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The East Asian Miracle and Information Technology

Strategic Management of Technological Learning

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FOREWORD

The transformation of Japan, Korea, Taiwan, Hong Kong and Singapore has been rightly recognized as one of the greatest development achievements of the twentieth century. This study argues that East Asia's miracle is, in part, due to strategic and selective support to information technology. This strategy led to the transition of these economies from a labor-intensive to a knowledge-intensive industrial structure.

The study draws on lessons for replicability. In particular, it examines the catalytic and strategic roles of government in unleashing private sector responses to develop the information technology industry, promote the wide application of this generic technology, and create national information infrastructures. It also examines the roles of corporate strategies, public-private cooperative programs, and industry associations in technological learning and diffusion.

The study should be of interest to policy makers, industry strategists, and aid agencies engaged in developing national capabilities to manage and compete in the information age. It offers an example of the World Bank as a connector in today's information-based global economy.

Jean-Francois Rischard
Vice President
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ABSTRACT

This study focuses on the process of technology catch-up and competitive advantage creation, drawing on the successful experiences of Japan, Korea, Singapore, Taiwan, and Hong Kong -- the newly industrialized countries (NICs). It shows how the NICs countries have exploited the opportunities made possible by the information technology revolution and built sustainable competitive advantage in many high value-added industries and services. Many lessons could be drawn from the East Asian information technology miracle.

These countries became leading producers and users of informatics by developing "consensual" strategic management, characterized by shared vision of the information revolution, outward orientation towards the global economy, strategic intent to build core competencies in informatics, agile planning and multi-level learning in developing their national information infrastructures, and the use of government-business partnerships to hasten response to opportunities. Their visions anticipated the key role of informatics as an industry, technology and infrastructure. Intent on mastering and diffusing informatics and building intelligent infrastructures, the NICs devised novel programs and intermediaries, and various processes for public-private cooperation. Learning was at the heart of these processes. National informatics strategies evolved, each building on experience and increasing the scope and collaboration among public and private agencies.

The study examines the role of government in unleashing private-sector response, promoting the IT industry, diffusing the technology, and focusing resources on strategic elements of the national information infrastructure. It contrasts this role among the NICs. The study explores the role of the private sector, particularly industrial associations, in influencing the development and use of the new technologies. The interplay between government and corporate strategies also presents important lessons for technological deepening and diversification.

The study focuses on areas where the experience of the NICs is replicable. It concludes with recommendations for aid agencies to help developing countries adjust to the emerging, information-driven, global economy. It argues that this new role is essential for aid agencies to remain relevant in the information age.

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Executive Summary

The transformation of Japan, Korea, Singapore, Taiwan, and Hong Kong since the 1960s is recognized as one of the great development achievements of the 20th Century. Studies of the "East Asian miracle" have analyzed the macroeconomic factors that contributed to these achievements. These analyses have for the most part ignored a crucial aspect of the transformation: the extraordinarily rapid rise of the information technology (IT) industry and its role in producing higher value goods and services.

The study focuses on the process of technology "catch-up" and competitive advantage "creation." East Asia's success is partly due to rapid accumulation and efficient allocation of physical and human capital. But their performance is even more superior in terms of rapid and sustained improvements in productivity: these countries derive 50 percent or more of their total output growth from total factor productivity growth, rather than from investment. While not attributing the East Asian miracle to a single factor, the study tries to redress the balance by focusing on the role of strategic policies affecting technological learning and productivity change. Accordingly, East Asia succeeded, in part, because it provided strategic, selective and consistent support to industries which were in the best position to facilitate their economies' transition from a labor-intensive to a knowledge-intensive industrial structure.

The newly industrialized countries (NICs) developed strategies that anticipated and sought the new opportunities arising from the ongoing information technology revolution and the associated managerial innovations. They set ambitious levels of performance, stretched their comparative advantage, and made commitments to particular skill areas well ahead of short-term market signals. They developed a competitively unique point of view about the future, which guided their investments in developing core competencies, their management of public-private coalitions, their search for strategic alliances, and their learning and experimentation. They also developed planning and management processes that are agile, collaborative and learning-oriented.

The study highlights distinctive IT initiatives that unfolded in the East Asian newly industrialized countries. These initiatives were guided by a consensual strategic management framework, which involved the creation of cohesive national visions, focus on international markets and competitors, and an array of coordinated public and private sector strategies to achieve technological mastery. The results defied both neoclassical and statist models of development and suggested a new model of building national competitiveness.

Computers, semiconductors, and telecommunications were the targets of government-industry coalitions. Within a decade of the founding of these coalitions, their countries became large producers in the global IT industry, and diffused IT across their economies and societies.

In Japan the 1973 oil crisis induced a shift from heavy industry to less energy- and material-intensive sectors. The information industry, led by electronics, has replaced heavy industry as the leading segment of the Japanese economy. Between 1975 and 1985, the share of electronics in total manufacturing output rose from 9.3 percent to 17.5 percent, the biggest increase in the proportion of electronics in output of any major economy. By 1989 Japan had captured 24 percent of the global electronics market.

Today, Japan produces 60 percent of the world's integrated circuits, 95 percent of advanced flat panel screens and has 33 percent of supercomputers. This manufacturing base has generated spin-off activities, including intra-and inter-firm data networks, software and systems-integration services, and telecommunications supplies.

Groups of companies -- the *Keiretsu* -- have led the development of IT, and government has been a catalyst. Since the 1970s the Ministry of International Trade and Industry has pushed a consensus with industry and academia for promoting the information industry. MITI's strategy guided the formulation of direct and indirect programs, from technology parks and research consortia to tax incentives and procurement standards.

In the mid-1960s, Korea was a low-cost exporter of labor-intensive products such as apparel. A decade later it had moved up to construction services and capital-intensive production of ships and steel. By the 1980s, the country had established a strong global position in technology- and knowledge- intensive products, particularly semiconductors and computers.

Since 1969 government has spurred the technological learning of large industrial companies, the *Chaebols*. In the mid-1980s the government supported the *Chaebols* joint ventures in computers with global technology leaders. Its information industry promotion plan has helped develop software, communications, semiconductors, and computers and diffused IT across society.

Today Korea is the world's third largest producer of dynamic random access memory chips (DRAMs). By 2000, Samsung, one of its largest conglomerates, is predicted to become the world's largest producer of DRAMs. In addition to manufacturing IT products for export, Korea has built a domestic software and information services market. Its growth averaged 37 percent per year between 1987 and 1990. Its 1990 output was $780 million.

The extraordinarily rapid rise of the IT industry in Taiwan has been focused on the manufacture of computer products for world markets by its many small entrepreneurial firms. From 1971 to 1976 there was a severe slowdown in Taiwan's leading sectors -- textiles, transport equipment, electrical machinery -- and promising new industries like electronics did not develop fast enough to compensate. The state responded in 1982 by designating IT as a strategic industry and launching a promotional plan. Direct and indirect support was mobilized to assist the small manufacturers at the vanguard of industry activity.

These aids ranged from extension services to boost quality and productivity of subcontractors, to overseas marketing assistance.

Between 1982 and 1985 IT exports leaped from $106 million to $1.22 billion. Today computer products account for 42 percent of the economy's exports, and the country supplies 67.4 percent of the world market for motherboards, 40 percent for monitors, 70 percent for scanners, and 22 percent for notebook computers.

Singapore has gone from a poor entrepot center to a global hub for high-value information technology production and use. In the 1960s government recruited labor-intensive foreign manufacturing companies. By the 1970s Singapore was facing competition from other lower-cost countries. A new strategy focused on creating "a second Industrial Revolution" in knowledge-intensive products and services. Public communications investments rose 239 percent in the 1970s to spur this strategy. The Economic Development Board targeted worldwide promotions at software and computer companies and financial services that could benefit from the advanced infrastructure. In 1981 the National Computer Board was created to guide the shift to an information-intensive "intelligent island." Between 1981 and 1988 computer exports rose from $40 million to $3.8 billion. Singapore has become the world's largest producer of disk drives. Exports of software and IT services grew sevenfold during the same period. Today Singapore is a critical node in the operations of high-tech multinationals.

Hong Kong's transition from a center of labor-intensive consumer goods manufacture to high-tech trading and services is reflected in the fact that manufacturing as a share of GDP dropped from 25 percent to 20 percent from the decade 1982 to 1992. Hong Kong's IT industry is two-tiered: a declining electronics manufacturing base that is redeploying physical assets, investment capital and managerial skills to the mainland of China, and a booming information services market led by banks, trading houses and insurance companies involved in international deal-making and gateway transactions with China.

The dynamism of the information services market has been supported by a communications infrastructure run by two telecommunications franchises. These franchises have built one of the world's largest fiber optic networks, and these networks have promoted the adoption of IT use by service firms of all types.

The Asian NICs recognized IT as a strategic industry, a generic technology, and an essential infrastructure. Viewing IT as a strategic industry, they orchestrated technological learning and built competitive advantages in higher value-added products. Recognizing IT as a generic technology, they promoted its use in capital and consumer goods and production processes, to enhance quality and cut costs and response time. They complemented market signals and incentives with organized social mechanisms for promoting the diffusion of new skills and technologies. They also used IT to support the organizational imperatives of lean production, just-in-time, total quality control, and continuous process improvement *(Kaizen)*.

They also exploited IT to improve traditional infrastructures like transportation and communications and develop national information infrastructures. They applied electronic document interchange (EDI) to clearance at airports and seaports and to procurement and production for industry transactions. They positioned themselves on the increasingly dense networks of global industries and services by building an advanced information infrastructure. They used informatics to modernize public administration, reduce transaction costs between business and government, and improve the delivery of public services. They promoted "one-stop non-stop" service and established public information "utilities" aimed at specific user communities such as health, education, law, and commerce.

National strategic management

These countries became leading producers and users of informatics by developing "consensual strategic management," characterized by shared vision, outward orientation, strategic intent to build core competencies, agile planning and multi-level learning, and the focusing of resources by public-private coalitions.

Their visions anticipated the key role of informatics as an industry, technology, and infrastructure. Rather than drawing up blueprints, Japan's MITI sought out expert groups and businesses and guided them toward ambitious targets. MITI's "program for advanced information infrastructure," for example, suggests that the principal means of generating economic value could shift from manufacturing to intellectual activity. Such national visions create awareness of possibilities, build long-term development orientation, and generate consensus on reforms. They are translated into corporate behavior through incentives, training, cooperative research, institutional support, and directed credit. Directed credit involved a relatively small share of overall credit, but functioned as a signal of the government's commitment to promising industrial segments and technologies, helping to reduce the perceived risks of private investors.

The desire to "catch up" and become exporters helped shape the outward orientation of government and business. Instruments supporting this external outlook included technology watch through specialized R&D institutes, market intelligence-gathering through general trading companies, science and industrial parks, technical education and training, and technology support institutions. The NICs sought new ideas and best practices from abroad. They systematically exploited know-how from trade and foreign investment channels. They invested in networks and strategic alliances. The information and communications revolution further enhanced their ability to learn from each other.

Except for Hong Kong, the NICs demonstrated a strategic intent to master core technological capabilities in IT. Their sustained efforts earned them entry into higher value-added products and services. Product sequencing and timing for market entry were crucial. They focused first on assembly of simple components, then on production of simple consumer electronics, and then on development of more sophisticated products like computers and telecommunications equipment. Firm-level efforts to develop core competencies were complemented by government instruments such as specialized education and technology support.

Intent on diffusing IT and building information infrastructures, the NICs devised novel programs and intermediaries such as technology diffusion groups and robot-leasing companies. They developed an understanding of the information needs of industry and coordinated public and private initiatives to pilot national applications. Government computerization helped teach managers to use IT and motivated multinationals to test advanced IT applications.

Agile planning and learning involved several levels of decision-making in the public and private sectors. At the national level, these processes identified economy-wide information and communication needs and targeted large-scale application areas for strategic and demonstration effects. The design of large transaction systems -- such as financial and tax administration -- required public-private cooperation. Industry's development of electronic networks, common databases and various value-added services required common standards for doing business. Funding mechanisms and common services supported bottom-up initiatives and learning.

Learning was at the heart of these processes. National IT strategies evolved. Singapore's success involved successive strategies, each building on experience and increasing the scope and collaboration among public and private agencies.

National IT management processes paralleled practices of innovative corporations. These processes enabled planning and experimentation at multiple levels and functions and the sharing of experience. Complex systems were tested, and then introduced in stages.

Public-private coalitions helped focus national resources, speed the learning process, demonstrate IT applications, build information networks, and exploit linkages and externalities. Government-business partnerships hastened response to opportunities, emerging technological changes and global competitive challenges, and also reduced the risks of failure of targeted public interventions. Consultative councils, trade associations, rural cooperatives, hybrid institutions, administrative "guidance," research associations, "relationship" banking, supplier-assembler links, and public-private working groups enhanced the focusing of resources. Cost-sharing schemes helped IT users, particularly export-oriented industries and SMEs, to absorb information and communications technologies. Recently the focus of public-private action has been on building common knowledge, applications, skills, protocols, standards, and policies to develop a national information infrastructure.

Role of government

Governments helped unleash private-sector response, promote the IT industry, diffuse technology, and develop the information infrastructure. It played several roles in developing the electronics industry: coach and coordinator for the private sector (Japan), creator of private conglomerates to compete abroad (Korea), incubator and supporter of SMEs (Taiwan), integrator and strategist (Singapore), and infrastructure provider (Hong Kong). Government responded to evolving local technological capabilities, global environment and competitive conditions, new opportunities arising from technological change, and its own development. Export orientation and active private sector participation in policy setting reduced the dangers of rent seeking that often arise from interventions.

The Japanese government worked with the private sector to develop: selective trade and foreign direct investment (FDI) protection, phased in with technological development; support for R&D through consortia and conditional loans; targeted technical education and training; and public procurement set at progressively demanding performance standards. In Korea government fostered conglomerates with the financial resources, technological depth and global reach to compete internationally. It promoted technical education and provided incentives for firm-based training and used public procurement to set progressively higher performance standards for local IT producers. With abundant entrepreneurial endowments, the Taiwanese government did not attempt to create conglomerates or to be as selective as Korea. Rather it developed physical and institutional support infrastructure to compensate for the disadvantages of small enterprises. The government also participated in public enterprises where economies of scale were critical, and in joint ventures with multinationals.

In contrast, Hong Kong demonstrates the limitations of a *laissez faire* regime. Because it did not promote complex activities, industrial deepening by "natural" progression did not occur. Singapore intervened mostly to develop infrastructure: to train specialized technicians and build a world-class port and airport and telecommunications infrastructures. It created institutions such as the National Computer Board to exploit the synergy among computers, software, and telecommunications, to improve national competitiveness.

Compared with other industrial countries, Japanese programs for IT diffusion were distinguished by their comprehensiveness and continuity. Incentives and support programs addressed the finance, marketing, information, managerial skills, and learning requirements of the new technology paradigm. Other NICs used IT to promote productivity and flexibility in key industries, such as garments (Singapore and Hong Kong) and woodworking (Taiwan). Following Japan's example, the national productivity centers of Korea, Taiwan, and Hong Kong, helped SMEs change their business processes and adjust their skills to benefit from generic IT applications. These programs succeeded to the extent there is genuine partnership between government and business during design and implementation.

Both parties brought something to the table: the government provided coordination and cost-sharing, and the private sector provided delivery channels, and knowledge of user preferences, market failures and learning requirements.

Governments built national information infrastructures (NIIs) by setting policies and standards, pooling resources, piloting and demonstrating, investing in telecommunications infrastructure and regulating its services, developing public information resources and networks, and protecting intellectual property rights. Governments led investment in the telecommunications infrastructure, and they have begun to liberalize or privatize. There is a growing realization that building the physical "information superhighway" must be complemented with services and applications. MITI envisages an NII that promotes on-line applications and databases in five areas: education, research, medical and welfare services, public administration, and libraries. Singapore led the region in creating electronic data interchange systems and in demonstrating how the government can work with users to develop protocols and specialized networks and to enable early adopters to articulate their needs and share their experience. The governments of Taiwan and Korea also helped develop advanced infrastructures to support integrated logistics management and rapid response.

Role of private sector

Apart from producing and using IT, the private sector promoted IT diffusion in several ways: associations offered advice on industrial policies and diffusion programs; corporations engaged in technological deepening and transferred knowledge to SMEs; SMEs developed flexible specialization; multinationals promoted services; and business invested in national information infrastructure.

Industrial associations have been important agents. In Taiwan, where the IT industry is composed largely of small firms, the Taiwan Computer Association developed a prototype of a Taiwanese notebook computer that was made available to the members of the alliance; competition then resumed. In Japan the Key Technology Research Center promoted cooperative research by providing equity for R&D companies, conditional loans to private joint-venture research firms, and basic information sharing infrastructure. In Korea, Hong Kong, and Singapore, industrial associations are also actively involved in the design of technical education curricula and the training of engineers and technicians.

Conglomerates in Japan and Korea pursued technological deepening and diversification, using their financial and human resources to cross-subsidize promising segments of the electronics industry. Their innovation and diversification strategies were reinforced by public policies that reduced the risks and shared the cost of R&D. Meanwhile, SMEs produced and diffused IT through their agility and dynamism. Multinationals acted as gateways to international markets and services.

As advanced infrastructures (AIs) are expected to be demand-sensitive, users must be aware of the potential benefits, have adequate incentives, and face no regulatory barriers to use. The private sector is encouraged to supply AI: training AI suppliers and users, financing R&D, keeping government informed of AI trends and their implications for national competitiveness, forming and supporting industry associations, and promoting complementary managerial and organizational practices.

Replicating the East Asia experience

The place of government in stimulating technological advance is changing. The experience of the Asian NICs is more relevant to developing countries than is earlier industrialization in the West. Moreover, the state's role for late industrializers must be viewed in relation to that of industrial countries, to ensure a level playing field.

Risks of state intervention should be weighed against the dangers of not intervening. Given the market failures inherent in building technological capability, reliance on free market policies alone may lead to industrial stagnation. Global competitiveness demands that the state perform a new role. A public-private collaborative approach may have become a prerequisite for latecomers to compete in technologically demanding industries. Governments have often reacted to the necessary restructuring too little, too late, and often were driven to protect ailing industries instead of focus on new and more profitable industries. Fast industrializers must harness scarce public resources for fast learning and maximum impact. They must develop agile and strategic planning capabilities. The NICs demonstrated that selective interventions are feasible and their risks can be managed.

In assessing the risks of targeting, a distinction should be made between "leader" and "follower" strategies. For a leader like the United States, targeting is difficult because of the uncertainties inherent in judging new technologies. For followers like the NICs, it was relatively easy to identify sectors that offered strong opportunities for productivity and growth because of the experience of more advanced countries. A second tier of followers may have more models and thus may be able to reduce uncertainties about technologies, industrial learning requirements, and the learning process itself.

Consensual strategic management can be learned. The NICs learned to hone state intervention, listen to the private sector, and adapt policies and programs. Developing countries may match their IT strategies with their joint public-private capabilities for learning, not to a static view of current institutional capacity. They should organize and develop processes for such learning as integral part of their strategies.

For most developing countries the pressing issue is how to promote IT diffusion. The NIC's, experience is even more relevant in this regard, since most IT users have been SMEs and traditional industries. Their diffusion programs emphasized low-cost extension of mature applications and relied on a blend of public and private delivery of extension services. They were complemented by national "movements" to promote productivity-enhancing technological and managerial innovations.

The NICs also show what should be avoided. Japan has been slow to standardize operating software systems, use packaged software, liberalize its telecommunications services, develop commercial Internet access providers, and create other measures crucial to economy-wide diffusion of IT. Except for Singapore, the NICs moved only recently to promote an IT "culture" and address individual and institutional resistance to technological change.

Most important is the systematic development of an NII. The Asian NICs invested heavily in telecommunications and specialized networks. In the process, they "leapfrogged" several generations of communications technologies. This strategy required national consensus. Government-business coordination guided standards, regulations, and network-based applications.

Role of aid agencies

Aid agencies should help developing countries adjust to the emerging, information-driven, global economy. They may help countries to build a NII, diffuse IT for private sector development, promote promising segments of the IT industry, train workers for an information-based economy, support development of a global information infrastructure, and build national capability for strategic management.

Aid agencies may help countries establish infrastructure development funds for the NII. Assistance to the telecommunications sector should promote the development of a responsive NII. To exploit its potential they may create innovation funds for NII-based applications.

Promising IT tools should be diffused to SMEs, similar to the agricultural extension systems that spread the green revolution. Diffusion programs may provide consultancy assistance for IT-based product and process innovation. Alternatively they may involve "hands off" measures such as establishing institutional, physical and knowledge-transfer infrastructures for SMEs.

Aid agencies may help developing countries overcome entry barriers into promising segments of the global IT industry, particularly software services. The case studies indicate the importance of focused and realistic strategies based on understanding of the different dynamics of international competition and technological learning required for each segment of the IT industry. Aid agencies can transfer international best practices in competitive assessment and strategic management.

