involved in the decision-making process. However, most lack the experience and skill, or even technical knowledge, about importing technology or equipment from abroad. As a result, ill-informed decisions sometimes result in importation of inappropriate technology.

In addition to these deficiencies, a serious constraint to computer application has been caused by a policy bias favoring hardware, as opposed to software, peripherals and other supportive services. In the past, each hardware developer had to produce its own software; thus, little serial production had occurred. Given this situation, very little in the way of plotters, terminals, storage devices, disk drives, and printers have been produced in China. Naturally, these are the areas in which China's lag is the greatest. Currently, the Chinese seem to be continuing to rely primarily on software packages available from the manufacturers of the basic domestic machines, instead of developing a software capability compatible with a large number of imported computers(Witzell and Smith: 1989). As a result, dependence on imported software is perpetuated. This dependence is complicated by the lack of copyright protection of software, which very likely dampens the volume of importation. It is noteworthy that the Chinese usually buy "only one or two software packages" (Stepanek: 1984). Without a copyright law to protect software, and with no proper reward for the work of software specialists, domestic developers' incentive could also be dampened.

6.3.4. National Level.

Recently, a number of LDCs, such as Argentina, Brazil, India, South Korea, Mexico, and Taiwan, have vigorously attempted to develop their own computer technologies. A brief comparison of their strategies and industrial performances with China's, as shown in Tables 6.7 and 6.8, should shed some light on our evaluation of China's policies.

1. Strategies.

Unlike "export-orientation" in South Korea and Taiwan, "import-substitution" in Brazil, Argentina, and Mexico, and "self-sufficiency" in India, China's computer development is characterized by at least three distinctions: multi-level-controls, defense-orientation, and a movement from COCOM-control[13] to foreign exchange-restrictions. Government intervention is a common charateristic among all these countries, including China. Despite claims to the contrary, South Korea's government has consistently, although selectively, intervened in order to promote a promising industry or sector such as computer technology. It has

Table 6.7. Policy Comparison of China with Selected LDCs in Computer Development

Policy	China	S.Korea	Taiwan	India	Brazil	Mexico	Argentina
Strategy	Defense-orientation & diffusion into civilian	Export-orientation (O-E)	(O-E)	Self-sufficient & tech independent	ISI**	ISI	ISI
Government intervention	Multiple-level-controlled	Selected intervention	n.a.	Capacity expansion & maximum size	Market reserve	Local-content requirements for producers	n.a.
Import restriction (year)	Tariffs, subsidies, & FE* allotment (1983-1985)	Moderate tariffs (1983)	Subsidies and tax reduction internally	Tariffs: 40-200 % (1970s)	Tariffs: 40% (1977)	Tariffs: 25 % (1981)	Tariffs: 100 % (1985)
Import prohibition	Critical needs on 8- & 16-bit micros	None	n.a.	Second-hand computers	Micros minis	None	None
Technology transfer	From complete to know-how & joint-venture	Licensing & multinational firms(MFs)	(MFs)	n.a.	n.a.	(MFs)	n.a.
Foreign ownership	25-100 %	Unlimited	Unlimited	Very limited: partial national ownership	30 %	49 % on micros, other unlimited	Unlimited

References: Cline (1987); Witzell and Smith (1989); and Pack and Westphal (1986).
* FE--foreign exchange; ** ISI--import-substitution-industrialization

Table 6.8. Industrial Results of the Computer Industry: China and Selected LDCs (in million)

Country	Output(year) ($)	Employment (person)	Output per worker ($)	Excess of domestic price above world level	Export of computers ($)
China	987* (85)	155,000 (85)	6,370**(85)	3-400 % in small- & medium-scale ICs, 700 % in large-scale ICs, 4-900 % in electronics system	Very small
S. Korea	429 (84)	5,000 (84)	85,800 (84)	World level	201 (84)
Taiwan	n.a.	n.a.	n.a.	World level	327 (84) 810 (85)
India	n.a.	n.a.	n.a.	n.a.	51 (83)
Brazil	644-849(84)	28,000 (84)	23,000-30,000 (84)	100-200 %	198 (81)***
Mexico	n.a.	n.a.	n.a.	25-35 %	51 (81)
Argentina	n.a.	n.a.	n.a.	200 %	84 (85)

Source: Cline (1987); Lin (1987: 51-78); and IPM, IE, and RPIUL (1986).

* This figure is obtained form the 3,655 million Yuan output in 1985 divided by the exchange rate of 3.73 Yuans per U.S. Dollars.

** This fact must take into account two factors: life-term employment in China and non-productive employment existing within the Chinese enterprises.

*** See Table 3.2.

helped carefully selected segments of the domestic sector gain comparative advantage through import-substitution _cum_ export-orientation (Pack and Westphal: 1986). In Brazil, the government has implemented a "market reserve" regulation for the domestic production of the microcomputers and lower-level minicomputers. India's government sets restrictions on capacity expansion and maximum size of foreign firms in computer sector development (Cline: 1987). As already discussed, the development of China's computer sector has experienced the systematic control by both vertical and horizontal administrative dimensions, i.e., "multiple-levels," in which both ministries and local authorities have been the major players.