They also need to analyze the implications of IT for the global division of labor and the skills required to manage and compete in the information age. Targeted programs could educate public and private managers to build a flexible workforce and develop specialized IT staff and information resource managers.

Developing countries must avert isolation from the emerging global information infrastructure. International agencies may create public-private forums to promote universal access, set technical standards, build user capabilities, mobilize private investment, demonstrate innovative uses, and finance priority applications for human and natural resources management.

Finally, aid agencies should help countries formulate strategies to diffuse IT in support of overall economic development. They may advise governments about the strategic implications of IT for key sectors like trade, finance, logistics, and education. The long-term assistance objective should be to build capabilities to scan the global environment and respond to the ongoing technological revolution.

CHAPTER 1: THE ANALYTICAL FRAMEWORK

Introduction

Technological change is a key source of industrial competitiveness and economic growth. Of all technologies of our time, information technology (IT) has the greatest influence on the global economy. Most industrialized countries and an increasing number of industrializing countries are applying IT in many areas, such as macroeconomic planning, public administration, education, health care, manufacturing, finance and banking, transportation, commerce, publishing, and energy conservation and environmental management. As some economic historians assert, the pervasiveness of IT on society amounts to a "second industrial revolution."

The process of IT generation and diffusion in most developing countries is more difficult than it is in industrialized economies. Most developing countries lack reliable information, with adverse consequences for achieving their numerous developmental objectives. Worse, IT's spread across industries and services in industrialized countries is so fast and pervasive, improving their price competitiveness and performance, that many developing countries are finding it increasingly difficult to compete internationally.

Even technologically mature labor-intensive industries in developing countries, such as textiles and footwear, are threatened by the microelectronics-based technologies and modern organizational practices in the industrialized world. According to some researchers, this new wave of technology will widen the gap between rich and poor countries. Yet a growing literature on the experience of some first-tier Nixes in IT diffusion, as well as the World Bank's experience in lending for IT projects in developing countries, suggests that IT can accelerate development. Several researchers have argued that some "latecomers" are better placed than even some OECD countries to take advantage of IT. According to this view, IT is a window of opportunity for developing countries to break the vicious circle of economic and technological dependency.

Many developing countries have responded to this challenge by formulating national IT policies, upgrading infrastructure such as telecommunications, developing human resources, and experimenting with various institutions and incentives to develop local capabilities in IT. Their experiences have not been extensively researched and shared. The patchy evidence suggests that a gap remains between the promise of IT and its actual use. Some Nixes in Asia, such as Japan, Korea, Taiwan, Hong Kong, and Singapore, have been more successful. Their lessons of experience could indeed be valuable to less developed countries. This study examines these Asian success stories.

The study is particularly concerned with the role of public policy in promoting IT. As with other technologies, the successful acquisition, absorption, improvement, and development of IT can be impeded by the market's failure to train people, undertake IT-related research and development (R&D) activities within firms, obtain information on technical change, options, and alternative suppliers of embodied and disembodied technology, finance the development of IT, including software and intangible information services, and build technical support services that have public-good features, such as telecommunications infrastructure, standardization, metrology, testing facilities, and technical extension services to small scale enterprises. Does this justify government action?

The study suggests a case for government action to promote the generation and diffusion of technology where the market fails. Contrary to conventional views of technology generation and diffusion based on unidirectional, "supply-push" or "demand-pull" models, the innovation process is complex, dynamic, interactive, and subject to market failures. As has been articulated in many studies, firms do not acquire technology, skills, information, finance, and other inputs in perfect markets, and therefore government action is justified. This is true of industrialized and industrializing countries.

Some "structuralists" perceive industrial policy as a tool for acquiring technological capability. They illustrate how East Asian governments have used industrial policy to promote the acquisition and absorption of technology. According to the structuralists, export success does not emerge overnight but is the outcome of a sequential process of learning and technological change. Governments can influence the technological learning process and firms' demand for technical change, as well as the nature, speed, and direction of learning. The study examines best practices in promoting IT among the NICs, their contribution to the "East Asian Miracle," and their replicability to countries at different levels of development.

Objectives of the Study

The primary objective of this study is to analyze a key but neglected aspect of the "East Asian Miracle": the extraordinarily rapid rise of the IT industry and its role in enhancing the competitiveness of these countries. The authors examine common approaches and identify best-practice mechanisms for promoting and diffusing IT and for building a national information infrastructure. The study views IT, or informatics, from three perspectives: as an industrial sector, covering the production of electronics products and components, computer hardware and software, and telecommunications equipment; as a generic industry technology, applicable across industries, production processes, and products; and as an information infrastructure, supporting services and production. The study focuses on the first two perspectives, as they have driven the strategies of the Asian NIEs and Japan until recently. The third perspective, IT as an information infrastructure, is the least explored. Yet the emerging infrastructure is the most profound competitive force in an increasingly information-intensive global economy.

The term "technological capability" is defined here as the ability of countries and firms to acquire and use technology developed locally or imported, and is not limited to their ability to innovate new technology and/or products. According to this definition, IT-related capability can mean any of the following: the capability to apply IT in other industries and services (such as the use of computer-aided design/computer-aided manufacture), the capability to produce IT products (such as computers, telecommunication equipment, semiconductors, software) by acquiring and absorbing technology developed elsewhere, or the ability to innovate new information technology.

The study draws on the economic literature of technology policy and on the strategic management literature, particularly that concerned with the strategic management and diffusion of IT. The am is to use key concepts of these two disciplines to explore an alternative interpretation of the East Asian Miracle, one that accommodates the great diversity of East Asian policies and emphasizes common strategic management tasks. The case studies suggest that the NICs have used different combinations of policies to enhance national competitiveness, and that their success was not dependent on any single, or stable policy mix. Rather, they indicate the importance of adopting certain strategic management processes to accelerate technological development. These processes involve the creation of cohesive national visions, focus on international markets and global competition, agile planning and multi-level learning that strategic allocation and focus of national resources, and the systematic development of networks and core competitiveness.

The rest of this chapter highlights key concepts used in the five country case studies that follow. The final chapter suggests policy implications for different groups of developing countries and the common elements of national strategic management for accelerated development of technological capability.

Technology Diffusion: Some Analytical Concepts

The "innovation process" has traditionally been viewed as a two step process. First, an innovation is developed and commercialized. Second, it is diffused. The diffusion curve of a new technology is assumed to be "S-shaped" -- because of uncertainty and lack of information about the new technology, firms differ in the speed with which they evaluate and adopt it. Some firms prefer to learn from the experience of others. The innovator's experience reduces the uncertainty of those who wait so that as diffusion proceeds, more firms gradually form a consensus regarding the worth of the innovation.[1]

[1] See Metcalf (1982). The imitative bandwagon behavior gives the diffusion curve its S-shape, similar to "epidemic" theories that depict the spread of disease. Conventional technology diffusion models, in their S-shaped representation, resemble product cycle models of international trade. See Hirsch (1965) and Vernon (1966) for notions of the product life cycle in international trade, and Soete (1985) for a discussion of technology diffusion models. According to the product cycle theory, technological change occurs in industrialized countries, where initial production takes place, but once the technology is mature, production is drawn by lower labor costs in developing countries. Meanwhile, industrialized countries introduce new industries based on new technological advances. In other words, the product cycle theory assumes that: each industry goes through a simple and similar progression to maturity and that the point of maturity is obvious: that at maturity, the industry will be pushed out to developing countries, irrespective of the state of the maturity of the developing country economy; and that all technological change takes place in industrialized countries, and that developing

In conventional diffusion models, developing countries are perceived to be passively engaged in the acquisition and use of technology that has been generated in industrialized countries, and available "off the shelf" in blueprints or codified knowledge.[2] In the real world, however, technology acquisition is neither costless nor quick, even if the technology is widely available. Technology acquisition and exploitation involves more than simply buying "black boxes" and setting them to work.[3] Technology is not just hardware but also the knowledge, means, and organization involved in applying science to the production of goods and services. A large part of technology involves tacit rather than codified knowledge, and the acquisition and absorption of tacit knowledge requires a minimum technological capability to assess, procure, assimilate, adapt, use or improve technology.[4]

Informed judgments about the suitability of different technologies must be made before adopting them. While easy access to foreign technology -- through direct foreign investment, licensing, imports of capital goods that embody modern technology, or other formal or informal means -- is essential, access alone may be insufficient to acquire and make best use of foreign technology. Firms should be able to identify their technological needs, search for foreign technologies, evaluate alternatives, negotiate terms, and procure them. The ability to assess technologies is particularly important for firms that plan to export.

It is usually necessary to adapt acquired technology to suit local conditions such as climate, raw materials, scale of production, or product markets. As Rosenberg (1972) argues:

> New techniques frequently require considerable modifications before they can function successfully in a new environment. This process of modification often involves a high order of skill and ability, which is typically underestimated or ignored. Yet the capacity to achieve these modifications and adaptation is critical to the successful transfer of a technology -- a transfer which is too frequently

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countries are simply passive recipients. For a critique of product cycle theory, see Stewart (1982). See also Mody and others (1992), which suggest that IT has resulted in the reversal of the product cycle in some industries. The standard technology diffusion model also resembles Rostow's theory of the stages of economic growth. See Rostow (1960) for his notion of the S-shaped pattern of "take-off," rapid growth with the "drive to maturity" followed by slower growth associated with the "age of high mass consumption."

[2] The perception of developing countries engaging in passive and costless technology acquisition is consistent with the gist of most trade theories -- ranging from the traditional Heckscher-Ohlin theorem (which assumes identical technologies and equal efficiency in the use of technologies among countries and firms) to "neo-technology" theories (which reject most neoclassical assumptions and identify technological differences between countries as a key determinant of comparative advantage).

[3] Economists traditionally assume that entrepreneurs are capable of switching between production techniques and that they have adequate information on which to base such choices.

[4] See for instance, Rosenberg and Frischtak (1985) and Scott-Kemmis and Bell (1988).

thought of as merely a matter of transporting a piece of hardware from one location to another.

If technologies are imported from different sources, the various designs, components, and processes may need to be standardized. It also may be possible to save energy, use local materials, create byproducts, or increase the market for products by making minor modifications.

Furthermore, firms or countries must be able to upgrade technology in line with developments taking place locally and abroad. Technology changes, and no industry in the world, however mature or stable, which does not experience technological change over time.[5] Contrary to the static representation of the diffusion process in standard models, both the innovating environment and its surrounding economic environment may change as diffusion proceeds, and one may expect improvements in the innovation as diffusion evolves.[6] Firms in developing countries would have difficulty in maintaining their market shares unless they continuously upgrade their products and processes.

As such, limited technological capability of the organization (firm or government) is a crucial impediment to IT diffusion not just in the developing world but also in OECD countries.[7] Learning curves and associated education and training requirements are frequently underestimated. New equipment may require jumps to entirely new learning curves rather than incremental progressions.[8] IT application and innovation also require planning and organizational management and entrepreneurship.[9]

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[5] See Lall (1987) for an account of differences in the nature of technological change in different types of industries, and implications for capability development in developing countries.

[6] Initial versions of new products or processes often suffer from flaws in design or manufacture (David (1992)). The identification and correction of defects depend on feedback from users. Rosenberg (1982) refers to this process as "learning-by-using," analogous to "learning-by-doing."

[7] Robert Solow has noted that some of the expected benefits of information technology -- particularly productivity improvements -- have been slow to materialize in OECD countries. McFarland (1992) has summarized the conclusions of sixteen studies concerning the obstacles to the full realization of benefits from IT investments in industrialized countries. Frequently cited obstacles are lack of organizational coordination and conflicts (100 percent of the sample), lack of management support (94 percent), inadequate training (62 percent), and insufficient staffing/recruitment (50 percent).

[8] The importance of absorptive capability has been stressed even by Perez and Soete, who are generally optimistic about catching up with the aid of IT. Perez (1985) argues that a "reasonable previous level of productive capacity and externalities and a sufficient endowment of qualified human resources in the new branches of engineering" are essential prerequisites. Similarly, Soete (1985) admits that the potential for technological "leapfrogging" into microelectronics remains subject to "critical income and absorptive capacity," and that these conditions are only fulfilled in a relatively small number of industrializing countries, let alone low-income developing countries. Noting the importance of the "non-randomness" of technological progress, Soete argues that learning-by-doing would reinforce the cumulative effects of technological advantage (Pavitt 1984, Dosi 1982).

[9] As Perez (1985) argues, many failures at computerization and information systems development stem from thinking that they are mere pieces of hardware that can be easily incorporated into the previous plant or office with some

The importance of a firm's capacity to absorb technology is more apparent if we consider IT as a new techno-economic paradigm, as opposed to the electro-mechanical techno-economic paradigm.[10] One hypothesis has been that the closeness of IT to scientific knowledge (considered a public good) makes it easier for developing countries to acquire it. This is based on the premise that the knowledge required to enter a techno-economic paradigm during its early phase is "public" knowledge available at universities; given the availability of well-qualified university personnel, a window of opportunity opens for autonomous entry of small firms and lagging countries into new products in a new technology system in its early phases (Perez 1988a). It is only as the paradigm evolves, the argument goes, that it generates knowledge and skills of a proprietary nature. With time, the system approaches maturity and, again, knowledge and skills become "public."

While IT has many public goods characteristics, some technologies also have "operative" techniques, often requiring substantial investment for the firm to adapt it to suit its uses.[11] This is particularly true of the use of computers in manufacturing. Adaptation and assimilation of IT to specific industrial needs requires initial technological learning in relevant production, and the availability of academically qualified scientists and electronics engineers *per se* would be insufficient. There is, however, a spectrum of information technologies with varying degrees of public goods features. Absorbing many early IT applications (such as computerization

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adjustments in capabilities and institutions. The same concern is expressed in Hanna and Boyson (1992) in a study of IT projects financed by the World Bank. The authors argue that the primary constraint to increasing the returns to the use of IT in developing countries lie in human capital and organizational limitations. For more about the importance of organizational capabilities, see Alan Cane's paper in *World Development*, volume 20, number 12, 1992. Cane asserts that automation takes second place to organization of production, in worldclass manufacturing. Also see O. Bertrand and T. Noyella (1988), Strassmann (1985), Zuboff (1988), Hammer (1993), and Peterson (1991).

[10] Some analysts, including several "evolutionary" theorists of technical change, have likened the IT revolution to the economic and social transformations that resulted from the steam engine or electricity (David 1989). According to this interpretation, the ongoing changes associated with IT are not just a set of changes in production techniques that involve greater use of electronic equipment but a much broader phenomena that includes organizational change within firms, as well as in their relationships with customers, competitors, collaborators, and other institutions. As with other techno-economic paradigms in the past, the IT revolution is paving the way for a restructuring of economies. Not only do some branches displace others, but also the relationships among branches are modified. The transition brings with it a wave of new investment opportunities together with either the demise or a profound transformation of many industries and services. Perez (1985) makes a distinction between "automation" and "systomation" in order to describe a "new trend towards merging all activities -- managerial and productive, white and blue collar, design and marketing, economic and technical -- into one single interactive system." See Perez (1985), p. 453. Also see Kaplinsky (1984) for an account of the concept of "systomation."

[11] Nelson (1980) distinguishes between two types of knowledge which could help understanding the "public good" features of IT: "basic research" -- inferences about how things work and identification of constraints and ways of overcoming them, and "operative techniques" -- ways to make things work that are specific to the task. Basic research possesses public good features since it has a wide range of applications. It can be communicated without major learning costs, and it could limit the capabilities of those denied access to it (OECD 1992). In contrast, public good features of operative techniques are limited. Their range of applicability is narrow, they need to be adapted to the specific needs of the user, and therefore, learning entails higher costs.

of banks, airlines, ports, railways, and utilities) was easier than acquiring the capabilities needed for computer-aided design (CAD), computer-aided manufacture (CAM), or introducing microelectronics in products. But as countries' industrial structures acquire sophistication, they need to move towards more sophisticated IT applications, in turn, necessitating greater technological capabilities.

The ability of firms to take advantage of the new techno-economic paradigm is further constrained by continuities from the previous paradigm. For instance, improvements to electro-mechanical technology could prolong its useful life, so its final disappearance may be a slow process.[12] Furthermore the learning process of IT is constrained by a firm's past practices, knowledge base, and the "innovative structure" (David 1990). These structures have significant inertia, and hence can change only slowly. Therefore, benefits accrue slowly when a technology is in the early phase of diffusion.

Given these strands of continuity, adoption of IT may depend on the capabilities of firms in both electromechanical technology and microelectronics, information processing, and system management. The ability to integrate past practices with new ones can be very important; firms that lack cumulative learning may find it difficult to make the transition.

All this means that firms in developing countries will vary in their capacity to take advantage of the new techno-economic paradigm. Successful adoption of technology may depend on the firm's technological capability -- its accumulated research and development, training and organizational practices, and so on. In cases where the firm has already invested in the development of its absorptive capacity in the relevant field, acquiring and mastering new technology would be easier and cheaper.

Determinants of Technological Improvements

Firms have very different objectives and strategies toward technology acquisition and mastery, with varying degrees of success. Some capabilities result from learning-by-doing, but passive learning alone is not sufficient to ensure technological competence in the long run. It is only through deliberate investments and specific efforts that firms can deepen their technological capabilities. As illustrated below, a firm's decision making and the nature, speed, direction, and the overall success of technological efforts are influenced by a number of demand- and supply-side factors.

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[12] As Rosenberg (1976) and Von Tunzelmann (1978) observed, the diffusion of steam power in the last century was retarded by a series of improvements to the existing water power technology which prolonged the economic life of water power.

1. The Demand for Technological Activity

What determines firms' demand for the acquisition and mastery of technology? What role can governments play in enhancing firms' demand? As shown below, a conducive macroeconomic context and a competitive market are essential.

The macroeconomic context. As with any investment decision, macroeconomic conditions such as interest rates, exchange rates, prices, fiscal and monetary policies would govern a firm's decision to invest in technological improvement. As such, governments in all East Asian economies have pursued conservative macroeconomic policies to create a stable, predictable environment for investment and trade (World Bank 1993b). Imbalances were addressed swiftly and decisively, keeping inflation low, exchange rates competitive, and debt affordable. In particular, fiscal deficits were limited to levels that could be prudently financed without increasing inflation. Because inflation was moderate and predictable, interest rates were far more stable than in low- and middle-income countries, encouraging private investment and long-term planning.

Competition. Another fundamental factor that stimulates firms' demand for investing in technological improvement is market competition, especially openness to international trade.[13] Competition pressures firms to improve productivity, quality, and product design -- which in turn drives them to acquire better technologies and introduce better work practices. Conversely, artificial restraints hold back investment in technological development and encourage firms to develop less efficient capabilities. Recognizing this, many developing countries are removing tariff and non-tariff barriers to trade, foreign exchange controls and barriers to entry and exit of firms such as industrial incensing, controls on ownership, size and labor regulations.

Different technologies require different learning periods. Acquiring and absorbing technology to produce garments may take a few months, but developing capabilities to produce automobiles takes years. There is an infancy during which an enterprise is less efficient than one that has undergone the learning process. This may warrant some infant-industry protection, which allows firms adopting new technology to absorb learning costs. The magnitude, length, and coverage of infant-industry protection, however, is at the heart of a debate over industrial policy. While infant industry protection can provide breathing space during which firms can develop new capabilities, interventions also pose dangers arising from the risk of government failure.

Indivisibility, inappropriability, and uncertainty affecting research and development. Research and development is essential to absorb knowledge from external sources.[14] Even though the public goods features of science have sometimes led to the simplistic

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13 A number of writers have tried to link rapid growth to openness. See World Bank (1991), chapter 5.

14 See Cohen and Levinthal (1989) for an account of the two "faces" of R&D. They argue that firms undertake R&D not only as a direct input to innovation but also as a means of absorbing external knowledge. Using data on R&D

conclusion that firms can avail themselves of the scientific knowledge generated by academia, at no cost, recent studies suggest that in-house R&D raises a firm's ability to take advantage of public science (Gambardella 1992). Rosenberg (1990), for instance, argues that even though scientific knowledge circulates in the outside environment, firms must undertake their own basic research to understand and utilize external science. Hence, as Rosenberg argues, in-house basic research is the price to "plug into the outside information network". The interactive character of innovation and the link between science and technology give an added advantage to firms that can effectively communicate with universities and laboratories.[15]

Despite the evident advantages in undertaking in-house R&D, there are many reasons why firms may not invest in R&D. Kenneth Arrow's famous 1962 article captures the traditional argument for government intervention in the generation of knowledge. Arrow identified three major sources of market failure that justify government funding of research: indivisibility of minimum efficient scale levels, inappropriability of the profit stream of research, leading to divergent public and private returns on investment, and uncertainty, the divergences in the riskiness of research for private and public sectors.