In both South Korea and Taiwan, the production of computers is heavily export oriented. Relying substantially on international technology and involving intra-industry trade, the strategy has attained favorable scale economies. Consequently, production at internationally competitive costs is frequently reached. Since import-substituting-industrialization has been the central common theme of the strategies of Argentina, Brazil, and Mexico, their policies have clearly differed from the more selective, export-oriented direction of computer producers in Southeastern

Asia (Cline: 1987).

As early as the 1970s, India was seeking technological independence, which was geared to developing and mastering sophisticated computer technologies, rather than by disseminating imported products and techniques throughout the economy at large (Cline: 1987). But in China, the computer sector has been oriented toward the defense sector rather than the whole domestic economy. For example, despite the enormous costs encountered in the process [14], the defense sector acts, not only as a major user, but also as the developer and the producer. Thus, the relationship between the developer, the producer, and the end-user tends to be much more confined since projects are generally chosen from above and coordinated within the same institution. In this "system within the system," active units have little, if any, contact with the local authority or economic environment of the geographical area in which they are located. In terms of overall economic and technological planning, they operate almost as an enclave inserted within, but not interacting with, a specific regional economy (Simon and Rehn: 1987).

All these countries were exercising, to some extent, import restrictions and subsidies to protect their infant industries. Since mid-1983,South Korea has been encouraging the use of domestic products by regulating importation and imposing tariffs. Taiwan's computer sector has enjoyed government absorption of a portion of start-up costs, availability of low-interest loans, and generous tax treatment of R & D spending. Although Brazil imposed a moderate tariff (40 %), much more moderate than Argentina (100 %), and not greatly out of line with Mexico (25 %), her other restrictions on import of some items have been even the strictest. After an extended period of pursuing a closed economy, India has partially liberalized her policy in pursuit of a more efficient reformulation of her strategy (Cline: 1987).

Based upon "critical needs," China began her protection of the domestic computer industry in the early 1980s (Brown: 1983). Unfortunately, the policy did not take effect until early 1985 when an increase in import tax levels was instituted. Meanwhile, one million Yuan was allocated for subsidizing purchases of domestic computers (Witzell and Smith: 1989), indicating a transition from a more liberal to a more restrictive computer policy.

It is arguable that China's policy prior to the late 1970s was not "self-reliant" [15]. It is, however, undeniable that in high-tech areas, such as computers, "self-reliance," or at least avoidance of dependence, was carried out by not relying heavily on one country, by dealing with a variety of supplying enterprises and by not going into debt. There is no doubt that importation was a critical factor in China's computer technology development, especially with respect to computer technology oriented to the defense sector. Having said this, however, it is important to note that exportation of computers from abroad was strictly controlled by the Coordinating Committee for Multilateral Export Controls (COCOM), an informal organization of the NATO countries and Japan, which constitutes all of the major countries supplying advanced technology to China. The goal of these joint export-control efforts is to prevent access by the Soviet bloc,including mainland China, to weapons and advanced technologies with military significance. China's importation of computer technology with a potential for military use, had been effectively curtailed until late 1985 when regulations on exports to China were relaxed significantly by COCOM [16]. Essentially, the relaxation accelerated Chinese acquisition of foreign equipment, i.e., the "computer fever," which resulted in a rapid depletion of foreign exchange reserves. Importation from COCOM members has turned out to be foreign-exchange-determined since, unlike many other LDCs, China has refused to go heavily into debt (OTA: 1987).

As we saw in an earlier chapter, the importation of complete equipment and turn-key plants used to be a major form of technology transferred to China. It minimized the initial time and effort required to transform production capacity. However, the danger with this mode is neglect of complementary know-how which would help to build the ITC needed for modification, improvement, and design of technologies. After all, suppliers of electronics technology often have close relationships with users and are very knowledgeable on the subject, including understanding the underlying reasons for various technical functions (Khanna: 1986). Only recently have China's technology imports been limited to those that can help her further her own computer development and production (Lin: 1987). Similarly, in the case of software development in South Korea, although combining worker and managerial training to complement imported technologies may cost more than hardware importation alone, it is believed by Korean decision makers to be an efficient way for acquiring ITC in the long-term (Pack and Westphal: 1986). Licensing has also been a vehicle favored by South Korea for acquiring foreign technology (Cline: 1987).