The degree to which firm-level R&D is critical to the pattern and speed of technology diffusion depends on the nature of the technology being diffused- the degree to which a particular field of knowledge is cumulative, is tacit, is targeted to the needs of the firm, and its pace of advance (OECD 1992). The more complex and generic outside knowledge is, the more important are R&D expenditures for exploiting it. The same is true when knowledge is tacit: time and effort are needed to set rules or routines that can make it useful to firms. The faster the pace of advance, the greater the effort required to keep up with developments.

As for IT, the type of R&D efforts needed to develop IT products can be significantly different from that needed to use IT as a technology in other industries and services. For example, the outside knowledge required to make computers is more complex, tacit, and cumulative than that needed to use IT in other industries and services.

Further, the complexity of knowledge required for developing capability in different IT products (say, computers versus software) can be very different. At the lower end of the spectrum are applications (say, use of computers in financial management, inventory control, and billing) that do not require much local R&D. Only as firms progress toward more sophisticated IT applications, such as computer-aided and computer-integrated manufacturing or application of microelectronics in products, does the importance of local R&D become essential.

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expenditures in the United States, they show that the second "face" of R&D plays an important role in a firm's decision to invest in R&D.

[15] As Pavitt (1991) argues, scientific research provides "skills, methods, and a web of professional contacts" that makes the firm better equipped to exploit outside findings.

The uncertainty associated with in-house R&D is particularly high in businesses dominated by short-term profit considerations. Indivisibility of research can retard R&D efforts of small and medium size enterprises (SMEs). Realizing this, governments in OECD countries and some East Asian NIEs have provided incentives to encourage firm-level R&D in IT, as well as support to universities and the research system linked to them. These institutions provide qualified personnel to access global knowledge, the base for applied research, and international R&D networks.

Lack of awareness about new technology. Firms' initiative for adopting new technology can also be impeded by their lack of awareness of the potential of new technologies to raise productivity and product performance. They may know little about the their potential payoffs, standards, support services, new skills required, or need for accompanying managerial and organizational changes. This was the experience at the outset of the IT revolution in OECD countries, especially among small and medium-sized enterprises and low-tech traditional sectors. An objective of most IT diffusion programs in East Asian NIEs has been to educate not just the potential user firms but also the general public of the scope of IT.[16]

Risk aversion. Even if a firm is aware of the payoffs, aversion to risk can dampen its demand for a new technology. Faced with deploying a new technology, firms tend to underinvest. Again, governments in OECD countries and some NIEs have provided incentives to increase firms' demand, such as consultants to explore applications and markets for IT products, shared facilities for consortia of firms, tax incentives, and other financial assistance.

2. Supply Factors

Firms must build manufacturing capability internally, but they depend on external sources for information, skills, and finance. Each of these factors has its own market and may suffer from market failure -- warranting government intervention.

Information. Access to technology and market information is essential for improving technology. The import of foreign technology itself requires information about various technological options, sources, and costs that would help firms to assess and negotiate the transfer of technology. In addition, firms need information to adapt and assimilate imported technology to local conditions, to use, and improve them. But most industrial firms in developing countries have limited access to information.[17]

Yet technical information may not always be costless. Much is freely available from technical journals, suppliers of machinery, buyers of products, visits to exhibitions, and so on. However, there is a range of technical information that are not provided by the "market".

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16 See Hanna, Guy, and Arnold (1994).

17 Lack of information could also hinder a firm's demand for technological improvement.

Contrary to the implicit assumptions of conventional diffusion models, some key technologies are simply not available "off the shelf" but can be acquired only by collaborating with firms that control them. Successful transfer of some technologies require tacit, or uncodified knowledge which firms in developing countries do not have. Diffusion of tacit knowledge may depend on the "public goods" features of such knowledge or the ability to appropriate that knowledge by its innovator.

Given information market failures and the near absence of private sector provision of information and support with public good features -- such as standardization, metrology, testing facilities, and extension services to SMEs -- East Asian governments disseminated them through their technological infrastructure.[18] In some countries including Japan, Korea, and Taiwan, technology support institutions are important sources of information, especially when technical and business information are coupled with a good technology extension system.

Skills. Skills are essential for moving up the technological ladder. Even the simplest technologies like those used in labor-intensive manufacturing industries like footwear and garments require a range of worker, supervisory, maintenance, quality control and adaptive skills in order to operate at world levels of efficiency. Success in sophisticated industries is contingent upon the availability of more complex, specialized skills. Furthermore, all technologies change over time, requiring firms to upgrade skills. It is difficult to remain internationally competitive in any industry in the long-run unless firms acquire higher technical and managerial skills.

A change in the techno-economic paradigm, such as the one caused by the IT revolution, imposes even greater pressure on countries and firms to rejuvenate skills.[19] IT has spurred new ways of information management, new forms of telecommunications, and new patterns of industrial relations, requiring managers, engineers, and technicians as well as plant workers to learn new skills and patterns of interaction. An international marketplace, evolving toward custom-made products and globalized production, has imposed greater demands for capabilities in strategic planning, flexible manufacturing, just-in-time and total quality control production, as well as new forms of global sourcing.

The garment industry provides a good example of the need for IT-based skills. Its global production and marketing are characterized increasingly by quick-response manufacturing,

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[18] As argued in World Bank (1993a), regarding industrial technology, in early stages of development, simple testing, quality assurance, and extension and information services are the most important needs. Simply informing firms of the need to invest and showing them how to go about it is critical. In later stages, standards, metrology, applied and basic research and coordination of information become predominant as firms internalize technological functions. However, even in mature industrial economies, firms, especially small and medium-size enterprises, need information on technology. Many industrialized countries have technology information services for small and medium-size enterprises; Japan has perhaps the most extensive and supportive public services. Also see OTA (1990).

[19] According to one study in the United States (by IBM), in computer science, knowledge becomes obsolete 2.7 years after graduation unless it is updated (OECD 1989b, p. 174).

computer-based production and "design-intensive" clothing. Computer-aided designing, for instance, allows faster generation of designs and cost savings on the integration of design with pattern grading, pattern marking, and fabric cutting. It increases speed, accuracy, material utilization, quality, and process control. Firms that do not deploy such new technologies are finding it increasingly difficult to compete internationally, especially when trying to move up market.[20] Just-in-time management (that reduces buyers' risk) has forced garment producers to respond quickly to small but diverse production volumes. IT can facilitate this process by linking design with production, or through linking buyers with producers.

Even though all kinds of education are needed for industrial progress, a greater emphasis on science and engineering training appears to be essential for coping with the IT revolution (Katz 1991). A complete rethinking of curricula may be needed at universities, secondary schools, vocational and technical training institutes -- not only to teach the new entrants to the labor force, but also to retrain managers, engineers, operators and so on.

Do governments have any role in improving the skills base of countries? While firms can build a significant amount of human capital with their own efforts, they need a base of manpower to draw from. This base can be provided only by the national system of education and training. The education "market," however, is subject to well known failures due to lumpiness of investments in education, imperfect foresight, and lack of information. Firm-level training also can suffer market failure. Firms may underinvest in training their employees if they fear losing them or if they do not fully perceive the benefits of training. Private markets are generally incapable of fully anticipating future skill needs of a country, especially when it is a question of building human capital in new technological spheres. This justifies policy intervention to ensure the availability of adequate manpower with the appropriate skills (World Bank 1993a). The case for government intervention is particularly strong for building human capital in generic IT, with its public-good features and high social rates of return.

East Asian governments have played a key role in education and training. In fact, their industrial success is a result of their investment in education, especially technical education and vocational training (World Bank 1993a). Limited public funding of post-secondary education focused on technologically sophisticated disciplines. In addition to improving formal education in IT-related subjects, most East Asian NIEs have launched policies and programs to retrain staff.

However, we lack basic understanding of what public action is most desirable. The adoption of new production techniques, such as just-in-time or total quality management, requires institutionalized procedures for trade union participation and a new approach to on-the-job training. Such changes also demand a change in trade union attitudes. Imaginative ways of

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[20] Using new technology such as computer-aided patern marking or designing would not necessarily undermine a country's comparative advantage based cheap labor. Sewing is the most labor-intensive stage of garment production, making it possible for developing countries to compete based on cheap labor, while deploying some high-tech elements in the manufacturing process.

intervention need to be explored, given the long history of "government failure" in many developing countries.

Finance. Capital market failure is one of the most important barriers to innovation.[21] Small firms in particular find it difficult to obtain financing for R&D. Although normal financing of working capital covers a number of technological activities that take place in production, it is often insufficient to cover training and other needs. As industrialization proceeds and technology becomes increasingly complex, the financing gap may become more serious. Financing needed for investments in new and risky areas, and the financial systems in most developing countries are not willing or able to provide it. This is particularly true for IT, both in developing and developed countries. Given the failure of capital markets to support technological innovation, governments in many advanced countries, including East Asian NIEs like Korea and Taiwan, have formulated policies to facilitate technological development.

Infrastructure. Another barrier is poor infrastructure, particularly telecommunications. In diffusing IT, the importance of telecommunications cannot be overstated. Financial market infrastructure in particular is highly IT-dependent, though IT will become important in other infrastructure such as roads or ports. An IT-intensive banking system is a prerequisite for engaging in modern trade. The alternative is to be outmaneuvered by faster, better-informed dealers in international financial markets.

Debate continues as to whether telecommunications promote economic development or vice versa, but the relationship between the two is becoming stronger. The rate of technological change in telecommunications is so high that it only makes sense to invest in the latest technologies, which are cheaper, more efficient, and more reliable than many of those around which OECD telecommunications systems have been built. Indeed, technologies such as PCN (Personal Communications Network) or high-frequency digital cellular radio offer low-capital-cost alternatives to traditional telecommunications that would leapfrog much of the terrestrial fixed links technology to which OECD countries are tied by historical investment patterns.

3. *Market Failure versus Government Failure*

Despite theoretical and empirical arguments for government intervention, public support for technology development remains controversial. Concerns about "more government" in technology emanates from fears of "government failure" or in other words, the fear of "policy-induced" distortions as well as governance issues such as accountability, transparency, rent seeking, and the like.

Most neoclassical economists recommend against policy-imposed distortions. Citing East Asian and Latin American NIEs as contrasting examples, the neoclassical school

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[21] See Stiglitz (1993) for an excellent discussion of financial market failures and the need for state intervention.

heralds the virtues of adopting an "outward-oriented" strategy of development, which is deemed to have allowed East Asian NIEs to gain from trade based on comparative advantage. The fundamental characteristic of an outward-oriented policy, according to this interpretation, is the absence of government-imposed biases toward local or international markets, or different industrial sectors. Incentives in East Asian countries were generally trade-neutral as well as industry-neutral.

By contrast, the argument goes, industrializing countries that had followed an "inward-oriented" path suffered from an anti-export bias in incentives, leading to lower economic growth. Recent neoclassical writings do not deny that some East Asian NICs -- especially Korea and Taiwan -- have benefited by promoting selective industries in view of infant- or strategic-industry considerations. But they conclude that selective intervention worked because the combination of import barriers and broad measures of export promotion added up to essentially neutral policies, equalizing incentives for producing for the domestic and export markets. Still, the neoclassical school warns against picking winners as a general rule, since targeting can potentially misallocate resources into inefficient uses and slow down economic evolution based on comparative advantage. Selective intervention can also waste resources by giving rise to rent seeking (Krueger 1974).[22]

Structuralist explanations of East Asian development focus on government action that go far beyond "getting the fundamentals right.[23] In addition to providing a conducive macroeconomic context, the structuralist argue that East Asian countries have actively promoted and facilitated dynamic and efficient industrialization. For some structuralists, the government's role was to remedy market failures -- in finance, skills, information, and technology. For others, the government has more than just compensated for market failures, it has coordinated and led markets in pursuit of dynamic comparative advantage.[24] Whatever the interpretation, according to the structuralists, the markets in East Asian countries were not "free."

Central to all structuralist interpretations of East Asian development is industrial policy, defined broadly as a set of coherent policies based on a strategic view of how a country's industrial development should evolve in relation to global changes. Distinguishing between established and infant industries -- particularly in Japan, Korea, and Taiwan -- structuralists assert that while the incentives for established industries were "policy -neutral", there was significant "industry-bias" in favor of selected infant industries (Pack and Westphal 1986). The set of selected industries, however, changed over time, and have benefited from a variety of policy instruments -- tariff and non-tariff protection, preferential credit, tax incentives, procurement policies, and so on. Infants, generally limited in number at a given point, were forced to export

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22 Also see Bhagwati (1982) and Bhagwati and Sirinivasan (1982) for more on rent seeking.

23 Some structuralists have even questioned the basis of the "right" fundamentals by asserting that some NICs got their prices "wrong" in the neoclassical sense. See Amsden (1989).

24 See Wade (1990).

quickly. In other words, governments avoided big policy mistakes by limiting the duration of support and enforcing performance standards. The threat of losing preferential treatment forced firms to perform -- and meet export targets. In sum, both the "carrot" and the "stick" were employed to discipline firms.

In contrast, the neoclassicals tend to denounce or at least downplay the importance of industrial policy, which is often (and misleadingly) equated with import protection and subsidies. To the extent market failures need to be addressed, the neoclassicals prefer "functional" but not "selective" intervention. Functional intervention is usually defined as government action that addresses the development of efficient markets in a manner that is neutral between activities. Selective intervention, as the term suggests, is directed at specific activities. It should be noted, however, that most structuralists do not suggest that every intervention is justified. Recent structuralist writings tend to differentiate between "good" and "bad" intervention. Instead of equating industrial policy with "picking winners," recent structuralist thinking focuses on creating the conditions for winners to emerge through clearly articulated, well designed industrial strategy.[25]

Are governments in other developing countries capable of managing technological change in a similar manner? This issue obviously requires indepth analysis of different country conditions. Our case studies suggest that country experiences are more complex than what is implied by one theory, and that the neoclassical framework in particular cannot explain the rapid industrial growth and technological development in East Asian NICs. Indeed, no policy orthodoxy can provide blanket solutions to the problems of all nations at all times, and substitute for pragmatic policymaking.

Strategic Planning and Management

The five country studies suggest that institutional mechanisms and processes have been critical to accelerating the technological learning and industrial deepening of the East Asian NICs. The new concepts of strategic planning and management provide useful tasks to understand these processes. We draw on these concepts to suggest that the modalities of strategic planning and management used by the NICs at the national and corporate levels have reduced the chances and costs of failures of government interventions and avoided many of the pitfalls of old-style planning.

[25] Government intervention in view of market failures can be justified within the neoclassical framework as well, even though many neoclassical writers contend that there are few inherent market failures and that existing market imperfections are by and large caused by policy failures -- licensing restrictions on production, interference with wage setting (Pack and Westphal 1986). Many neoclassical writers further recognize that inherent market failures involving dynamic considerations may warrant a certain degree of government promotion of industry. However, the neoclassical and structuralist writers disagree on the means of promoting industry. The neoclassicals insist on uniform infant industry incentives across industries without administrative discretion (*ibid*, p. 89).

Old-style corporate planning has been discredited for reasons that are similar to national planning: it assumed a predictable future in an uncertain environment, it was the sole responsibility of a central staff; it was slow and rigid in the face of a change; it focused on comprehensive blueprints; and it ignored incentives, participation, communication, capabilities, and other critical factors. The solution was to improve strategic planning, not to abandon it. The need to plan remains: to understand the direction of competition, clients and markets, and resources and technologies, and to think strategically about competitive advantage. Leading-edge corporations began to address these limitations in the 1980s, and they introduced concepts, tools, and processes to support strategic thinking, flexibility, and management. Best practices in corporate planning and strategic management have the following qualities:[26]

- *Agility*. Planning should emphasize agility, selectivity, and flexibility to focus management on anticipating strategic issues in a timely manner. The process should be informed but not enslaved by analysis and documentation. It should engage managers in developing alternative scenarios and managing uncertainty.

- *Externally-oriented*. Strategy should be borne out of close relations with clients and markets. Strategic planning should promote thinking about the external environment, understanding potential competitors and collaborators, and experimenting and learning. Increasingly, outward-orientation is extending to global markets and transnational alliances.

- *Ownership*. Strategy formulation and implementation are both top-down and bottom-up processes. While led by top management or policymakers, these processes should engage all stakeholders to ensure commitment and implementability. Strategic management facilitates decentralized and yet coordinated decisionmaking. It provides common frameworks and clear guides for all choices, but not a blueprint for central control and mechanical implementation.

- *Learning-oriented*. Planning should be action-oriented. It should incorporate multiple and continuous feedback. It should support piloting and experimenting. Strategic management seeks opportunities and institutionalizes organizational learning.

- *Capability-enhancing*. Strategic management is concerned with both the strategy and the capabilities needed to support this strategy. It is concerned with building capabilities for strategic flexibility. It is also concerned with shaping the appropriate information systems and incentives for superior performance.

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26 See Nagy Hanna (1985).

1. Diversification and Portfolio Management

Portfolio management techniques allocate resources among diversified businesses. Diversified companies examine the contribution of each business to the corporate portfolio and manage resources among them. They invest resources from mature businesses (and from candidates for contraction or divestiture) in new growth markets or industries and companies that enjoy current or potential competitive strengths. These techniques also allow top managers to set strategies for each business in accordance with its needs. They also guide decisions on divestitures and acquisitions.

There is a parallel between corporate portfolio management and the national industrial portfolio. Corporate strategists play to the strengths in the portfolio. On a national scale, this process involves difficult political choices. Yet with global competition, governments must make hard choices. This is not an issue of whether countries should have a national industrial policy -- they often do have one that supports weak and unpromising industries. [27]

Through MITI and the banking system, Japan supported industries that enjoy high potential. In developing countries with underdeveloped capital markets, scarce professional management and few large companies, portfolio management may be even more important. Yet portfolio management tools have their limitations and alone cannot define corporate strategies. Increasingly businesses are related, and successful corporations have recognized the value of relationships. Corporate diversification strategy is moving beyond acquisition, divestiture, and restructuring and towards exploiting synergy among businesses. One source of synergy is skills and expertise that can be transferred and shared among similar activities in different businesses. The activities and skills involved must represent competitive advantage.

Another source of synergy is R&D and service networks. They exploit economies of scale and help diversify product lines. Synergy can be encouraged by a strong corporate identity and vision; incentives that rewards cooperation, cross-business-unit task forces, and other integrating methods.

These concepts are applicable to national economic and industrial diversification. Advanced skills, physical and institutional infrastructures, and related and supporting industries are necessary platforms for successful diversification.

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[27] For applications of portfolio analysis at the national level, see Marcus C. Bogue III and Elwood S. Buffa (1986), *Corporate Strategic Analysis*. The Free Press, New York.

2. *Core Competencies and Strategic Intent*

Recently two concepts have been introduced to explain superior and sustained corporate performance: core competence and strategic intent.[28] The corporation is a portfolio of competencies, not simply businesses with particular products. Core competencies are the skills in the organization -- how it coordinates production capabilities and integrates diverse technologies. If the diversified corporation is viewed as a tree, then the core competencies are the roots, providing sustenance and stability. The trunk and major limbs are core products, the smaller branches are business units, the leaves and fruits are end products. The strength of a corporation is not just its products. The roots of competitiveness are competencies.

Successful companies are in a race to build the core competencies that determine global leadership. Canon, Honda, NEC or Sony may seem to preside over portfolios of businesses unrelated in terms of customers or distribution channels. But Canon's core competencies in optics, imaging, and microprocessor controls have enabled it to excel in copiers, laser printers, cameras, and image scanners. Honda's core competence in engines and power trains gave it a distinctive advantage in car, motorcycle, lawnmower, and generator businesses. In NEC, digital technology, especially VLSI and systems integration skills, are fundamental to its business. So is Sony's capacity to miniaturize.

These companies have systematically identified, developed, and applied their core competencies. At least three tests identify core competencies. First, it allows access to a variety of markets. Second, it contributes to the perceived customer benefits of the end product. Finally, it should be difficult for competitors to imitate. Competencies, not just profitability or market attractiveness, guide diversification and market entry.

The development of core competencies requires "strategic intent." It involves communication across profit centers and organizational boundaries. For example, in the early 1970s NEC articulated a strategic intent to exploit the convergence of computing and communications (C&C). It constituted a C&C committee of top managers to strengthen its position in semiconductors and components. As they entered collaborative arrangements, NEC's operating managers understood the rationale for these alliances and the goal of internalizing partner skills.

Strategic intent challenges the traditional concept of fitting resources (including capabilities) and opportunities. Companies that have risen to global leadership invariably followed ambitions out of proportion of their resources. They created an obsession with winning at all levels of the organization and sustained it over decades. Management focuses on the essence of winning, motivates people by communicating the value of the target and eliciting personal commitment, sustains enthusiasm by establishing teams and maintains its vision to guide resource

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[28] See C.K. Prahalad and Gary Hamel, "The Core Competence of the Corporation," *Harvard Business Review*, May-June 1990, pp. 79-91; and "Strategic Intent," *The McKinsey Quarterly*, Spring 1990, pp. 41-61.

allocations. While strategic intent is clear about ends, it is flexible as to means. Management challenges the organization by creating a sense of urgency, developing a competitor focus, establishing milestones to track progress, and building new advantages.

Strategic intent assures consistency in resource allocation over the long term. Articulated challenges focus the efforts of groups and individuals in the medium term. And by attending to opportunities, it promotes continuous improvement and innovation in the short term. This consistency provide the key to leveraging limited resources in pursuit of ambitious goals.

Finally, strategic intent may explain learning within international strategic alliances. Not all partners are equally adept at learning. Studies suggest, for example, that Western firms entered alliances with their Asian counterparts mainly with substitution intent, to avoid investment in particular skill areas.[29] In contrast, the Japanese counterparts in these alliances seemed to possess explicit learning intents. Systematic learning took place only in the context of a clear intent. Whether a firm possessed an explicit internalization intent seemed to be a product of: whether it viewed collaboration as a more or less permanent alternative to competition or as a temporary vehicle for improving competitiveness, its relative resource position vis-à-vis its partner and other industry participants, and its calculation of the payoff to learning. In those firms where internalization intent was strongest, the skills to be acquired from the partner were seen as critical to the growth of the company. Without clear corporate goals for competence building and an appreciation for the critical contribution of core competence leadership to long-term competitiveness, business units appeared unlikely to devote resources to learning. And learning within an alliance takes a positive commitment to resources -- dedicated staff, test-bed facilities, and time to internalize and test what has been learned.

3. The Competitive Advantage of Nations

Porter (1990) makes an important contribution to bridging the gap between strategic management and economic literature, and draws on the theory of competitive advantage at the firms level to offer insights into the determinants and dynamics of national competitive performance.[30] Four sets of variables influence firms' ability to establish and sustain competitive advantage.

First, endowments provide initial advantages that are extended and reinforced through advanced factors such as communications infrastructure, skills, and research facilities. Advanced factors are the most significant and enduring for competitive advantage.

Second, domestic demand provides the impetus for improving competitive advantage. Firms are sensitive to customer needs, and home demand is particularly important in

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[29] See Gary Hamel, "Competition for Competence and Inter-Partner Learning Within International Strategic Alliances," *Strategic Management Journal*, vol. 12, 1991, pp. 83-103. John Wiley & Sons Ltd.

[30] Porter, M.E. (1990). *The Competitive Advantage of Nations*. Free Press, New York.

shaping products and pushing quality and innovation. Sophisticated domestic customers affect the creation of advanced factors and investment in technology and skills.

Third, related industries are a source of competitive advantage. Successful industries tend to be grouped into clusters of supporting companies. That is because an industry's investments in advanced factors have spillover benefits. Economies that are external to individual firms and industries are internalized within the industry cluster. This is best illustrated by the Silicon Valley in the United States.

Fourth, systemic differences among business sectors are important determinants of competitive advantage. These differences include corporate strategies, industrial organization, managerial practices, and domestic rivalries. For example, the small, family-owned companies in Italy as well as Taiwan, Singapore, and Hong Kong may have been conducive to success in industries where flexibility and entrepreneurial responsiveness to fashion or market changes are competitive advantages. Managerial practices in Japan, which emphasize the long term and life-long employment, are an advantage in industries where continuous labor training is important. Because domestic competition can be more personal, and intense than foreign competition, domestic rivalry is particularly effective in promoting competitive advantage.[31]

These four influences are interdependent (*figure 1.1*). The interaction creates complex dynamics, and its intensity affects international success. Competitive advantage is a dynamic process of continuous learning, guided by strategic intent to create and maintain core competencies.

The firm's resource base is not simply a function of its investments but is determined by resource supply and creation. This interaction between firm-level and country-level sources of competitive advantage suggests important roles for government.

Government can contribute to the conditions that are most conducive to upgrading competitive advantage, working through each of the four variables and improving their interaction.[32] In some instances, government may, for example, invest in technical education, training and infrastructure; create incentives for private investment in technology diffusion; and encourage dissemination of information. Often, government pushes and challenges. It can set regulations and standards for quality, safety and environment that anticipate or respond to emerging international trends. It can also act as an early, sophisticated buyer and standards-setter, as the United States and Singapore governments did in software and other information technology

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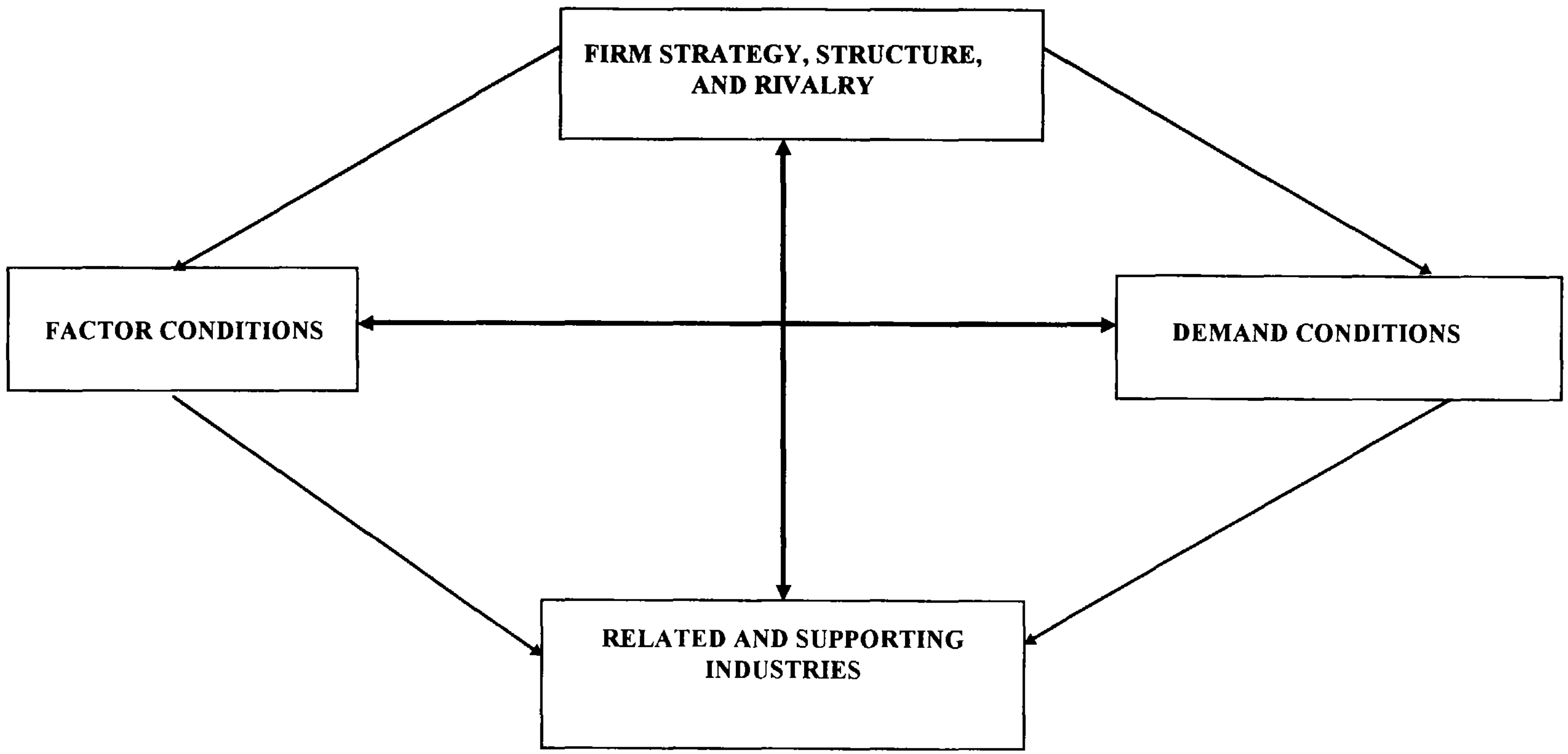
[31] In Korea and other Asian NICs, this rivalry was expanded to include contests and rewards for export performance. This export push provided domestic rivals a powerful mechanism for technological upgrading and access to best-practice technology. (See *The East Asian Miracle: Economic Growth and Public Policy*, 1993, World Bank, Washington, D.C.)

[32] Porter's analysis suggests governments can strengthen the base of skills, technology and institutions that firms can use to develop. But his analysis does not account for failures in factor or product markets.

industries. It can also support change between universities, research institutes, industries, consumers and infrastructure providers.

The following country studies demonstrate how public-private coalitions have strategically managed the continuous upgrading of national competitive advantage in the IT industry. They further explore how IT has been systematically used to enhance economy-wide competitiveness. Strategic planning and management concepts are key to understanding these processes.

Figure 1.1: The Determinants of National Advantage



CHAPTER 2: INFORMATION INDUSTRY IN JAPAN

Introduction

The Japanese model of information technology industry development has been as the forerunner and guide to all other national initiatives in the region. First to move up the "diamond of industrialization" to higher-value, higher-productivity use of organizational and technical skills, capital, and technology, Japan has acted as pacesetter in its policies and strategic approaches.

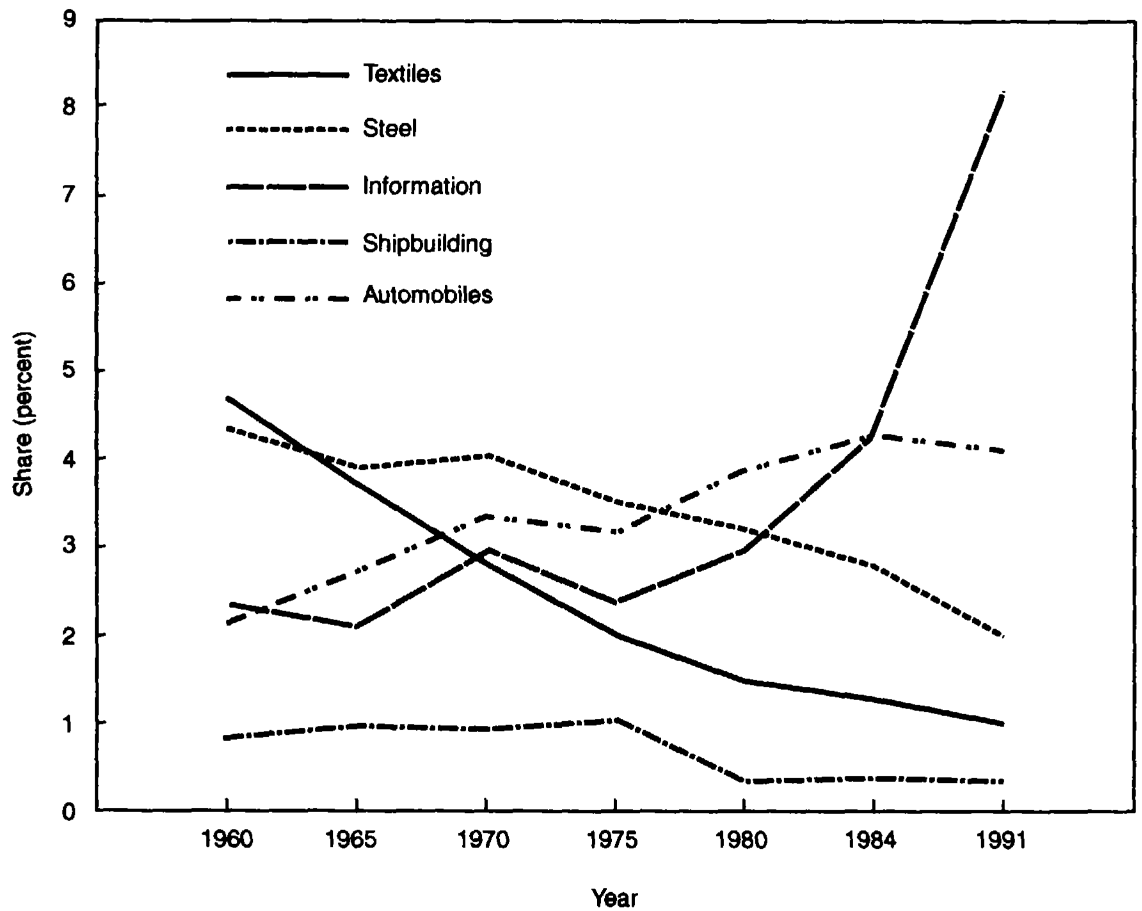
Japan's 1973 oil crisis induced a shift away from heavy industry to less energy- and material-intensive sectors, spearheaded by electronics and telecommunications. This shift resonated throughout the region and was echoed in Singapore's 1979 call for a knowledge-based economy and Korea's and Taiwan's similar call in the 1980s. Japan's contributions have included public-private collaboration; research and technology development consortia; internationalization of information industry activities, such as the seeding of electronics production plants throughout the region and investing in Western information industry firms and universities to acquire leading edge technologies; and cultivating selective technology competencies.

Yet one must see beyond the myth, to the contradictions and deficiencies that remain barriers to Japan achieving an information society. Low levels of computerization in business, low levels of systems networking and on-line access to databases and the Internet, and bureaucratic and regulatory inefficiencies compound Japan's difficulties, already serious given the drastic restructuring regimen imposed on its leading companies (especially electronics companies) by regional competition and international recession. The hope persists of a widespread turnaround similar to the come back of Nippon Telephone and Telegraph (NTT), which is starting to emerge from a drastic restructuring involving payroll cuts of 200,000--and which regained the biggest market valuation in the world -- US$141 billion -- in 1993 (*BusinessWeek* 1993). Perhaps, NTT's comeback as the purveyor of the most advanced IT infrastructure in Japan speaks to the resilience of the national goal of optical fiber to every home by 2010, and to the dynamic nature of the information industry in Japan.

Profile of the Information Industry

The information industry, led by electronics, is now the leading segment of the Japanese economy, having replaced heavy industry as the motive force of development (*figure 2.1*).

Figure 2.1: Share of Leading Industries in Total Domestic Product



Source: Sato.

Japan's information industry is based on its vanguard electronics manufacturing position in the international arena. This manufacturing base has generated spinoff activities, including rapidly globalizing intra-firm and inter-firm networks, telecommunications, software development and systems-integration services and slow but steady diffusion of IT to civil society. The critical mass of national IT prowess is highlighted in *box 2.1*.

Box 2.1
Indices of Japanese Strength in Information Technology

- Japan spent the second largest sum on information-related products and services in 1991. Its 19 percent of OECD spending was behind the United State's 34 percent share.[33]

- Japan accounts for one-fourth to one-third of worldwide demand for semiconductors. In 1991 Japan's semiconductor market was $23.8 billion.[34]

- Japanese production of integrated circuits has grown from $2.3 billion in 1978 to $20.3 billion in 1988, 60 percent of the world production of $33 billion.[35]

- Japan owns 95 percent of the global market for advanced flat panel screens, an opto-electronic product with $9.4 billion in projected sales by 2000.[36]

- From 1982-92, Japan tripled computer production, and its leading corporations increased their share of global computer sales from 7 percent to 23 percent.[37]

- Japan has 390,000 robots in production, compared to America's 45,000, a 15-20 year lead.[38]

- Japan has one-third of the world's installed base of super-computers.[39]

Sources: (Listed below)

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[33] Japan Economic Newswire, March 18, 1992.
[34] *Economist*, May 30, 1992, p.63; and *Businessweek*, Sept. 28, 1992, p.81.
[35] Wellenius, Bjorn, "Developing the Electronics Industry," World Bank, 1993, pp.139 and 185.
[36] *Businessweek*, May 10, 1993, p.48.
[37] *Fortune*, March 9, 1992, p.33.
[38] *Fortune*, Sept. 21, 1992, p.15.
[39] Office of Naval Research--Asian Office, Scientific Information Bulletin, vol. 18, Nov. 2, April-June, 1993, p.5.

1. Electronics Industry

Between 1975 and 1985, Japan had both the biggest increase in the proportion of electronics in total manufacturing output and the largest absolute share of electronics in manufacturing output (*table 2.1*).

Table 2.1: Share of Electronics in Total Manufacturing and GDP Selected Countries (percent)

	Share of Manufacturing Output			GDP		
Country	**1975**	**1985**	**2000[a]**	**1975**	**1985**	**2000[a]**
Japan	9.3	17.5	22.0	2.3	6.2	7.0
South Korea	9.7	12.0	25.0	2.1	3.0	7.0
Taiwan	11.6	14.6	20.0	2.1	6.2	7.0
West Germany	11.0	13.7	15.0	3.7	4.5	5.0
United States	8.1	11.1	15.0	1.8	2.5	3.3
United Kingdom	8.3	9.9	12.0	2.2	2.2	2.9
France	8.0	7.6	11.0	2.1	2.0	2.8
Italy	8.9	9.7	11.0	2.5	2.6	2.9

[a] Estimates.
Source: Economist Intelligence Unit 1991.

Japan's rapid increase in electronics output and its growing threat to competitors can be appreciated by comparing global market shares over the 1973-89 period: Japan's share of the electronics market rose from 9.6 percent to 24 percent, while the U.S. share declined from 28.9 percent to 18.3 percent, and the EC-9 share declined from 44.7 to 28.6% (*table 2.2*).

Table 2.2: Shares of World Trade in Electronics Selected Countries, 1973-89

Country	1973-79	1979-82	1985-88	1988-89
United States	28.9	23.8	19.2	18.3
Japan	9.6	17.0	23.4	24.0
East Asian NICs	3.1	8.7	13.4	15.1
EC-9	44.7	37.4	30.8	28.6
Others	13.7	13.1	13.2	14.0

Source: Guerrieri and Milana 1991.

This dramatic increase in market share suggests why Western economies fear being overrun by Japanese technology products.

Japanese competitiveness in electronics has tended to concentrate on consumer products. Yet the commercial/industrial electronics segment is a major part of the country's electronics production output. In 1990 it was worth over $120 billion, behind only North America and Western Europe in commercial/industrial production *(table 2.3)*.

Table 2.3: World Production of Electronics Equipment, 1990
(billions of U.S. dollars)

Region	Consumer		Commercial/industrial		Government/military	
	Value	Share (percent)	Value	Share (percent)	Value	Share (percent)
North America	16.6	12.4	175.9	33.6	59.3	40.8
Western Europe	24.4	18.2	135.2	25.8	19	14.3
Japan	45.1	33.6	120.3	23.0	3.2	2.4
Four Tiger	26.4	19.6	30.8	5.9	1.1	0.8
Other	21.9	16.3	60.9	11.6	55.4	41.7
Total	134.4	100.0	523.1	100.0	133	100.0

Source: Electronics Outlook Corporation 1990.

Recently Japan has exhibited symptoms of a hollowing-out phenomenon in electronics, with production of color televisions, compact disc players, videocassette recorders, and the like, shifting to lower-wage countries. In 1993 output of electronics equipment and components dropped 5 percent to 9 percent (the second consecutive annual decline) to about $190 billion. Industrial electronics production fell 6.9 percent to 9.8 trillion yen ($89 billion), including an 11.4 percent decline in the production of computers to 4.8 trillion yen ($44 billion), as domestic corporate spending on automation was sharply restricted (*New York Times* 1993). This may be a temporary adjustment caused by recession and a strong yen.

2. *Telecommunications*

The telecommunications sector has grown rapidly in the post-war era. In 1952 only 2 percent of Japanese households had telephone service, compared with 50 percent in the United States, a result of the devastation of telecom infrastructure in World War II. The creation of the Nippon Telegraph and Telephone Corporation (NTT) for domestic telecom services and Kokusai Denshin Denwa Company Limited as a provider of international communications services launched a rebuilding and modernization initiative.

Beginning in the mid-1960s, the spread of phone service picked up speed. By 1975 subscribers reached 30 million and by 1987, 47 million, or 80 percent of households. Since NTT was privatized and the telecommunications market deregulated in 1985, long-distance rates have declined 15 percent, local rates 30 percent, leased circuit rates more than 10 percent, and pocket pager rates 15 percent (Sato 1989).

Another impetus to telecommunications usage has been the creation of global computer-integrated manufacturing networks by manufacturers, increasing the connection of production, sales, design, and development centers around the world. Seiko-Epson has built a 52-country "SEIGIS" network; Canon, a "Ginka" network to link five research centers in France and the United States and production centers in Hong Kong and the west coast of the United States; and Mitsubishi Heavy Industry, Kawasaki Heavy Industries, and Fuji Heavy Industries have established a digital "simultaneous" design system with Boeing in the United States (Office of Naval Research 1993).

3. *Information Services*

The rise of IT production and the surge in telecom investing and usage contributed to a buildup in local information services (*table 2.4*). Some analysts speculate that the market for information systems in Japan will rise to 33 percent of capital investment, 44 percent of new jobs, and 22 percent of the growth of the industrial base by 2000 (Elkus 1991). That is optimistic given the current industrial recession and persistent barriers to internal IT diffusion (relative to the United States).