In foreign investment, there are no limits on foreign equity participation in South Korea; and until recently foreign investment enjoyed tax exemption for five years and a 50 % tax reduction for another three years (Cline: 1987). A similar policy prevails in Taiwan. India (restrictive) and Brazil (liberal, with exceptions already noted) stand on the opposite extremes for regulating foreign investment. It was not until late 1983 that joint-ventures and multinational enterprises were allowed to operate in China. Currently, 25-100 % ownership of businesses by foreign firms is possible. A number of favorable policies have been instigated since then [17]. A key issue is that a joint venture must export a certain amount of its products in order to earn some foreign exchange to balance its foreign exchange outflows (Witzell and Smith: 1989).

2. Industrial Performance.

Despite impressive strides in Chinese computer technology, China's overall accomplishments do not compare favorably with the other computer-producing LDCs. First, productivity in terms of output value per worker in the

Chinese computer sector is not only much lower than the U.S. figure of $150,000, but also far behind that in South Korea and Brazil.

Second, compared with other LDCs, China's computer producers are far from reaching optimum economies of scale. One reason is that the domestic price level is much higher than that of the other selected LDCs. Also, economic returns are low. As a proportion of returns realized in the U.S. or Japan, China's economic returns vary between 10% and 70% for small-scale ICs; 30-40 % for medium-scale ICs; and 20-25 % for large-scale ICs (Simon and Rehn: 1987).

Third, all of the selected LDCs except China are currently exporting their computer products. Among them, Taiwan and South Korea have demonstrated the strongest ITCs in computer production, followed by Brazil. Only recently has China been trying to gain a portion of the world market (Witzell and Smith: 1989).

It is difficult to avoid concluding that the inadequate industrial underpinnings have diluted China's effort in developing almost all segments of her computer sector. The situation appears much more severe than the policy makers often perceive. Technology from abroad has not been effectively and efficiently absorbed, assimilated, adapted, and diffused in the computer sector. With this in mind, it would seem appropriate for China to be more selective in what technologies to be imported and what to be produced domestically. The primary aim is to obtain maximum economic benefits on the basis of her long-term, dynamic, comparative advantage (Khanna: 1986).

6.4. Summary

Compared with industrialized contries, and even with a number of NICs, China is facing a serious gap in developing her computer technology. This is especially true in terms of her overall industrial performance. Since the country cannot afford a huge investment in production facilities and R & D, technology transfer must play a salient role if she is to succeed in closing the gap.

However, the country's progress in absorbing, assimilating, adapting, and diffusing foreign advanced technology is limited by the systematic barriers between defense and civilian sectors, among multiple ministeral administrations, between central and local authorities, between enterprises and research institutions under different jurisdictions, and even between different units within the same institution. As a result, there is no articulated interaction between the developer, the producer, and the user of computer technology. This is in addition to a number of other factors, as stated above, such as manpower deficiencies. Clearly, a one-shot infusion of transferred modern technology will not be sufficient to close the existing technological gap. If the process of technology transfer is inappropriately perceived, additional costs will be incurred [18], and the pursuit of a reasonably stable, consistent policy can never be established. These effects, if not avoided, are likely to make the prevailing gap even wider.

Notes:

1. While it is notable that the Soviets were not world leaders in computer development, such a narrow difference still indicates some competitive computer achievements of the Chinese (Witzell and Smith: 1989) since the Soviet Union was the first and the only country from which China imported computer technology in the 1950s.

2. There were also several other reasons leading to the influx of microcomputers during 1984-1985: (1) the relatively healthy state of China's foreign exchange reserves and (2) funding sources from the World Bank and United Nations, e.g., $200 million from the World Bank's University Development Project (Brown: 1983).

3. About two-thirds of the electronics firms are located in the interior. More importantly, the positive effect of the reform could be offset by their less advantageous locations, lower productivity, and small scales of production (IPM, IE, and RPIUL: 1986).

4. As pointed out by Simon and Rehn (1987), this is relatively high by national, as well as local, standards.

5. It was reported in the case of the Shanghai Components Factory No.5 that each of the research and the production workshops feels responsible only for a limited range of activities across the spectrum of the innovation process (Simon and Rehn: 1987).

6. Applied engineering is more akin to absorptive R & D than to creative R & D and is necessary for the assimilation and adaptation of imported technologies to obtain maximum economic benefits (Khanna: 1986).

7. The initial attempts to link R & D and production were made by setting research institutes within individual enterprises in 1980-1981 (Simon and Rehn: 1987). In 1985, the S & T reform was designed to make contractual R & D more appealing (See 5.4.3.).

8. Reverse-engineering, which should be distinguished from copying, is useful as an educational or training mechanism, especially for acquiring design technology, because it allows a gradual understanding of the reasons for a product's design. Although it has a fairly long tradition in the electronics sector even in DCs, it may have limited usefulness for China's current needs in electronics technology since it is becoming more difficult with increased circuit complexity and miniaturization, along with the rise in importance of software and hardware (Khanna: 1986).

9. China now has 5,000 to 6,000 large- and medium-scale industrial corporations, 30,000 to 40,000 small scale industrial enterprises, 20,000 transportation units, 6,000 research institutions, 60,000 hospitals, more than 1,000,000 rural industrial units, 4,000,000 shops, 150 city administrative departments, 5,000 hotels, and 30,000 wholesale companies (Lin: 1987).