Table 2.4: Japanese Information Industry Sales (millions of yen)

Year	Total	Information service	Software development	Card punch	Machine time sales	System maintenance	Information providing services	Research	Other
1973	167,163	70,422	21,647	22,348	11,803	12,081	7,620	13,761	7,480
1978	460,241	154,677	88,973	60,987	12,007	66,521	27,069	31,540	18,466
1980	699,844	204,343	153,985	74,205	15,345	104,103	44,059	38,676	35,128
1981	805,692	258,711	225,549	83,393	14,173	71,806	60,737	48,228	41,096
1982	911,907	276,412	300,098	83,944	11,252	88,495	52,342	52,187	47,177
1983	1,095,301	315,606	364,377	100.550	15,694	102,511	78,713	58,485	39,365
1984	1,385,974	377,790	512,398	108,166	17,467	127,427	96,654	63,117	83,003
1985	1,561,829	390,713	658,030	109,650	19,164	117,699	100,762	56,980	108,831
1986	1,915,932	427,826	912,742	120,324	12,073	144,323	114,306	72,989	111,352

Source: The Ministry of International Trade and Industry. Cited by: Miwa, Mekiku.

4. Software and Database Industry

Software has been at the heart of information services expansion. From 1978 to 1986, employment in software increased 157 percent, while total employment increased 12 percent (World Bank 1993). Revenues from system integration, professional services and packages rose from $2 billion to $5 billion between 1982 and 1986 (Kent 1989). By 1990 packaged software revenues were $3.9 billion (World Bank 1993).

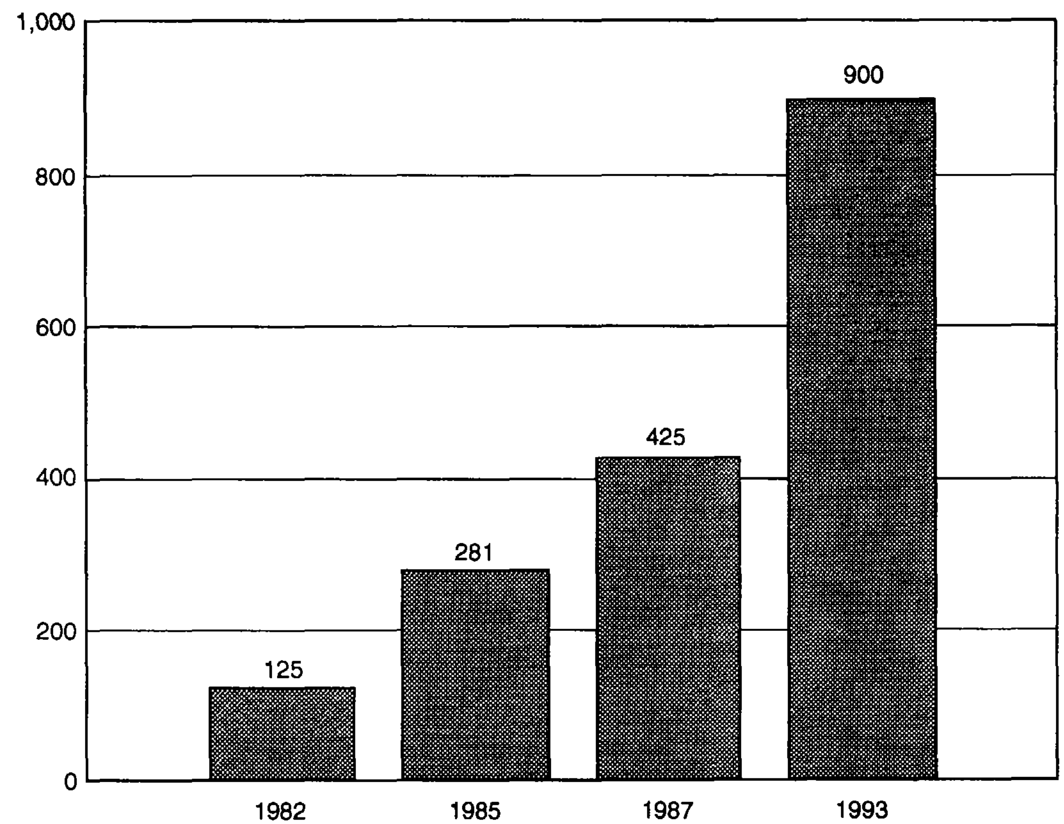
Growth in subscribers to on-line services and in databases have been strong. Between 1987 and 1993, P.C. VAN (NEC) and Nifty-Serve (Fujitsu), Japan's two major on-line services for personal computers, went from zero subscribers to 500,000 subscribers each. During the same period the number of databases went from 425 to 900 (*figure 2.2*).

Despite these indices of growth and dynamism, serious structural problems remain. First, enormous differences remain between the United States and Japan in the pace and extent of IT diffusion. The proportion of digital telecom switches -- a key component of data transmission capacity -- in the United States was 15.6 percent in 1986, compared with 6.2 percent in Japan. Most NTT equipment installed in the late 1970s still falls within the usual twenty to thirty-year depreciation cycle, whereas the United States has replaced more of its telecom equipment with newer technology.

The second problem is deficient use of office automation and personal computer networks. Despite double-digit worldwide sales of personal computers, the $6 billion personal computer market in Japan shrank 6 percent in 1992 (*Fortune* 1993). Similarly, the $54 billion data processing market has remained flat since 1991 (Electronics 1992). This stagnation could be part of the global recession, which restrained spending on hardware, software, services, and training in OECD countries (*figure 2.3*).

At a more fundamental level, however, Japan lacks hardware and software standards and compatible disk data storage systems, as the major domestic computer companies -- NEC, Fujitsu, and Toshiba -- have gone their own ways. This has constrained the growth of networks. The shortage of radio frequencies in heavily populated areas, has made wireless communications expensive and slowed its diffusion. These constraints are highlighted by comparing IT use in the United States and Japan (*table 2.5*).

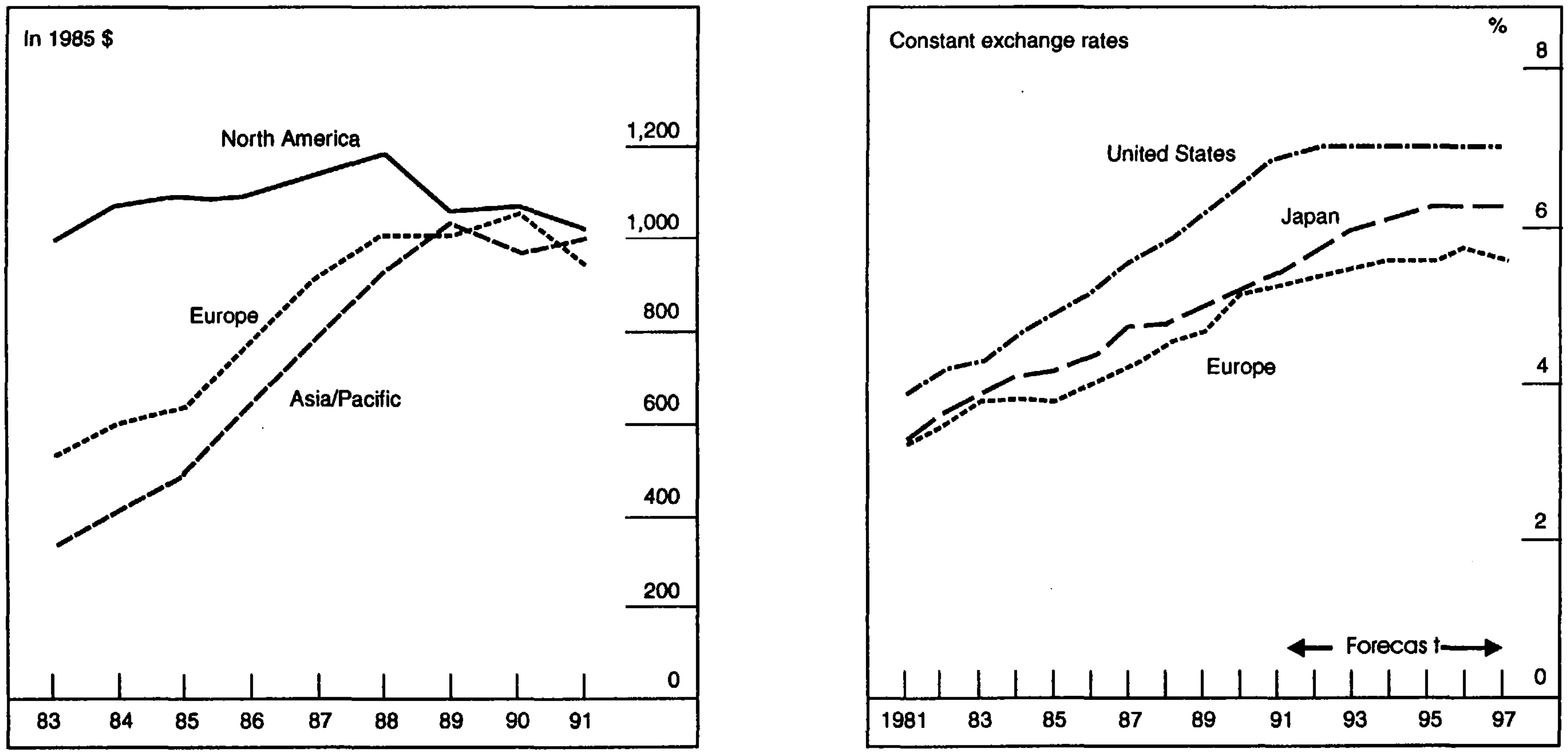
Figure 2.2: Growth of Domestic Databases



Source: Miwa.

Figure 2.3: Spending on Hardware, Software, Services and Training

Spending per white-collar worker[a] **Installed base as percentage of GDP[b]**



[a]Hardware, software and services.

[b]Total stock of hardware and software in the economy.

Sources: McKinsey & Co., Booz, Allen & Hamilton. Economist, February 28, 1993, p. 25.

Table 2.5: Use of Information/Communications Technologies, Japan and the United States

Variable	Japan	United States
Personal computers used in business per 100 workers	9.9	41.7
Local Area Network connections per 100 PCs used in business	13.4	55.7
Cellular phones in use per 100 people	1.4	4.4
Computers connected to Internet	39,000	1.18 million
Cable subscribers per 100 households with television	2.7	60

Source: New York Times 1993.

Government's Role in Information Industry Development

1. Policy Framework

The oil crisis of 1973 had a powerful effect on Japanese society and government. The core heavy industries that had grown up after the war, such as steel, chemicals, and ship-building slowed down as oil prices soared. At the same time, the rising value-added of the electronics industry and its superior features as a lower-energy higher-skill sector made it the growth pole of a new economy (*table 2.6*).

Table 2.6: Value-added in Manufacturing by Subsector

Year	Electronics	Transportation	Iron and steel	Total manufacturing
1971	37.6	30.3	25.1	35.3
1972	38.7	30.4	28.0	36.1
1973	39.3	32.0	31.4	36.7
1974	39.5	30.5	28.6	35.2
1975	38.0	29.3	22.3	33.2
1976	39.4	31.2	23.9	33.7
1977	38.6	30.1	23.2	33.4
1978	39.3	27.5	27.3	34.7
1979	40.4	27.4	31.8	35.2

Source: Baark 1985.

With this potential identified, the government constructed a new concept of industrial development. The Ministry of International Trade and Industry (MITI) became the lead agency in engineering the transition.

MITI's "Vision for the 1970s," "Long-term Vision of Industrial Structure (1975)," and "Vision for the 1980s" were concerned with development of a creative, knowledge-intensive industrial structure (including the small and medium-size industrial sector), aid to structurally depressed industrial sub-sectors, adjustment for trade frictions, and improved energy and environmental security.

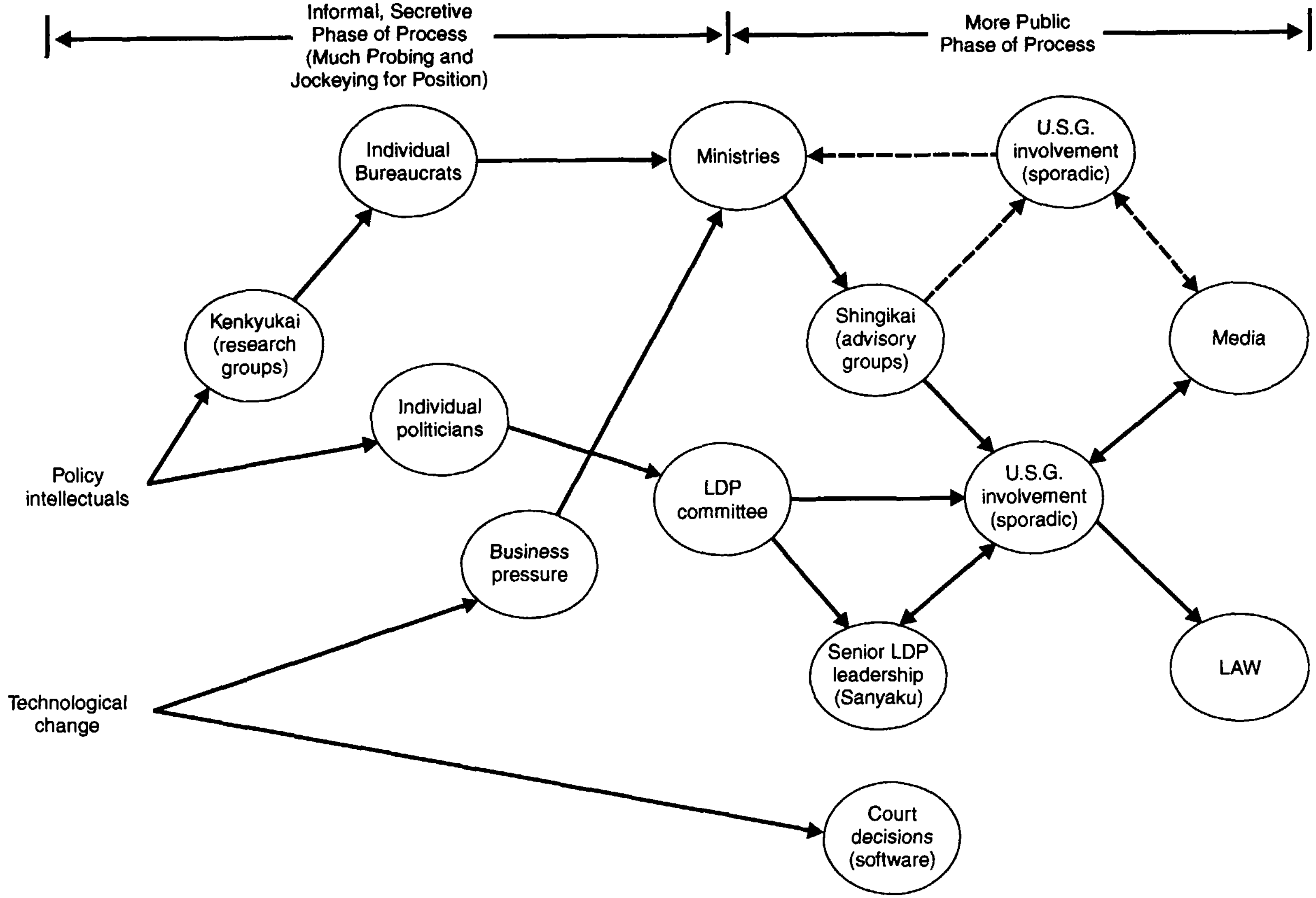
MITI's studies were practical responses to a maturing industrial landscape and the Diet's intrusions on its ability to intervene in the economy through financing for target industries. Particularly after the revision of the Anti-Monopoly Law in 1977, which minimized its ability to provide administrative guidance, MITI has focused on drawing up Visions after extensive consultations among government, industry, and academics. The reports, which sought consensus on problems and solutions, were developed through advisory councils and study groups. Support of specific advisory councils usually meant the recommended policy would be smoothly implemented in industry. The work of these councils led to a call for knowledge-intensive economy.

The knowledge-intensive industries that are being promoted are those in which MITI found that capital and energy were relatively small inputs, and intellectual and scientific labor were large inputs. These include integrated circuits, computers, robots, fine chemicals, new materials, fashion, information services, and sophisticated assembly industries like aircraft and numerical control machines. These industries have shown high productivity increases (nearly 10 percent a year) and low increases in per-unit wage cost (zero or even negative increases) since the early 1970s. MITI's articulation helped catalyze government activities and private promotional initiatives.

MITI's strategy did not mean that implementation would be consensual or frictionless. Calder (1989) documented the long process of policy formation and execution, involving research groups, business pressure, ministries, and politicians (*figure 2.4*).

The major ministerial players have been MITI, which is responsible for organizing high-level national projects for technology development and for many aspects of intellectual property regime management, and the Ministry of Posts and Telecommunications which drafted the Telecommunication Business Law in 1985 that liberalized the telecom sector and which regulates NTT. The Ministry has sought repeatedly to expand its involvement in value-added networks and information services issues. Its push has placed it in conflict: with MITI over software industry jurisdiction, which it lost to MITI; with the Japanese Agency for Cultural Affairs of the Ministry of Education; with its Copyright Deliberation Council, which is rewriting the laws on software protection; with the Science and Technology Agency, which plans national science and technology budgets and is responsible for interministerial coordination; and with the Ministry of Finance, which controls a great deal of NTT stock and funnels funds to major industries.

Figure 2.4: Typical Japanese Policy Making on Information Processing Issues



Source: Calder (1988).

2. *Development Policy*

Among what Calder calls "policy intellectuals," the Kennkyukai and Gakkai, a subgroup of an academic research association, play significant roles. Among business associations, the Keidanren, Japan's largest business group, is a powerful force. Its influence has superseded the Information Industry Promotion Dietman's Association (Joho Sangyo Shinko Giin Renmei), MITI's high-tech business support association whose first chairman was secretary general of the Liberal Democratic Party (LDP).

At the political level, policymaking has been dominated by the information industry "zoku" -- informal tribes of LDP Diet members who guard telecommunication/information industry interests and intervene deftly as needed. This traditional schematic of LDP political decisionmaking is shown in *figure 2.5*.

The often complex web of information industry policymaking is illustrated by the privatization of NTT and the self-interested interactions between LDP politicians, ministries, and the financial sector that made it possible *(figure 2.6)*.