10. The current exchange rate for a U.S. Dollar is about 3.73 Chinese Yuan.

11. This estimation is intended only to indicate the general situation. As the reader may notice, on the one hand, not all firms in these provinces are operating at economies of scale. On the other hand, some of enterprises located in the rest of the regions may have a large scale of production.

12. The central government still structures a good deal of innovative activity through the "guidance" in which it provides in announcing "key national projects" (Simon and Rehn: 1987).

13. The Coordinating Committee for Multilateral Export Controls.

14. It is reported that defense research and production units operate on the basis of "cost plus 5.0 %", thus ensuring a set profit no matter how long or how many funds it takes them to meet a given task (Simon and Rehn: 1987).

15. Lang (1984) provided a cogent thesis demonstrating that China's experience of technology transfer was distinguished by "self-reliance" as opposed to the "dependence" that is prevelant among many LDCs. However, Lin (1987) argues that China's computer industry is not at present self-reliant. As evidence, beginning in 1983, China has had to import $ 1 billion worth of computers and related equipment each year.

16. COCOM review is still required for more sophisticated dual-use technology, for military exports, and nuclear exports. However, COCOM's control is subject to differences in the approaches to export control taken by various supplier countries and different interpretations of the technologies of export-control specifications for particular products (OTA: 1987).

17. These policies include a tax exemption from customs duties, a reduction or exemption from industrial or commercial taxes on products manufactured for sale abroad, an exemption from income tax in the first two profit making years, and a 50 % reduction in income tax for the next three years (Witzell and Smith: 1989).

18. It is estimated that China will waste between $20 to $80 million by not taking proper care of the computers imported in 1984-1985 (Lin: 1987).

Chapter 7

CONCLUSIONS AND POLICY RECOMMENDATIONS

The case study of China's computer sector, has concluded that technology transfer is essential to the development of Chinese computer technology. Furthermore, without significant efforts in formulating a proper policy, including improvement of the institutional environment, the country cannot maximize the really generous benefits from imported technology through the enhancement of internal technological capabilities. The role of technology transfer in the absence of a facilitating environment is limited indeed.

It is true that, without any special incentives, manufacturing firms, especially in the traditional sectors, can continue to acquire their ITC through routine learning and engineering activities. In this sense, technology transfer would necessarily enhance ITC in the recipient firms or countries. But this form of technological progress proves to be too time consuming and too slow to be effective. Worse still, these types of learning appear to be exhausted quickly. In the case of importing computer technology, even under rather benign assumptions, such enterprise-level activities cannot ensure that a firm will reach the technological frontier because of the rapid pace of computer technology development globally.

On the other hand, at a national level, China accomplished some distinguished achievements in indigenous computer technology through a strategy of concentrating limited resources on importing technology and on developing it within a few selected sectors, such as her defense R & D projects. However, it proved that such a strategy was too expensive and inefficient when achievements were not shared with other sectors in the economy. An improper policy cannot lead technology transfer to the most successful contribution to the development of the economy as a whole.

As we saw in previous chapters, identifying the locus of technological change and the determinants of the pace and direction of such change requires an understanding of prevailing institutional structures. Institutions and technology, as institutionalists claim, are two major themes in economic development. More importantly, an intimate interaction exists between these two factors. In general, institutions evolve passively and can be resistant to technological change. China's planning system could, in theory, stimulate the development of computer technology through coordinating the developer, the producer, and the user. In effect, however, the bureaucratic institution of the planning apparatus has acted as an impediment rather than providing the impetus.

Technology, the "genetic material," on the other hand, plays an active role in its environment. In the long-run, technological change can weaken institutional resistance by calling for associated adjustments or reforms in economic, or even political and cultural structures. Because of the dynamic nature of technology, institutional change must sooner or later accommodate to the direction of technological change [1]. Otherwise, technological advance will be stifled completely.

A close study of such an environment, as believed by the new institutional economists, is essential to formulation of government policy. However, in the evolution of China's S & T policy, China has consistently underestimated the cost of technology transfer, especially in the sense of simultaneously acquiring internal technological capacities. There has also been the equally persistent overestimation of China's S & T status and her ability to assimilate imported technology within the economy. As a guide for evaluating her overall computer technology level, China has tended to use a few technical parameters such as operating speed. Accordingly, using this limited criterion, once the Chinese were capable of producing extra-high-speed computers, the gap would have been closed. During "computer fever," however, they were convinced that technological modernization could be accomplished once they were able to import the most advanced technology and equipment. Essentially, this is why China could not formulate a reasonably stable policy or strategy in guiding computer development and computer technology transfer and in guiding China's overall S & T development.

Under their planning system, the Chinese can boast of several computer technology achievements in the defense sector and even some in the civilian sector. Yet there exist a number of factors which systematically increase the cost of acquiring ITC from imported technology and which reduce the possibility of assimilating, absorbing, and properly adapting technology: (1) the lack of interactive linkages between the military and civilian industries, among departmental agencies, between R & D activities and applications; (2) the overwhelming problems of manpower provision; (3) the lack of market forces, especially on the demand side; and (4) the weakness in computer infrastructure in terms of software, peripherals, services, etc.

It is important for China to formulate a reasonably stable policy instead of one different ambitious program after another. In formulating such a policy, a limited, but useful, role of technology transfer must be taken into account. Above all, the policy should be selective and feasible. Based on these requirements, several concrete policy recommendations can be made:

1. Application.

The development of China's computer technology should aim at applying computers within the civilian sector instead of emphasizing the defense-oriented sector and/or high technology performance in terms of narrowly defined technical criteria (e.g., attaining the highest calculation speed). Application of computers throughout the economy can provide computer technology with a broad and stable infrastructure which in turn will help the computer sector form her own technological path. The objective should be to achieve and sustain productivity gains in broad-based economic activities. Not only is this a sound economic goal *per se*; it is also a far more feasible one than catching up with the technological frontier by the year 2000. Not only can the civilian sector be a potential user, but through backward information feedback it can also become a source of necessary learning by producers which leads to technological innovations in both products and processes.

To complement the application of computers, several directly-related goals are:

(1) To develop software technology to meet the currently-increasing demand for solving local problems; China will benefit from such technology-intensive or information-intensive products through adapting it to her own conditions.

(2) To encourage serial production which involves the production of peripherals and other related equipment and components, and to help set up services infrastructure, all of which seem to be weak and inadequate in China.

(3) To encourage serious experimentation with technological blending, which, if successful, will greatly enhance the geographic and sectoral scope for applying computers in local conditions. Significant acquisition of technological capacity can come about without causing drastic institutional upheavals, e.g., massive changes in

employment and skill requirements.

2. Institutional Reforms.

To implement computer technology development, necessary institutional adjustment must be given priority regardless of whether it is already involved in current reforms.

(1) Commercialization is one such change to improve the institutional environment. As we learned, the most imposing barrier to computer technology diffusion in China is the dearth of demand-pull forces.

This recommendation goes beyond the computer industry itself. Potential using enterprises must be put under some pressure to cut costs, maximize efficiency and improve quality. Market forces provide a more effective vehicle for appropriately shaping managerial behavior than an administrative apparatus, e.g., the central planning authority. By no means does this imply a complete shift to a laissez faire economy; it merely advocates a greater use of market mechanisms as a means of elevating and directing incentives.

It should be noted that commercialization can improve supply-push incentives in the computer industry as well.

Without patent protection, inventor certificates or copyrights (for software), appropriability of gains from R & D is impossible. One can assume a priori that innovative activity would be invigorated if these legal provisions are established and enforced.

(2) The government should play a proper role in the total effort. For example, gradual reduction of the government's direct controls of computer production and importation, at both the central and local levels, should be realized as enterprises improve their internal technological capabilities in searching, bargaining, and procuring technology. Gauging the proper pace for removing regulation is a difficult task, but it is extremely important in the case of the Chinese computer industry because "multiple-level" barriers are severe for internal technological diffusion.

(3) Correspondingly, significant reforms in the personnel system are required. In the short- or intermediate-run periods, if it is impossible for China to meet her manpower requirements, this makes it doubly desireable that scarce skilled personnel be efficiently employed. This also requires a proper, active role of the government in organizing and coordinating the reform

process and in ameliorating resistance to desired change.

(4) Competition must be stimulated through encouraging the involvement of foreign investment in such arrangements as joint-ventures. This is especially true if China wants to utilize the international market to absorb part of her domestic production. It is also believed that competing internationally is an effective avenue for reaping the benefits of economies of scale in computer production.

(5) It is easy to understand that partnerships between enterprises and R & D institutions should further the accumulation of ITC since it is one of methods of nurturing relationships between R & D development and its application. On an experimental, selective basis, if a more robust role for university R & D proves fruitful, this activity could be expanded in the future.

3. Technology Transfer.

Based on the primary goal of applying computers, technology transfer must be consistent with this objective in the following respects:

(1) Infant-industry protection must be considered as a relatively short-term measure. If there are not realistically based expectations that an industry, or sub-

industry, can attain a competitive status within 5 to 10 years, it should not ordinarily be a candidate for protection. Inappropriate protection can only impede the acquisition of ITC and the process of internal technological diffusion.

(2) Government intervention should be influential in encouraging importation of pure technology or technical know-how rather than turn-key equipment and plants which are mainly intended to increase production capacity.

(3) The tendency to import the most advanced technology should be avoided if it cannot support the application of computers within the domestic sector. Hard-headed economic criteria should be the controlling factors, not engineering or performance criteria viewed in isolation.