Figure 2.5: Key Actors in LDP Information Policy Decisionmaking

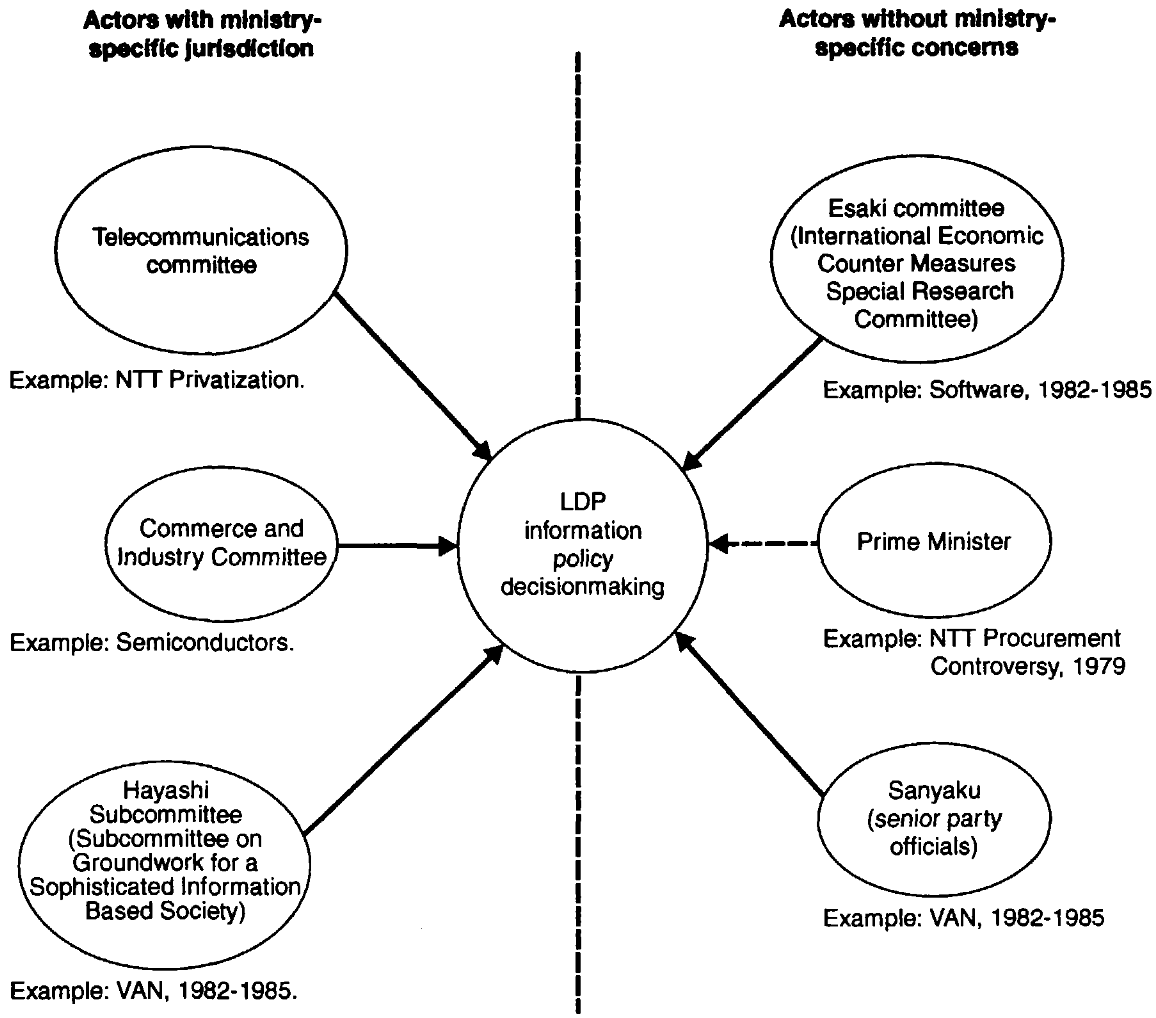
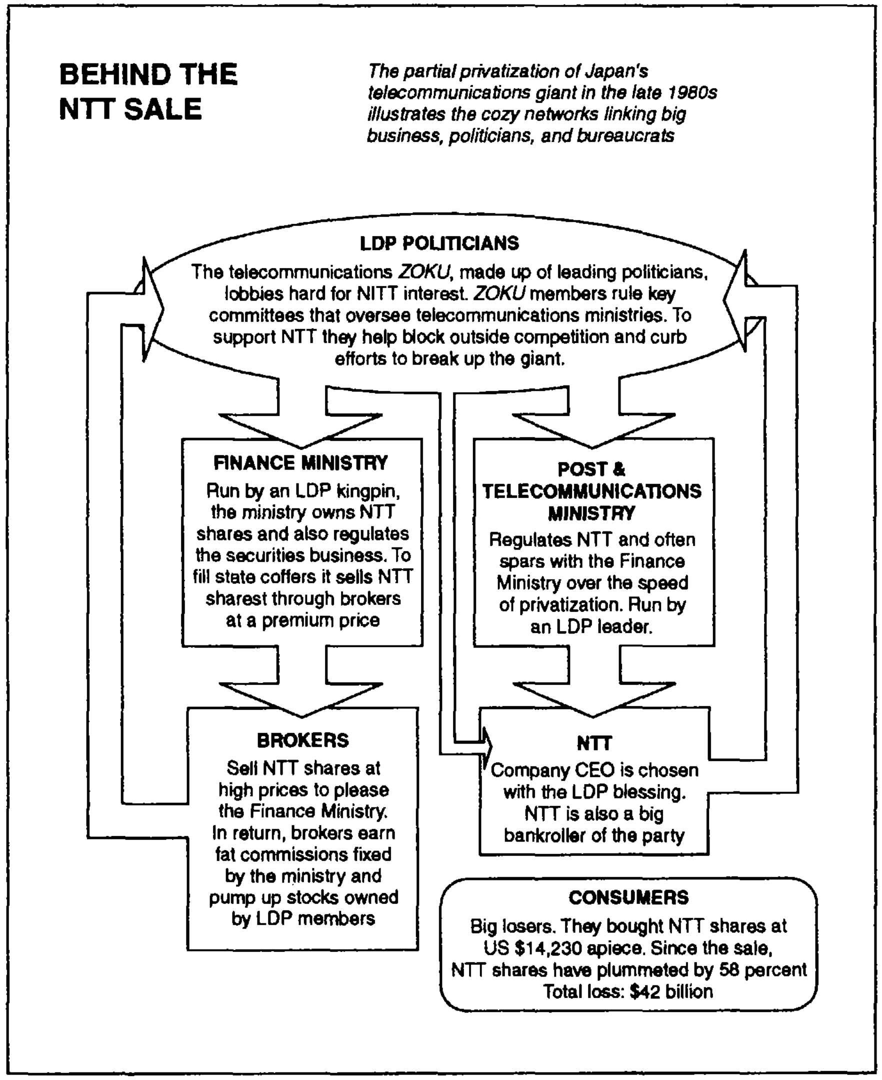


Figure 2.6



Source: BusinessWeek, 1991.

Despite the morass of ministerial rivalries and special-interest politics, significant stimulative information-industry policies have been installed. These include:

- *Firm-level restructuring policies:* Incentives for *software* development has been put into place, including long-term, low-interest loans, tax policy incentives, such as 50 percent of income on packaged software sales can be set aside as a tax-free reserve for four years to cover future software developments and re-training grants for programmer. For example, first Japan Development Bank distributes low-interest loans to finance new equipment for computer producers and accelerated depreciation of capital investment is also given (Magaziner 1990).

- *Sectoral-level restructuring policies*: The computer and telecom industries have been shielded from external competition through closed procurement processes, rather than duties and quotas. In the three years before the U.S.-Japan Telecommunications Treaty, NTT's total foreign procurement totaled less than $150 million and the NTT family -- NEC, Hitachi, Fujitsu, and Oki -- accounted for almost two-thirds of all NTT purchases. Today the NTT family and their affiliates still control over 75 percent of the total Japanese telecommunications market.

- The Ministry of Posts and Telecommunications publishes papers on info-communications and has gained consensus for policies to construct high-capacity global networks and domestic local information services. MPT's Telecommunications Technology Council, an advisory board of manufacturers, users, and universities issued standardization recommendations related to broad-band Integrated Services Digital Network (ISDN), facsimile and teleconferencing, PBX-to-PBX communications systems, and packet-switching and message handling to replace the domestic monopoly of NTT and its suppliers with a more open and competitive mechanism (Besen 1991).

- MITI-sponsored firm consortia have assisted Japan's international competitiveness in information industry activities. Typically, MITI will respond to a group of firms who choose a generic process they want to develop into a major industry. The group investigates every potential applications so they can construct a "tree of applications, technologies, development needs, and capabilities." They then assign tasks and share development of the generic technology. Groups are sent to the United States and Europe to gather information, an R&D consortia is formed and a common database and library established, cluster groups for developments and applications are assigned areas of research, and a special magazine is published to organize papers associated with the project. The $200 million Very Large Scale Integration project in the 1970s helped domestic producers gain technical mastery in memory chips that led to global dominance. The $82 million optics electronics project in the early 1980s led NEC to announce in 1989, the first 1,000-bit optical logic chip, an important step toward replacing slower electric signals with laser pulses in computers (*BusinessWeek* 1989).

- MITI-led "Technopolis" legislation in 1983 established bold technology restructuring of provincial industrial bases, pooling local governments, industries, and universities in each region to create science complexes of research institutes, laboratories, and business incubators to support innovation. MITI provided tax incentives, subsidies, and low-interest loans to help communities and networks of young entrepreneurs in small and medium scale enterprises develop technology-intensive product concepts concepts and advanced production support services -- to create the relationships similar to high-tech creative meccas like Silicon Valley. Technopolis activities are underway in several areas.

Box 2.2
Stimulating the Software Industry

MITI and its quasi-governmental spinoff, the Information Technology Promotion Agency (IPA) have used training, financial resources, and administrative leverage to stimulate the software industry. This effort is designed to help Japan network all sectors by overcoming shortages in software specialists, a lack of interoperability among incompatible systems, a concentration of computers and skills in Tokyo, and computer security.

MITI/IPA initiatives have included establishment of a software technology center in 1981 to lead R&D of interest to computer manufacturers and users, university research institutes and the information service industry, such as language computers, CAD/CAM database systems, and process methodologies and tools. It also organized large cooperative projects, such as SIGMA, a program to link software resources across Japan with a central database of software assets. SIGMA was opened to Korea, China, and Singapore for participation in 1987, a move seen as a way to tap plentiful software expertise in those countries. In 1990 SIGMA was spun off as a private company, a joint venture among seventy companies for:

- Development and dissemination of eleven basic courses for programmers, with instruction in information processing systems, hardware, assemblers, and the operation of the system; and eleven specialist courses to train system engineers, ranging from project management to artificial intelligence.

- Generation of dynamic credit facilities, with IPA acting as a guarantor of funds loaned by financial institutions to software developers and information processing service companies to purchase computers, develop computer programs and train engineers. IPA also guarantees loans by financial institutions to ordinary companies for computer program development or advanced training. In 1989 IPA's credit fund was approximately 3.3 billion yen, which underwrote its credit guarantee service and could authorize loan guarantees up to a value equal to 10 times the credit funds.

Source: Technology Transfer International, "Software Reuse in Japan," 1992, Colorado Springs, Colo. pp. 187-201.

Information Technology Diffusion

The government has accelerated IT diffusion in two main ways: promoting civil service computerization and supporting a nationwide network of technology extension centers to serve small and medium-size enterprises.

1. *The Public Sector*

Computerization in the government began in the 1950s, with scientific and technical calculations and statistical dataprocessing. As an outgrowth of an administrative reform, the Cabinet made its first formal policy on computerization and put forward measures:

- Promoting research and development on information technology
- Expanding applications and implementation of various standards
- Resolving issues to promote computerization
- Promoting training of computer experts
- Promoting shared computer facilities and information resources among ministries.

The Administrative Management Agency was appointed to coordinate interministerial information systems development. Its links to ministries, agencies, local governments, and public corporations have expanded over the years.

Renamed the Management and Coordination Agency, MCA, can tap some 6,000 automation personnel in the thirteen ministries, 1,500 contract personnel, and 17,500 computer personnel in 3,300 local government offices (Snellen 1991). The interministerial computer center is the focal point of the network, where common databases are developed and brought on line with the ministries.

Database development has been a key feature of civil service computerization. In 1987 the Cabinet adopted a databases plan for the government, intended to encourage each ministry to establish decisionmaking databases, develop databases common to ministries, and establish a central function available for government staffs and the public, cataloging books, papers, and reports issued by each ministry and making databases available commercially (Ohashi 1989).

By 1989 more than 200 databases were under development. Database applications are illustrated in *table 2.7*.

Table 2.7: Government Information Technology Applications

Ministry or agency	Sets	Major Areas
Fair Trade Commission Policy Agency	1	Information retrieval
(National Public Safety Commission)	6	Reference of identified criminals, reference of motor vehicles, management of motor-vehicle drivers' records, statistics
Management and Coordination Agency	3	Legal tax retrieval, parliamentary proceedings retrieval, payroll management, statistics
Hokkaido Development Agency	3	Technical computation, accounting of public works cost, payroll management
Defense Agency	50	Procurement management, technical computation, meteorological data processing
Economic Planning Agency	1	Statistics, economic analysis
Science and Technology Agency	14	Technical computation
Environment Agency	3	Information retrieval, technical computation, statistics, payroll management
Okinawa Development Agency	3	Payroll management
National Land Agency	2	Payroll management, information retrieval
Ministry of Justice	18	Management of criminal records, management of migration records
Ministry of Foreign Affairs	7	Information retrieval, management of passport issuance, exchange of telegram messages
Ministry of Finance	21	Statistics, information retrieval, budgeting and accounting, capital management, taxation
Ministry of Education	9	Statistics, information retrieval, analytical calculation, technical computation
Ministry of Health and Welfare	19	Statistics, information retrieval, management of social insurance programs, management of pension programs
Ministry of Agriculture, Forestry and Fishery	22	Statistics, inventory management, technical computation, information retrieval
Ministry of International Trade and Industry	22	Statistics, analytical calculation, information retrieval, technical computation, Patent management, management of export insurance programs, management of JIS (Japanese industry standard)
Ministry of Transport	79	Statistics, analytical calculation, information retrieval, technical computation, Motor-vehicle registration, meteorological data processing, air traffic control, Management of seamen's records.
Ministry of Post and Telecommunications	87	Management of savings, management of post office insurance programs, management of radio regulatory programs
Ministry of Labor	12	Statistics, management of employment insurance program, management of employees' accident compensation insurance program, collection of labor insurance premium, job placement
Ministry of Construction	20	Statistics, technical computation, accounting of public works cost, administration of rivers and roads, digital data on land, budgeting and accounting
Ministry of Home Affairs	1	Statistics

Source: Snellen 1991.

Even with this scope of applications, Snellen (1991) reports that the pace and extent collection has been constrained by the Japanese script and language. Despite the improvements made in converting Hyragana into Kanji, inputting information is still a laborious process.

Applications by prefectural (local) governments also have been considerable, but constrained. Environmental pollution, hospital and medical service, taxation, water supply and sewerage, finance and accounting, civil engineering, pensions and welfare, and resident records all are fields of IT application. With a local government structure eight to nine times that of the Netherlands, Japan has only twice as many automation personnel.

2. *The Private Sector*

The major mechanism that diffuses IT to small and medium scale enterprises is a network of 170 public technology extension centers, called kohsetsushi centers -- (Shapira 1992). The centers, which have a combined budget of $500 million, mostly from prefectural governments, offer one-stop shopping for the following services:

- *Applied research.* Of the 6,900-member work force in these centers, 5,300 are engineers and other technicians. They spend almost half their time on industrial research for local manufacturing consortia.

- *Information dissemination.* The centers run study groups, seminars, and exhibitions, publish research, and maintain technical libraries.

- *Testing.* Labs test products and materials for compliance with Japanese and foreign standards, and help firms resolve quality and product development problems. Firms use the services more than 900,000 times each year.

- *Advice and guidance.* The centers provide technical help from telephone assistance to sending out specialists. They register private technology advisors (engineers and the lkike) to consult with firms. Firms used centers for advice more than 450,000 times in 1989, including 2,500 site visits.

- *Training and use of laboratories.* Centers provide new technology training, and specialized equipment for research, prototyping, and even pilot manufacturing. Such facilities are used 64,000 times annually.

Another institutional mechanism is the technology diffusion groups. These groups maintain technology exchange forums and networking among small and medium-scale enterprises. Launched by MITI's Small and Medium Enterprises Agency in 1981, the groups number 2,000, with 70,000 member firms (Shapira 1992). These technology exchanges also have been established by commercial and industrial leadership groups, such as the estimated

280 exchange groups working with the Chambers of Commerce and Industry. In addition, many "technology exchange plaza groups" had received national or prefectural grants but they now operate as "veterans' groups", without government assistance. Other exchanges help subcontractors combine resources to bid for large orders and combine distribution companies and manufacturers to probe for the seeds of new commercial products. Automation exchanges unite companies that produce microelectronics and automated equipment and systems with firms that need their technology (Jetro 1988).

Perhaps the most famous private technology exchange is the Kyoto Project. It has seventy-three dues-paying companies researching five main IT themes, including factory automation, optical technology, and local area networking. Among its products are a microcomputer-driven fuel control system for small and medium capacity boilers; an automated system for cloth inspection and injection molding for the mechanical dyeing industry in Kyoto, and a micro-components-controlled ergometer to measure health functions (Jetro 1986).

In many ways, these exchanges merely augment the transfer mechanisms between large firms and small and medium-scale enterprises. MITI's 1987 white paper on small and medium-scale enterprises found that 43 percent of subcontractors received technology assistance from large firms, and almost 10 percent reported joint R&D with large firms.

Another vehicle for IT diffusion to small and medium-scale enterprises has been a network of government-sponsored robot-leasing companies. Through leases, firms can avoid some of the steep sunk costs of new technology and the risks of getting locked in to a generation of technology that might quickly become obsolete (MITI 1985).

The prototype, the Japan Robot Leasing Company (JAROLE), was established in 1980 by a consortium of twenty-four robot manufacturers and ten insurers. It buys robots and flexible manufacturing systems from member manufacturers and leases them long-term to firms, with funds borrowed from the Development Bank of Japan. The company provides high quality technical service and backup facilities.

Information Technology Development

1. Research and Development

Japan's achievement in catching up to the United States in science-related spending and in share of leading patents has been remarkable *(table 2.8)*. While the United States spends more on research in absolute terms, in relation to its size and gross national product Japan leads the world in combined government, industry, and university R&D spending -- 3 percent of its GNP in 1991 compared with the United States's 2.65 percent. In 1991 Japan spent $102 billion on R&D, the U.S.

spent $145.3 billion. But unlike the U.S., where government controls 40 percent of R&D spending (half of which is military), Japan has relatively little military or university research spending. Industrial research accounted for $76 billion, or 75 percent of Japan's research budget (*New York Times* 1993).[40]

The intense focus of R&D on product and process innovation has led to technical strength. This strength was measured in a recent study by CHI Research, which monitors technical trends for the U.S. government. It assembled a database of patents issued to create an index of technical strength. By 1990 Japan had almost pulled even with the United States (*New York Times* 1991):

Table 2.8: Number of Influential Patents per Country, 1990

United States	104,541
Japan	76,984
Germany	17,643
United Kingdom	8,795
France	7,672
Taiwan	1,000
South Korea	400
Former Soviet Union	400

Source: *New York Times*, "In the Realm of Technology, Japan Looms Ever Larger," May 28, 1991, p.B5.

The Japanese government has traditionally played a smaller role in providing R&D funds than the U.S. government, accounting for only 21 percent of R&D expenditures in 1985 (National Science Foundation 1988). In fact, its share of total R&D expenditure is the lowest among all OECD countries (Kim 1993).

Despite its relatively small share of R&D investment, the Japanese government's involvement in organized national R&D projects has been important. Since 1961 the government has mobilized seventy research consortia (*BusinessWeek* 1989). As the recession grinds on in Japan and industrial research budgets tighten, more companies are looking to the government for an expanded R&D role. And the government increased its spending 6.2 percent -- about $21 billion in 1994. In particular, computer makers are urging the government to expand support beyond current MITI R&D projects for the information industry (*box 2.3)*.

[40] *New York Times*. "Japanese Now Cut Outlays for Industrial Research," November 29, 1993. p.D3.

MITI's involvement in R&D through its sixteen labs and research institutes is only part of an extensive R&D infrastructure that supports the information industry. This infrastructure and key IT projects are described in *box 2.4*.

Box 2.3
Major Japanese Research and Development Target, 1993

R&D Targets	Description
Foreign language database system development	Four-year, 3 billion yen project launched in 1989 to develop databases in languages other than Japanese, develop systems capable of searching more than one database at a time, support Asian networks in the development of database systems and networks.[41]
Intelligent Manufacturing System (IMS) development	A ten-year, 150 billion yen international project aimed at next-generation factory-automation technologies and solving standardization problems that prevent the ready diffusion of global computer-integrated manufacturing. It is to research "bottoms-up factory automation"--management of production and supply cells as intelligent, autonomous modules that either produce or consume resources, with delegation of responsibility for scheduling, resource allocation, and monitoring downward. This concept, called Holonics, differs markedly from top-down manufacturing resource and planning approaches in the West.[42]
International Multimedia Association	In response to a report issued by the Electronics Industry Association of Japan forecasting that sales in multimedia -- advanced computing, software and information service -- will reach $95 billion by 1995 and, at least $240 billion by 2000, MITI and 100 major corporations established this association in 1992 to develop multimedia hardware, software, applications, and distribution channels and to help build vast video and image data libraries. In addition, MITI, Hitachi, Ibaraqi, prefecture, and the Tokyo National University of Fine Arts and Music plan to build a $1.1 billion Video Research Park for 300 companies in Toride City; also twenty companies have invested $15 million in a feasibility study for a media research park to open in 1995 to link media theory to advanced computers and communication.[43]
Opto Electronics Development	MITI, universities and private companies invest $200 million a year and dedicate a combined network of 3,000 opto electronics specialists (2/3 of whom are in corporate labs) to develop numerous home, office and telecommunications applications (particularly, on optical disk storage).[44]

[41] Online News Service 1989.
[42] Yankee Group 1992.
[43] New Technology Week 1992.
[44] BusinessWeek 1990 and 1993.

Box 2.4
Information Industry R&D Support Infrastructure

Organization	Description	Noted Projects
Agency of industrial science and technology (AIST)	Unit of MITI that runs sixteen laboratories and research institutes including the Electro Technical Lab, established in 1981 and the largest national research center on electronics, emphasizing solid state physics, computer architecture, and software engineering; the mechanical engineering lab, emphasizing robotics and advanced production technologies; and the Industrial Products Research Institute, emphasizing human factor and materials engineering.[45]	• *High speed computer system for scientific and technological uses* (1981-1989)-- R&D on ultra-fast processing of information from satellites, simulations, and the like. • *Advanced robot technology* (1983-1990)-- R&D on advanced technology systems to support workers in dangerous or difficult conditions. • *Automated sewing system* (1982-1990)-- R&D on an industry sewing system that can help manufacturers address competitive changes.[46] • *Inter-operable database system* (1985-1991)-- R&D on distributed databases and multimedia -- that is, technologies of information infrastructure. • *Super high performance electronic computer* (1961-1971)-- Supercomputer system. • *Pattern information processing system* (1971-1980) Computer technology for the recognition and processing of pattern information such as characters, pictures, and speech. • *Flexible manufacturing system complex using laser* (1977-1984)–R&D on production system able to rapidly and flexibly produce small batch compounds. • *New electronics devices* (1981-1990)-- R&D on superlattice electronic devices with superfine structures tailored to atomic scale. • *Three-dimension integrated circuits* (1981-1990) -- R&D on three dimensional arrangements of active elements and insulation layers in semiconductors.
Science and Technology Agency	Plans and implements all science and technology policies and coordinates interministerial activities, including science an technology budgets. The Research Development Corporation of Japan (RDC), wholly owned by the government, was created to help transfer R&D from university, government and public institutions to industry by contracting companies to develop promising science findings into technical prototypes and evaluating national lab technologies for suitability for licensing to industrial clients. Eighty percent of development costs were covered by licensing income generated by their later commercialization.[47]	RDC's exploratory research for advanced technology is the most creative, investigator-oriented R&D program in government, with thirty researchers engaged in open-ended research around themes such as Nano-mechanism solid surface; terrahertz, electron wave-front, and bio-information transfer.[48] Bio-information program is focused on R&D into information computer circuits built from bio-engineered cells.

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[45] Tokyo Office of U.S. National Science Foundation, "Directory of Selected Japanese Scientific Research Institutes" Report No. 114, Dec. 24, 1986.

[46] Magaziner, Ira. *The Silent War*, Vintage Books, 1990, p.347-369.

[47] Yuan, Robert. "Japanese Biotechnology," report prepared by Biotechnology International, University of Maryland, 1989. p.38.

[48] Ibid. pp.39-40.

Box 2.4 *continued*

Organization	Description	Noted Projects
Key Technology Center	Corporation supported by government and industry, whose purpose is to promote research and development on "fundamental key technologies of private industries," technologies of special concern to MITI and the Ministry of Posts and Telecommunications. The Center makes available loans for private sector applied research, and does contract research for private firms and supports international research.[49]	Projects have included: · Second generation Opto Electronic Integrated Circuits to improve the transmission speed of OIECs by one order of magnitude to the 10 gigabit level. (Participants: NEC. Toshiba, Sumitomo and 9 others.) · Advanced Video Information System with functions for information processing--to develop an entirely new information system for video, audio and database services (Participants: Sumitomo. Fujitsu and Matsushita.) · Electronic Dictionary for use in natural language. to develop a large-scale language data set to be processed in machine-readable formats. (Participants: Fujitsu, Toshiba, Hitachi, etc.) · Basic research on Automatic Interpreting Telephone. R&D on voice recognition, machine translation, voice synthesis and database networking. (Participants: ATR International, IBM Japan, Ltd., NTT.[50]
Nippon Telegraph and Telephone Corporation	NTT provides a complete array of telecom, telegraph, data communications, video conference, and other services. NTT has nine R&D labs including Telecom networks lab, radio communication, communications and info processing, integrated communications labs, and Software labs.	Construction of national digital network, implementation of intelligent machine processing, advanced opto electronics, and nano second and nanometer electronic technologies.
Tokyo University Research Center for Advanced Science and Technology	One of world's largest labs for bioelectronics, with a staff of forty-four.	Scientific studies combine semiconductor fabrication techniques and biochemistry to produce unique electronic devices and sensors from living organisms. One group has linked neural networks and ten membrane-based sensors that detect odors to produce an experimental machine to test perfumes and sniff out hidden explosives.

49 Ibid. Report Memo No. 98, April 23, 1986. pp.1-10.

50 Tokyo Office of U.S. National Science Foundation, Report Memo No. 91, January 16, 1986.

The government's science establishment, while assisting the enormous technical buildup of the country, has nevertheless made several mistakes. MITI's research failures include an undersea oil-drilling rig controlled by remote control that cost $36 million but turned out to be no better than conventional rigs, cold weather integrated circuits costing $11 million that no one wanted to buy and MITI's fifth generation project initiated in 1982 that has yet to deliver a natural language computer system (*Fortune* 1990).[51]

Perhaps the government's biggest failure has been HDTV, high definition television. Japan's Public Broadcasting Corporation has sponsored HDTV development for twenty-five years and helped generate $1.3 billion in private investment. NHK also broadcasts HDTV programs eight hours a day. Still, only 10,000 HDTV receivers (priced at $8,450) have been sold, mostly to electronics firms and public institutions. The chronology of HDTV failure is shown in *box 2.5*.

Box 2.5
HDTV's History

1968	Japan's NHK starts research
1979	NHK's first test transmission
1986	An international meeting in Dubrovnik, Yugoslavia, supports NHK's version as the world standard. European countries object. The European Community begins research.
1987	U.S. Federal Communication Commission sets up an industry-run advisory committee, which begins evaluating 23 rival systems.
1989	U.S. government rejects firms calls for $1.35 billion of aid.
1990	U.S. General Instrument announces the first all-digital HDTV system.
1991	NHK starts regular broadcasts. The European Community fails to persuade satellite broadcasters to use an early version of Europe's HDTV, even with a subsidy.
1992	European Community ministers fail to agree on further subsidies.
1993	NHK's version is eliminated from the ECC's competition, leaving four digital systems. The FCC's advisory committee calls for more testing. The EC abandons its effort to promote its own version and indicates it may adopt whatever version wins the ECC's competition. Analysts speculate that Japan, where HDTV has flopped, may do the same.

Source: Economist 1993.

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51 *Fortune*, Feb. 13, 1989. p.108; and *BusinessWeek*, "Innovation," 1990. p.79.

NHK's analog HDTV system which used a decoder to modify broadcast signals from satellites, was swept aside by General Instrument's announcement of an all-digital system. Since digital data could be manipulated, suddenly the prospect was that an HDTV receiver could be more than just the passive boxes made and sold by Matsushita and Sony; it could someday be an interactive home information appliance, linked by fiber-optics laid by phone companies, made easy to use with sophisticated software, powerful computer chips, and one, easy-to-use master control box (*Newsweek* 1993). Thus the strategic persistence of NHK and its electronics consortium turned out to be inflexibility and lack technological agility.

2. *Building the Technopolis: Contrasting Experiences*

The Technopolis Law (also called the Regional High-Technology Industry Promotion Law) empowers prefectures to designate areas for construction of a "technological mecca," high-tech industry cities with 40,000 to 50,000 population adjacent to cities with 200,000 to 300,000 population. Planning has involved businesses, prefectural governments, and universities, and implementation experiences have varied.

The Tsukuba science city took seventeen years and 1 trillion yen to create. It is located thirty-seven miles northeast of Tokyo and is home to forty-six of the ninety-eight national research institutes, representing 40 percent of both the annual budget and the number of researchers at all the institutes. Tsukoba has 11,000 research employees. It is one of the largest science complexes in the world *(table 2.9)*.

Table 2.9: Particulars of World's Principal Science Cities

		Tsukuba Science City	Research Triangle Park (United States)[a]	Novosibirsk Science City (Russia)	South II de France Science City (France)	Sophia Antipolis Science City (France)	Louvain University Science City (Belgium)[b]
Designed Scale	Area (hec-tares)	2.700	2.3000	1.300	3.500	2.400	900
	Popu-lation	136.000		50,000	112,000		50,000
Objectives		Alleviate over concentration of population and industrial plants in Tokyo area and construction of a "brain city" concentrating research institutions	Foster of industries that demand higher levels of technology, create job opportunities, and promote local industrialization	Purse elementary and applied research to develop Siberian natural resources	Construct science city by concentrating research institutions, private industries, and so on.	Construct international city to promote education, science, and technology (to be completed in 1990s)	Promote education through respective languages to eliminate cultural disputes arising because of language differences
Core institutions		44 national or quasi-governmental research organizations and universities[2]	More than 35 governmental, academic and private research institutions	20 national research institutions and universities	26 research institutions, universities, and the like.	49 research institutions, universities, and the like.	Catholic University of Louvain IBM Research Center
Number of employees, etc.		11,000 employees, 31,000 residents	8,000 employees	18,000 employees, 45,000 residents.	13,000 employees	2,800 employees	
Distance from capital or large city		60 kilometer from heart of Tokyo	11 kilometer from Raleigh (population 130,000); 23 kilometer from Chapel Hill (population about 35,000), and 24 kilometer from Durham.	25 kilometer from Novosibirsk (population 1 million)	15 kilometer from Paris	Between Nice and Cannes, 22 kilometer from Nice	

[a] Although they are not shown in this table, the United States has more than 150 research parks.

[b] Louvain is typical of research areas in the United States and Western Europe.

Source: Science & Technology in Japan 1983.

Tsukuba is home to the Electro Technical Laboratory, the largest organization specializing in electronics, the mechanical engineering lab, and the Industrial Product Institute. It is a thriving center of industry developments.

In contrast with this government technopolis model, industry-driven Kyushu Region Technopolis is often called the "Silicon Island" of Japan. Annual semiconductor production in Kyushu accounts for more than 30 percent of national production. The regional semiconductor industry experienced average annual growth of 40 percent from 1975 to 1982. Over 163 domestic and foreign companies employing 7,000 people are flourishing at Kyushu.

The semiconductor companies were drawn to Kyushu by: clear water, rapid transit networks, cheap and abundant labor, land for industrial uses at prices below the national average, low concentration of advanced assembling industries, a developed software sector and communication networks undergoing an information revolution, and eager invitation by local governments (LTCB Research 1986).

The technopolis activity of the regional government therefore is built on a thriving information industry. The government promotes the return of local "brain workers" who have left the region, improves local research institutes, and aids local suppliers to serve larger semiconductor firms, including helping firms from outside the sector, such as steel and footwear manufacturers develop relations with semiconductor industry suppliers.

Tsukuba and Kyushu are successes, but the jury is still out on the Kumamoto Technopolis. Despite the establishment of a Techno Research Park, including an applied electronics research center, subsidies and loans to municipalities, and low interest loans and technical advice to small and medium-scale enterprises, Kumamoto's new plants have not been established as planned, new policies for local firms have not been implemented, local firms have not taken advantage of facilities and organizations, and linkages between local small and medium-sized enterprises and large firms from outside have not been extensive (Kitayama 1993). Thus the technopolis experience suggests mixed results, and more time is needed to identify critical factors.

Cross-Cutting Policies for Information Technology Infrastructure

1. Telecommunications

A critical force in IT diffusion is the privatization of Nippon Telegraph and Telephone (NITT) and the opening of type 1 (owners and operators of transmission and switching facilities) and type II (leased facility service providers) services to competing common carriers to improve the variety and availability of telecommunications.

The overriding concept of public sector IT diffusion has been NTT's "Information Network System" introduced in the early 1980s. NTT proposed to digitize the nation's communications network step by step, digitizing switching systems, laying optical fiber, and using satellite networks to create integrated transmission and processing capabilities for data, voice, and image (Baark 1985). NTT began with a pilot Integrated Services Digital Network (ISDN) in the Tokyo suburbs in 1984, the first commercial ISDN service in the world. The project established NTT's leading role and helped its family of enterprises and suppliers in international markets.

We have described how NTT uses "family members" and procurement contracts that favor them and are demanding enough to help them become globally competitive in computing, components, and communications technologies. NTT's $3 billion budget for telecom equipment and computer hardware and additional procurement for government ministries gives it enormous clout to promote standards and accelerate diffusion throughout the government. Since privatization NTT has spun off 170 affiliates and 100 subsidiaries working in such areas as value-added networks, database services, video text, software and information processing, consulting and engineering services, and "intelligent" building services.

The proliferation of type I and type II common carriers has also diffused information technology across the public sector. New common carriers include Japan Telecom Company, a joint venture of Japan Railways, Sumitomo, Mitsui, and others and Teleway Japan Corporation, a joint venture of Toyota, Mitsubishi, and the Highway Services Facilities Association to install fiber-optic systems along their rights-of-way (Sato 1989).

Another potential source of public sector IT diffusion has been the two-year, $26 billion "anti-recession" spending plan announced in April 1993. Its focus is the creation of a "social" infrastructure to buy supercomputers, personal computers, work stations, fiber-optic cables, switching gear and local area networks. There will likely be a $1.7 billion fiber optic network linking up to twenty supercomputers in government and university labs, modernization of networks in Tokyo's governmental complexes, introduction of personal computers into high schools, and construction of test facilities for high definition television transmission over fiber-optic cable. Control over spending will likely fall to the Postal Ministry rather than NTT. The ministry is interested in offering new services in the market to help defray the $280 billion cost of running fiber to the country's 42 million households (BusinessWeek 1993).

The Postal Ministry has relaxed telecom regulations and mapped out highspeed network testbeds in several cities as steps in wiring every home by 2010. The ministry also envisions a pan-Asian information highway. Its top official met with his South Korean counterpart to exchange information on network experiments and plan joint seminars and personal exchanges as steps in creating common standards and protocols. The highway would draw other Asian countries early in the twenty-first century. Its development could be critical for Japanese companies, which are beefing up offshore production to hold down costs. They could use these communication channels with headquarters to boost product development (*BusinessWeek* 1994).

2. *Venture Capital*

Another source of IT development and diffusion has been venture capital. Investing in international companies for technology acquisition and transfer has been an important vehicle for IT development. Twenty major private venture funds are investing in local and foreign technology companies. In 1988 the stock of venture capital investments was 241 billion yen ($1.91 billion), an increase of 39 percent since 1984 (*Economist* 1988).

Since 1984 these companies have invested in agile high-tech startups like Dainichi Kiko, a robotics firm which has entered alliances with Nippon Electric in computers, with Japax in spare-metal working machines, and with Nigata Engineering in controllers (LTCB 1986).

Japanese multinationals are aggressively engaged in venture capital activities. From 1988 to 1989 their venture investments in the United States grew from 40 deals worth $166 million to 60 deals worth $350 million (*BusinessWeek* 1990). Hitachi Koki and Nissei Sanyo companies' acquisition of Data Products Corporation, a California computer printer maker, and NNK Corporation's $35 million investment in Silicon Graphic's three-dimensional workstations were typical.

3. *Developing Human Capital*

There has been a dramatic investment education at every level since 1950. This increase, which has provided the workforce for today's information industry sectors, is highlighted (*table 2.10*).

Table 2.10: Changes in Human Capital Accumulation, 1950-80

	1950	1960	1970	1980
Literacy Rate (percent)	99.2	99.9	99.90	99.90
Environment ratio for second level (percent)	49.2	57.5	82.10	93.50
Graduates from mid-level education	105,800	158,400	404,300	569,600
Engineers engaged in research and development	37,977	118,150	286,400	390,800

Source: World Institute of Development Economics Research 1988.

Higher education, particularly engineering, has enabled Japan to close the gap with the United States in information industry technical leadership skills *(table 2.11)*.

Table 2.11 Engineering Human Resource Bases, Japan and United States

Indices	JAPAN	U.S.
Enrollments in first-degree electrical and computer engineering programs, 1985	95,429	132,917
First university degrees in engineering among 22-year-olds, 1985	71,396	77,871
Doctoral degrees as a percentage 27- year-olds, 1985	0.5	0.7
Scientists and engineers engaged in research and development per 10,000 labor force, 1986	69.3	67.1

Source: U.S. National Science Foundation 1988. Computed from various tables.

The Kohsetsushi public technology centers and technology diffusion groups have provided institutional support to higher education and have been instrumental in IT industry-specific training. Manufacturers of numerical control machine tools have followed on the tradition of sewing and knitting machine manufacturers by maintaining low-cost training schools for numerical control operators to help develop their market (Watunabe 1985).

The Institute of the Japan Small Business Corporation, established in 1980 to carry out education and training for management rationalization and technological improvement, has four training institutes. Courses train prefectural and small and medium-scale enterprises and personnel in charge of technical and management advice and other technicians and managers from these enterprises. There are about 6,000 trainees per year. Seventy percent of participants are enrolled at the Tokyo institute, which provides training in factory automation, industrial design, mechatronics, and telecommunications. Until 1986, the central government bore 75 percent of training costs. Since then, it has provided only two-thirds of the funding. Instructors were drawn from companies (28 percent of technical instructors) and colleges and universities (21 percent of technical instructors). Training materials are developed by a research institute.

An extensive training system for small and medium-sized enterprise employees is run by prefectural and ten large city governments. A considerable number of these courses cover automation, mechatronics, robotics, computer-aided-design and computer-aided-manufacture applications, and flexible manufacturing systems. Financing comes from the central government, prefectures, and recipients.

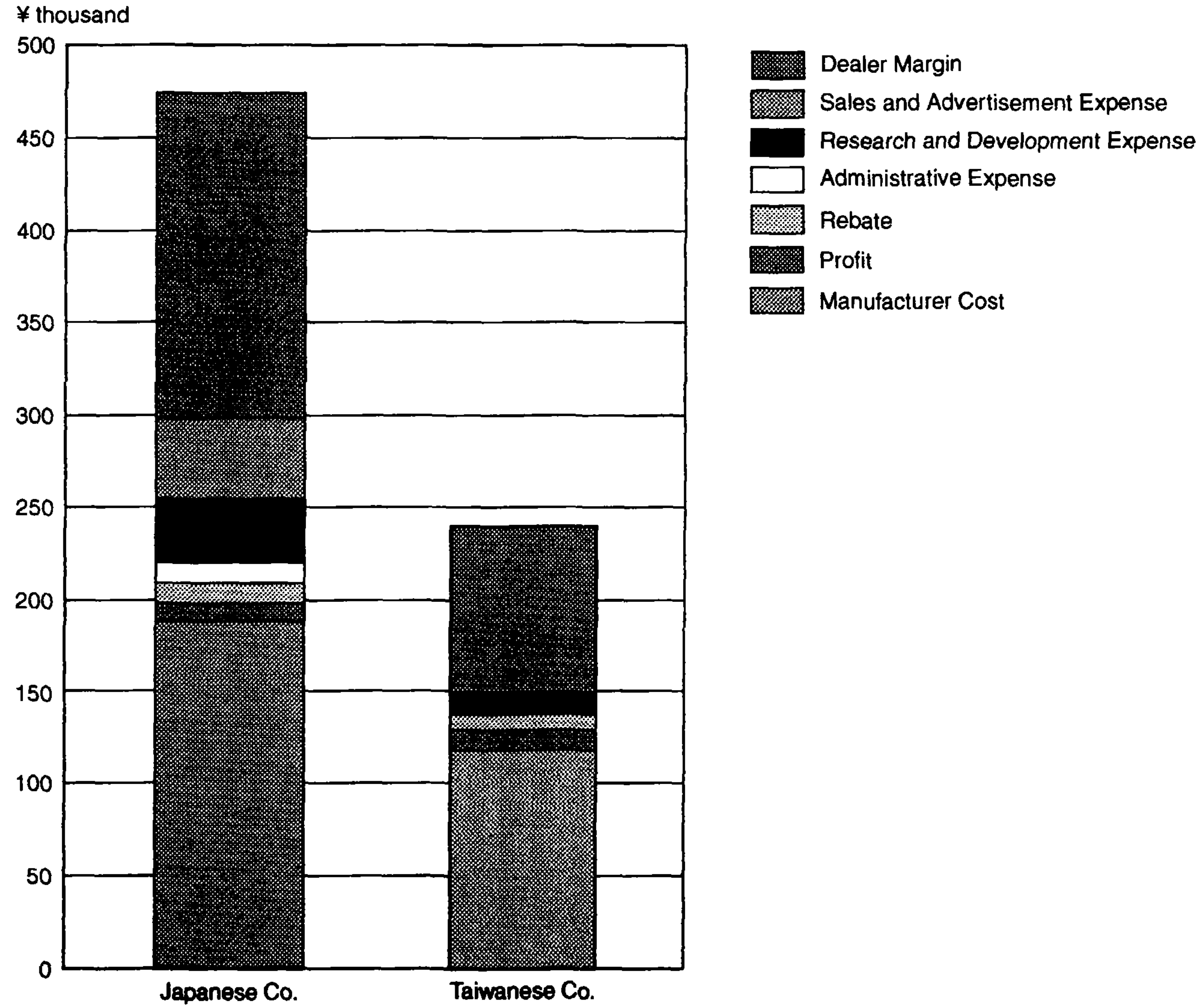
The Private Sector's Role in Information Industry Development

1. Producers

The rise of the computer industry in Japan can be traced to the early 1950s and the research of the Electro Technical Lab of MITI, and the production of the first transistor computer in 1957. This technology was transferred to NEC and Fujitsu, which produced their own computers that same year. In 1962 MITI started the Fontac Computer project with NEC, Fujitsu and Oki and introduced systems concepts through helping Japanese computer manufacturers contract for technology from U.S. companies. NEC and Honeywell, Hitachi and RCA, Mitsubishi and Scientific Data, and Toshiba and General Electric all entered into technology transfer agreements that helped Japan catch up to the United States in computer hardware and components by the late 1970s (Sato 1990). By the late 1980s Japan dominated global markets in semiconductors, integrated circuits, and advanced flat panel screen.