China has demonstrated her ability to develop computer technology through accumulation of her own R & D infrastructure, production skills, and importation experiences, etc., which can provide her with an opportunity for reaching the technological frontier in the computer sector. However, the country also requires a reasonably stable strategy through which the economy as a whole reaps the benefits from computer technology. Having realized the limited effectiveness of imported technology in achieving this goal, enhancing internal technological capacity through a conscious and significant effort is warranted. Furthermore, taking into account variety of costs and disutilities in the process of developing China's computer technology, the strategy should be narrowly defined instead of a broadly ambitious program. If computer policy is formulated with an emphasis on computer application, on improvement of the institutional environment, and on being selective, China's computer development can be far more robust.

Note:
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1. A similar point of view was expressed by Marx in terms of the classical struggle.

REFERENCES

Ayres, C.E. 1944. The Theory of Economic Progress (Third Edition). Kalamazoo, MI: New Issues Press, 1978.

Baark, Erik. 1987a. "Putting Domestic Technology to Work: Chinese Researchers and Scientists Get Down to Business." The China Business Review (May-June): 53-55.

___________. 1987b. "Commercialized Technology Transfer in China 1981-86: The Impact of Science and Technology Policy Reforms." The China Quarterly 3 (September): 390-406.

Barnett, A. Doak. 1977. "The Policy Context." In Science and Technology in the People's Republic of China. Ed. Organization of European Co-Operation and Development (OECD), 19-36. Paris: OECD

Bell, Martin. 1984. " 'Learning' and the Accumulation of Industrial Technological Capacity in Developing Countries." In Technological Capability in the Third World. Eds. Martin Fransman and Kennth King, 187-209. New York: St. Martin's Press.

Blair, Calvin P. 1986. "Buy, Beg, Borrow, and Steal: The Forms and Fashions of Technology Transfer." Mexican Studies 2:2 (Summer): 215-233.

Brown, Chris. 1983. "Computer Sales." The China Business Review (March-April): 30-37.

Chow, Gregory C. 1985. The Chinese Economy. New York: Harper & Row, Publishers.

Chwang, Tek Ling, and Richard L. Thurstont. 1987. "Technology Takes Command: The Policy of the People's Republic of China with Respect to Technology Transfer and Protection of International Property." The International Lawyer 21:1 (Winter): 129-167.

Cline, William R. 1987. Informatics and Development: Trade and Industrial Policy in Argentina, Brazil,and Mexico. Washington,D.C.: Economics International,Inc.

Cooper, C. and F. Sercovich. 1971. The Channels and Mechanisms for the Transfer of Technology from Developed to Developing Countries. UNCTAD, TD/B/AC. Vienna: UNCTAD.

Dahlman, C.J. and F.V. Fonseca. 1978. From Technological Dependence to Technological Development: The Case of the USIMINAS Steel Plant in Brazil. IDB/ECLA Research Programme on Science and Technology. Working Paper No. 21. Buenos Aires.

Davenport, Alice. 1987. "Local Technology Import Decision: Learning How to Buy Foreign Technology the Hard Way." The China Business Review (May-June): 40-43.

Dean, Genevieve. 1972. "A Note on the Sources of Technological Innovations in the People's Republic of China." The Journal of Development Studies 9:1 (October): 187-199.

________________. 1977. "Research and Technological Innovation in Industry." In Science and Technology in the People's Republic of China. Ed. Organization of European Co-Operation and Development (OECD), 157-170. Paris: OECD.

DeGregori, Thomas R. 1985. A Theory of Technology: Continuity and Change in Human Development. Ames, Iowa: The Iowa State University Press.

Enos, John L. 1982. "The Choice of Technique vs the Choice of Beneficiary: What the Third World Chooses." In The Economics of New Technology in Developing Countries. Eds. Frances Stewart and Jeffrey James, 69-81. Boulder CO: Westview Press.

______________. 1985. "A Game-Theories Approach to Choice of Technology in Developing Countries." In Technology, Institutions, and Government Policies. Eds. Jeffrey James and Susumu Watanabe, 47-80. New York: St. Martin's Press.

Fang, Yi. 1978, as cited in Orleans, L.A.(ed.), Science in Contemporary China, Appendix A, pp. 546-556. Stanford, CA: Stanford University Press.

Ferguson, C.E. 1966. Microeconomic Theory. Homewood, IL: Richard D.Irvin, Inc.

Fransman, Martin, and Kennth King. 1984. Technological Capability in the Third World. London: McMillian.

Furubotn, Eirik G. 1962. "The Adaptability of Fixed Productive Services in the Short-Run." Southern Economic Journal 28:4 (April): 329-339.

____________________. 1965. "The Orthodox Production Function and the Adaptability of Capital." Western Economic Journal 3:3 (Summer): 288-300.

____________________, and Rodolf Richter. 1986. "The New Institutional Economics." Journal of Institutional and Theoretical Economics 142:1 (March): 2-3.

Hagen, Everett E. 1980. The Economics of Development (Third Edition). Homewood, IL: Richard D. Irwin, Inc.

Heertje, Arnold. 1973. Economics and Technical Change. New York: John Wiley & Sons.

Higgins, Benjamin. 1968. Economic Development. New York: W.W. Norton & Company, Inc.

IPM; IE; and RPIUL (Institute of Policy and Management at Chinese Academy of Sciences [CAS]; Institute of Electronics at CAS; and Research Policy Institute as University of Lund). 1986. Development of Electronics and Employment in China with Special Emphasis on Application. Maastrich, The Netherlands: The United Nations University, New Technology Center Feasibility Study.

Ishikawa, Shigeru. 1972. "A Note of the Choice of Technology in China." The Journal of Development Studies 9:1 (October): 161-186.

____________________. 1988. Technology Import and Indigenous Technology Capacity in China. World Employment

Programme Research Working Papers,No.185. Geneva:ILO.

James, Dilmus D. 1987. "The Economics of Technological Progress: A Comparison of Non-Institutionalist and Institutionalist Dissent from the Neoclassical Position." Journal of Economic Issues 21:2(June):733-741.

________________. 1988. The Impact of Technology Imports on Indigenous Technological Capacity: The Case Study of Mexico. World Employment Programme Research Working Paper,No.184.Geneva: International Labor Office.

________________. 1989. "Importation and Local Generation of Technology By the Third World: An Institutionalist Perspective." In Development Economics: Theory, Practice, and Prospects. Ed. Thomas R. DeGregori, 291-370. Hingham, MA: Kluwer Academic Publishers.

Katz, Jorge M. 1982. "Technology and Economic Development: An Overview of Research Findings." In Trade,Stability, Technology, Equity in Latin America. Eds. Moshe Syrquin and Simon Teitel, 281-315. New York: Academic Press.

Khanna, Anupam. 1986. Issues in the Technological Development of China's Electronics Sector. World Bank Staff Working Paper, No. 762. Washington, D.C.: World Bank.

King, Alexander. 1980. The State of the Planet. Oxford: Pergramme Press.

Krugman, Paul R., and Maurice Obstfeld. 1988. International Economics: Theory and Policy. Glenview, IL: Scott, Foresman and Company.

Kuznets, S. 1966. Modern Economic Growth: Rate, Structure and Spread. New Haven, Conn.: Yale University Press.

Lall, Sanjaya. 1984. "Export of Technology by Newly-Industrializing Countries: An Overview." World Development 12:5/6 (May/June): 471-480.

Lang, S. Ivy. 1984. "From Dependency to Self-Reliance: An Evolution of China's Experience of Technology." In Appropriate Technology: Choice and Development. Ed.

Mathew J. Betz; Pat McGowan; and Rolf T. Wigand, pp. 67-81. Durham, NC: University of Duke Press Policy Studies.

Li, Peng. 1986. See Inside China, No.15 (Jan./31).

Lin, Yen-che. 1987. "Computer Development in Mainland China." Issues and Studies 23:10 (October): 51-78.

Lin, Zhixian, and Mingyu Wu. 1984. "An Exploration of Some Questions Concerning China's Strategy for Technological Development." In Managing Science Policy and Technology Acquisition: Strategies for China and a Changing World. Eds. Rustam Lalkaka and Mingyu Wu, 13-26. Dublin: Tycooly International Publishers.

Lower, Milton D. 1987. "The Concept of Technology within the Institutionalist Perspective." Journal of Economic Issues 21:3 (September): 1147-1176.

Mowery, David C. and Nathan Rosenberg. 1982. "The Influence of Demand Upon Innovation." In Inside the Black Box. Ed. Nathan Rosonberg, 193-241. Cambridge: Cambridge University Press.

Murnane, Richard J. and Richard R. Nelson. 1984. "Production and Innovation When Techniques Are Tacit." Journal of Economic Behavior and Organization 5 (December): 353-373.

Nelson, Richard R.; S.G. Winter; and H.L. Schuette. 1976. "Technical Change in An Evolutionary Model." Quarterly Journal of Economics 90 (February): 90-118.

__________, and S.G. Winter. 1974. "Neoclassical vs Evolutionary Theories of Economic Growth." Economic Journal 84: 886-905.

__________. 1977. "In Search of a Useful Theory of Innovation." Research Policy 6 (Summer): 36-76.

__________. 1980. The Schumpeterian Trade off Revisited. Institution for Social and Policy Studies, Working Paper, No.834. New Haven, CT: Yale University Mimeo.

Nochteff, Hugo. 1985. Government Policiies for the Data Processing Industries in Argentina, Brazil, and Mexico. 7 May, ID/WG.440/7, Regional Meeting for the Initiation of a Regional Network for Microelectronics in the ECLAC Region. Vienna: United Nations Industrial Development Organization (UNIDO).

O'Connor, David C. 1984. "Policy Issues Relevant to the International Transfer of Semiconductor Technology to China." In Managing Science Policy and Technology Acquisition: Strategies for China and A Changing World. Eds. Rustam Lalkaka and Mingyu Wu, 188-199. Dublin: Tycooly International Publishers.

__________________. 1985. "The Computer Industry in the Third World: Policy Options and Constraints." World Development 13:3 (March): 311-332.

OTA (Office of Technology Assessment). 1987. Technology Transfer to China. OTA-ISC 340. Washington, D.C.: Government Printing Office.

Pack, Howard and Larry E. Westphal. 1986. "Industrial Strategy and Technological Change:Theory vs Reality." Journal of Development Economics 22:1 (June): 87-128.

Perkins, Dwight H. 1988. "Reforming China's Economic System." Journal of Economic Literature 26:2 (June) 601-645.

Pugel, Thomas A. 1981. "Technology Transfer and the Neoclassical Theory of International Trade." In Technology Transfer and Economic Development. Eds. Robert G.Hawkins and A.J.Prasad, 11-37. Connecticut: JAI Press, Inc.

Ranson, Abldwin. 1987. "The Institutionalist Theory of Capital Formation." Journal of Economic Issues 21:3 (September): 1265-1278.

Ren, Jian-xin. 1981. "Some Legal Aspects of the Import of Technology and the Utilization of Foreign Investment in the People's Republic of China." International

Review of Industrial Property and Copyright Law 12:21.

Rosenberg, Nathan. 1982. "Learning by Using." In his Inside the Black Box (ed.), 120-140. Cambridge: Cambridge University Press.

Roth, Timothy P. 1979. "Empirical Cost Curves and the Production Theoretic Short-Run: A Reconciliation." Quarterly Review of Economics and Business 19:3 (Autumn): 35-47.

Scott-Kemmis, Don and Martin Bell. 1985. "Technological Dynamism and Technological Content of Collaboration: Are Indian Fi rms Missing Opportunities?" Economic and Political Weekly 20:15 (November): 1991-2004.

Sercovich, F.C. 1980. State Owned Enterprises and Dynamic Comparative Advantages in the World Petrochemical Industry: The Case of Commodity Olefins in Brazil. Development Discussion Paper, No.96. Cambridge, Mass.:Harvard Institute for International Development.

Simon, Denis Fred and Detlef Rehn. 1987. "Innovation in China's Semiconductor Components: The Case of Shanghai." Research Policy 16: 259-277.

________________. 1988. Technological Innovation in China: The Case of the Shanghai Semiconductor Industry. Cambridge, MA: Ballinger Publishing Company.

Stepanek, James B. 1984. "Microcomputers in China." The China Business Review (May-June): 26-29.

Stewart, Frances. 1972. "The Choice of Technique in Developing Countries." Journal of Development Studies 9 (October): 99-121.

________________. 1981."International Technology Transfer: Issues and Policy Options." In Recent Issues in World Development: A Collection of Survey Articles. Ed. Paul Streeten and Richard Jolly, 67-110. Oxford: Pergamon Press.

"A Survey of China's Economy: A World Turned Upside and

Down." 1987. The Economist 304 (August): 46.

Suttmeier, Richard P. 1987. "China: The Search for Strategies." In Learning by Doing: Science and Technology in the Developing World. Ed. Aaron Segal, pp.157-187. Boulder: Westview Press.

Teitel, Simon. 1981. "Creation of Technology Within Latin America." The Annals of the American Academy 458 (November): 136-150.

Todaro, Michael P. 1985. Economic Development in the Third World (Third Edition), 64-65. New York: Longman.

Urrutia, Miguel. 1988. "The Computer Industry in Mexico." In Economic and Social Progress in Latin America: 1988 Report, 167-179. New York: The Inter-American Development Bank.

Vaitsos, Constantine V. 1974. Intercountry Income Distribution and Transnational Enterprises. Oxford: Claredon Press.

White, Lawrence J. 1978. "The Evidence of Appropriate Proportions: A Survey." Economic Development and Cultural Change 27:1 (October): 27-60.

Williams Silveira, Mary Pat. 1985. Research and Development: Linkages to Production in Developing Countries. Boulder, CO: Westview Press.

Wionczek, Miguel S. 1986. "Industrialization, Foreign Capital and Technology Transfer: The Mexican Experience 1930-1985." Development and Change 17(April): 283-302.

Witzell, Otto W. and J.K. Lee Smith. 1989. Closing The Gap: Computer Development in the People's Republic of China. Boulder, CO: Westview Press.

Yang, Mu. 1987. "The New Technological Revolution and the Technological Progress in Industries." Chinese Economic Studies 20:4 (Summer): 50-67.

Ye, Yuansheng. 1987. "The World Technological Revolution and China's Policy of Technological Innovation." Chinese Economic Studies 20:4 (Summer): 68-80.

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