Intense restructuring is underway among major IT leaders, driven by cost competition from other Asian producers and technological competition from the United States. Between 1984 and 1991 the return on assets of electronic components manufacturers shrank from 15 percent to 5 percent, forcing companies like Oki Electronics out of the 16 megabyte DRAM production; Canon, Casio and Nippon Steel abandoned personal computer manufacturing, and Mitsubishi Electronics quit making hard-disk drives. Japanese difficulties are revealed in that it costs half as much to produce a personal computer in Taiwan *(figure 2.7)*.

Figure 2.7: Manufacturing Costs for IBM-compatible Personal Computers



Nomura Research Institute

Source: Electronics, 1992.

Japanese manufacturers have lagged behind American firms in commercializing multimedia products. Only Sony has launched a major multimedia product, a "palmtop" computer, that has not been well received. Japanese firms have played support roles to U.S. companies in this emerging field, as in Sharp's work with Apple on the Newton personal digital assistant and Toshiba's work with Apple on a multimedia product named Sweat Pea (*Wall Street Journal* 1992). Domestic cost and technology disadvantages have spurred the internationalization of IT production, services and research activities in the 1990s (*table 2.12*).

Table 2.12: Internationalization of the Japanese Information Technology Industry

Production

- By June 1992, 872 Japanese electronics plants were operating outside Japan, 514 in Asia alone -- a 60 percent increase over 1991.[52]

Technology investment

- Japan investments in U.S. high-tech companies grew from forty deals worth $166 million on 1988 to sixty deals worth $350 million in 1989. They exceeded $400 million in 1990.[53]

- Thai/Japanese joint venture, Asia Pacific 21st, is to provide computer systems integration and marketing software.[54]

- PC-LAN Information Technology Inc. is a joint venture to develop automatic office equipment including a laser printing system.[55]

Research and development

- NEC opened a $25 million AI lab in Princeton, New Jersey, and Sharp set up an artificial intelligence (AI) laboratory at Oxford University to research AI and opto electronics. Toshiba set up a semiconductor physics lab at Cambridge University.[56]

- MIT established an advanced Institute for R&D on IT in Japan in 1989[57]

IT producers are undertaking other strategic reorientations of their research and business functions. These realignments vary depending on the existing and potential core capabilities of

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52 Office of Naval Research, op. cit. p.16.
53 BusinessWeek, Special Innovation Issue, 1991.
54 Reuter Textline, Bangkok Post, July 15, 1992.
55 Hinhua General Overseas News Service, June 3, 1988.
56 Financial Times, March 11, 1991.
57 Japan Economic Journal, Dec. 16, 1989, p.14.

each company. Toshiba, NEC, Fujitsu, and Hitachi are restructuring, but in different directions (*table 2.13*).

Table 2.13: Status of Japanese IT Producers

Company	Description	Restructuring Activities
Toshiba	World leader in laptops and notebook PCs.	Attempting to reverse course and invest heavily in a semiconductor technology. "flash memory,"–that allows storage of information without constant electrical simulation. making it ideal for portable electronic products, such as hand-held computers. Toshiba invented this technology but it was commercialized by Intel. while Toshiba went on to focus on dynamic random-access memory chips.[59] Targeting HDTV, liquid crystal displays, next-generation batteries and superconductors and has launched joint ventures with IBM and Motorola, after cutting its R&D budget by 12 percent in 1993, its first decline in a decade.
Fujitsu	Patterned after IBM, the number two Japanese computer maker fixed on mainframe and minicomputers and never developed the personal computer/workstation business, leaving it vulnerable as the global industry shifted down to smaller machines.	Trying to diversify into multimedia. It led the establishment of a 64-member group, "The Epwing Consortium," to create a CD-ROM standard that could become the electronic publications standard.[60] It is expanding its computer integrated manufacturing consulting business to SMEs.[61] The company has also begun a pay-for-performance system for its 10,000 managers.[62]
Hitachi	Computer and chip division of this $62 billion-sales company makes more money than Motorola, Intel, and Sun Microsystems combined,[58] but has been overly wedded to mainframes, leaving it as vulnerable as Fujitsu. Net income in 1992 plunged 45 percent.	Retrenching in DRAM memory chip business to focus on semicustom chips and microprocessors; promoting big government computer systems projects, such as IT distribution system in the Shinjuku Station District of Japan; and spending almost $2 billion in R&D on electronics, including neutral networks, and virtual reality.
NEC	Japan's largest semiconductor company was largest in world until recently passed by Intel; controls half of Japan's PC market. Under attack from U.S. companies in domestic market and international move toward standards generated by IBM.	Investing heavily in color liquid crystal display screens to offset losses in PC business; and expanding sales of memory chips to U.S. PC makers as the U.S. PC market booms.[63]

Source: (Listed below)

[58] BusinessWeek, 1992.
[59] Wall Street Journal, 1991.
[60] Electronics, 1992.
[61] *Wall Street Journal*, 1993.
[62] Fortune, 1993.
[63] New York Times, 1993.

2. *IT Users*

An emerging theme among IT users is networking and achieving system-gains, as opposed to the stand-alone factory automation of management information components of an earlier phase.

A recent study of 900 U.S. and Japanese companies revealed the following:

- Japanese stress flexible factories, expanded customer service, and rapid generation of new products.

- They rate themselves ahead in flexibility.

- They are committed to staying ahead through advanced technology, such as computer-aided design, automated materials handling, and robotics. Japanese companies are 25 percent more likely than U.S. companies to emphasize these technologies and have bigger investments in them.

- Three out of four manufacturers say that IT spending (on flexible manufacturing systems and computer-integrated manufacturing) is aimed at enhanced flexibility (*Fortune* 1992).

A major concern has been how to synchronize shipments of small batches of products from these flexible factories, and how to get more timely feedback from stores so sales and distribution are as flexible as production. Toward that end, wide area information networks linking production, sales, and distribution functions are emerging as critical IT investments, as Japanese companies attempt to forge global strategies and integrate distributed activities in an organic fashion.

According to a recent Japan Management Association survey of more than 200 manufacturing companies, 4 percent had completed wide-area networks by 1989, 37 percent were in the process of adopting them, 15.1 percent were expected to begin adopting them within a year or two, and 26 percent were studying adoption. Thus, more than four out of five were interested in moving beyond factory automation to integrating all aspects of production, distribution, and sales into online networks (Kahaner 1993). The strategies of leading IT users in moving toward integrated networks for flexible tool production-distribution-sales systems are shown in *box 2.6*.

Fujitsu has begun into serving this market, using its factory automation and robotics technologies as core competencies and entering into an alliance with Tokki Corporation. Fujitsu is responsible for host computing to control orders and manage production planning and flows, and Tokki deals with data systems for factory floor robots. Fujitsu has established a computer-integrated manufacturing consulting center in Tokyo to provide seminars, demonstrate technologies, and conduct rapid diagnostics of client systems. NEC Corporation, which has such centers in Tokyo, Nagoya, and Osaka aimed at medium-size companies.

Box 2.6
Integrated Information Networks: Beyond Flexible Manufacturing to Flexible Total Production, Distribution, and Sales Systems

Examples of the shift to integrated networks in Japanese industry include:

KAO Corporation is the biggest manufacturer of soaps and cosmetics in Japan, with 1991 sales of $4.7 billion, has an information system that links production and purchasing, sales and shipping, accounting, R&D, marketing, shopfloor cash registers, wholesaler, sales force, and hand-held computers. The wholesaler can deliver goods within twenty four hours to any of 280,000 shops, with average orders of just seven items. When KAO introduces a new product, point-of-sale information from 216 retailers gives almost instantaneous consumer feedback on who is buying the product, the attractiveness of the packaging, and what to change in the product. This sensitivity helped KAO go from nowhere to second in market share in less than a decade.[64]

Honda has established an international information system uniting local car dealerships, regional parts warehouses, and Tokyo headquarters. A clerk at a Honda dealership on Long Island, New York, can order new inventory through a computer network that is tied to regional U.S. warehouses, which in turn are tied to Honda's U.S. headquarters and parent Honda in Tokyo.[65]

Nissan's Intelligent Body Assembly Systems, flexible robotics lines, are being expanded so that data from Japan can be transmitted by phone or satellite and production of a new model can begin simultaneously in any plant in the world.[66]

Other uses of integrated information systems include a model computer-integrated system for shipbuilding developed by a consortium of seven shipbuilders in 1992. The system integrates order receiving, planning, design, building, task control, and delivery. With this system, the receipt of orders from outside Japan, coordination of technical specifications development, estimating and re-estimating total plan costs, modification of computer-assisted design elements, process scheduling control, tooling support, pipe arrangement, and structural arrangement decisions are pulled together into a computerized system. In the bearing production industry, NIPPON has installed "centralized control systems linking production and sales that have shortened order fulfillment from twenty days to three days.[67]

Sources: (Listed below)

[64] Fortune 1992.
[65] BusinessWeek 1989.
[66] Fortune 1992.
[67] Kahange.

Conclusion

As the pioneer, Japan's information industry has been the model for other Asian NICs in our study. A key feature has been its systematic cultivation of core electronics manufacturing capabilities. Through tight controls over foreign technology imports and licensing, MITI helped engineer advantageous technology transfer agreements with U.S. and European firms (IBM, Phillips, and so on) in the 1950s and 1960s that enabled Hitachi, Fujitsu, and other manufacturers to surpass world standards in the 1980s. Industry-led research consortia, backed by MITI money and labs, helped continuously upgrade technical infrastructure during the catch-up period, and in today's recessionary environment they are favored mechanisms to explore new directions while reducing risk.

One should not overstate MITI's power. As the electronics industry matured, MITI's ability to influence competition receded. For example, in the 1970s, the key mainframe computer producers -- Hitachi, Fujitsu, and Nippon Electric -- were urged by MITI to consolidate, but they all rejected the proposal (Magaziner 1990). Still, MITI's many forums for listening to firms and its ability to anticipate technology trends have enabled it to remain relevant to specific sectors. Its opto electronic consortia helped restructure the technical base of Fujitsu and Hitachi in the era of downsizing computer systems.

Systematic promotion of information industry suppliers has also been vital in cultivating core national capabilities. The public technology extension system, the technopolis with its economies of agglomeration and regional links to information industry development, and the diversity of financial incentives for equipment and technology modernization, including the robot leasing companies, have provided management and marketing support for small and medium-sized enterprises. This system has helped these companies overcome technology and information gaps and market failures. Leasing and positive equipment depreciation rules also helped the firms absorb or avoid steep sunk costs for new equipment. In short, small and medium-size enterprises remained agile and ready to move to the next generation of technology.

Finally, government and business embraced a strategy to position the electronics sector internationally. Their partnership sought, over time, to maximize total factor productivity and market penetration by organizing production and investment networks throughout the region and world, even while retaining protective barriers against international competitors for critical activities. The international orientation of the electronics manufacturing industry was not shared by the telecommunications infrastructure industry. NTT and its supplier firms were heavily shielded from both internal and external competitors.

Until 1982 it was illegal to connect a computer to a telephone line without NTT's permission (Calder 1989). NTT's is dominance suppressed high-value information services in Japan. The 1985 liberalization is only starting to help build the information industry infrastructure necessary to compete internationally in high-tier services.

NTT has streamlined since its privatization. It has also begun to compete internationally by creating NTT International Corp., 53 percent owned by NTT, to consult with Asian phone companies, and by teaming with Electronic Data Systems, to do systems integration work for U.S.-owned companies in Japan, as preparation for entering the U.S. market (*BusinessWeek* 1989).

NTT's reinvention is critical for the whole domestic information industry given its market valuation, the largest in the world. NTT's ability to stay at the forefront of change will help determine Japan's ability to become an information society.

Another historic constraint on information services development has been the lack of compatibility and inter-operability of software systems in Japan. The MITI-sponsored IT research and standardization center, the Japan Information Processing Development Center, and the Japan Electronic Industry Development Association have all worked on this process, but, software standardization has lagged. Only about 10 percent of software in Japan is packaged; the rest is customized for each company customer (Besen). Recently MITI has sponsored a $200 million Software Industrialized Generator and Maintenance Aids (SIGMA) project involving 192 companies (some foreign-affiliated, such as IBM-Japan). SIGMA is developing a standardized interface between application programs and a UNIX operating system to encourage the adoption of UNIX and save programming resources. As Besen notes, it is not clear whether this open-systems orientation will conflict with manufacturers' insistence on proprietary technologies and operating systems to protect confidential technical data.

Thus, deficiencies in infrastructure, software, and emerging areas such as multimedia will have to be overcome for Japan to continue its information industry growth in the face of escalating competition from Asian manufacturers, and U.S. service sector companies.

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Thus, deficiencies in infrastructure, software, and emerging areas such as multimedia will have to be overcome for Japan to continue its information industry growth in the face of escalating competition from Asian manufacturers, and U.S. service sector companies.

CHAPTER 3: INFORMATION TECHNOLOGY IN KOREA

"National power does not come from guns, but from the accumulation of science, technology, and information."

Kim Young-sam
The President of South Korea

Introduction

Korea has rapidly transformed its economy with export-led growth. Starting as an exporter of low-cost, labor-intensive manufactures such as garments in the mid-1960s, Korea became well known as an exporter of ships, steel, and construction services by the late 1970s, even challenging some established suppliers in industrial countries. By the mid-1980s, Korea had also made its mark in more technology- and knowledge-intensive industries such as automobiles and electronics, including semiconductors and computers. Korea is now the world's fourth largest producer of electronics, behind the United States, Japan, and Germany.

Korea is the world's third largest producer of dynamic random access memories (DRAMs), an advanced semiconductor product. Its mastery of advanced semiconductor manufacturing is regarded by some writers as a landmark in Korean economic development.[68] Samsung, the well-known Korean conglomerate, ranked the world's fifth largest producer of DRAMs in 1991, and is expected to be the world's largest by year 2000. Korea has also made impressive strides in acquiring and mastering technological capabilities for producing computers and peripherals; it is now a significant exporter of computers to the United States and Western Europe.[69] Furthermore, Korea has built up fairly advanced capabilities in telecommunications technology. The development of time division electronic switching (TDX) technology, for example, is a milestone in Korea's technological development.

[68] The production of semiconductors was virtually ignored until about 1982 (World Bank 1992a). Thanks to a worldwide shortage in semiconductors, which raised their price and impeded the production of consumer electronics, leading electronics firms in Korea vertically integrated and moved aggressively into semiconductors. A surge of investments in semiconductor production followed. In 1983 alone investments amounted to $300 million, compared with a total of $200 million between 1974 and 1982. Investments climbed in 1984, 1985 and 1986, to about US$400 million each year. Today semiconductors constitute the largest segment of the Korean electronics industry.

[69] The computer industry dates back to around 1979, when a few firms began producing dumb terminals (Kim and others, 1987). In 1980 small entrants started producing Apple-compatible, eight-bit personal computers. The number of computer producers rose from 4 in 1980 to 50 in 1985. The share of computer hardware in GNP grew from 3.5 percent in 1984 to 11.8 percent in 1990. While electronics exports grew from $2 billion in 1980 to $4.3 billion in 1985, the export share of computers and peripherals within electronics increased from 0.3 percent in 1980 to 9.2 percent in 1985. Computers are now Korea's second largest electronics export, trailing only semiconductors. Compared to semiconductors and computer hardware, software's share in GNP is small, but it has risen from just over 0.5 percent in 1984 to 4 percent in 1990. See *Electronics Korea*, March 1990.

Korea is also amongst industrializing countries that apply information technology (IT) as a generic technology, and as an essential infrastructure. The country has 222 mainframe computers per million persons, a much higher ratio than other industrializing countries. As with other East Asian newly industrializing economies such as Taiwan (China) and Singapore, Korea's public sector is a main user of IT. In the private sector, manufacturing, especially computer-automated production and planning, is emerging as a key user. Confronted with the erosion of the advantage of cheap labor, most private entrepreneurs have realized that factory automation is key to international competitiveness. A recent survey of manufacturing firms showed that more than half had deployed computer-aided design and computer-aided manufacturing systems.[70]

Korea had 28.3 telephone lines per 100 persons in 1989, a high level for an industrializing country, allowing access to a range of services including facsimile and data bases. Providers of value-added services, who do not own a network but use the basic network have emerged and are growing rapidly. As are Taiwan (China), and Singapore, Korea is entering a new phase of information and communication characterized by online dissemination through commercial networks and vendors, strengthening of the private data base industry, and the deregulation and privatization of state telecommunication services (Lee 1992).

In contrast to basic communications (such as telephone and telegraph services), specialized services (data bases, data processing, and data communications) are still in their infancy, but are growing rapidly.[71] In the late 1970s to early 1980s, many government organizations began using computerized data bases for administrative purposes. The number of subscribers to data base services has grown, from just 145 in 1985 to 5,325 in 1989. Similarly, subscribers to data communication networks rose from 443 to 5,082 in the same period.

The leading role in Korea's informatics sector has been played by the private sector, particularly the large business conglomerates.[72] The private sector's early experience with consumer electronics and its aggressive strategy to acquire and adapt foreign technology have been key to its rapid mastery of IT-related capability. The government has played a crucial role in this process. IT has benefited from a number of IT-specific and other policies including infant industry protection, government procurement, preferential financing, human

[70] *Electronics Korea*, February 1990, referred to in OECD 1992.

[71] As an indicator of the diffusion of basic communications, the number of telephone lines. The number of telephone lines quadrupled between 1980 and 1989. (Kim and others, 1992).

[72] The electronics industry is concentrated in a handful of *chaebols*-- Samsung, Goldstar, Daewoo and Hyundai. In 1988 subsidiaries of these four business conglomerates controlled 56 percent of electronics output. (Bloom 1991). 1991).

resource development policies and research and development (R&D) policies.[73] These policies have been implemented through a well managed "technology infrastructure" of public R&D institutes, universities, standards institutes, and industry associations.[74] All this, of course, have been in addition to a conductive macroeconomic context, geopolitical factors, and other historical and socio-political factors that explain the Korean "miracle."

Building Capability in Information Technology

The Korean electronics industry has been transformed in the past three decades, from assembly of imported parts to a major producer and exporter of advanced electronics. Consumer electronics preceded the development of the IT subsector, and private firms' experience in consumer electronics, no doubt, influenced the building of IT-related capabilities. The evolution of IT, in fact, provides a classic example of how Korea diversified its industrial technological capability.

1. Private Sector Strategies for Acquiring and Mastering Technology

The Korean electronics industry dates back to 1959, when Goldstar started assembling radios for the domestic market. In the 1960s the electronics industry expanded into assembly of black and white TVs, integrated circuits, and radio communications equipment. Production of VCRs, microwave ovens, calculators, and hybrid integrated circuits followed in the 1970s. The 1980s brought the production of computers, and 4- and 16-megabyte DRAMs. The share of electronics in manufacturing output rose from 2 percent in 1970 to nearly 20 percent in 1990.[75] Electronics exports rose from $19.5 million in 1968 to $20.2 billion in 1991. In 1992 electronics accounted for nearly 30 percent of total exports and employed about 10 percent of the country's factory workers.

Production was initiated by domestic firms, principally for the domestic market. Foreign firms became important in 1966, when U.S. firms like Motorola, Signetics, and Fairchild Semiconductor Control Data, started assembling semiconductors - attracted by Korea's cheap labor. A series of joint-ventures between Japanese and local firms followed, mainly to assemble consumer

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[73] The significance of direct and indirect government assistance to Korean electronics is also evidenced by the introduction of anti-dumping laws in the United States against Korean electronics, and mounting pressure from the United States and the European Union urging the Korean government to reduce subsidies to electronics.

[74] Three government ministries deal with IT: the Ministry of Science and Technology, the Ministry of Trade, Industry and Energy, and the Ministry of Communications. To a lesser extent, the Industrial Promotion Agency, Patent Agency, and the Ministry of Culture and Sports, promote or regulate IT activities.

[75] Value-added per worker rose to more than $20,000 by 1989.

electronics. This includes Samsung Electronics, founded in 1969 as a joint venture with Sanyo of Japan. In the early 1960s the electronics industry was driven mainly by American and Japanese investment totaling $23 million between 1962 and 1966. In 1968 wholly foreign-owned firms accounted for 71 percent of exports (*table* 3.1).[76] By comparison, local firms accounted for 21 percent and joint ventures accounted for 8 percent.

The importance of local firms steadily increased. By 1980 domestic firms' share of electronics exports had risen to 48 percent and foreign firms' share had fallen to 37 percent.[77] This was due to two factors: (a) a reduction in foreign investment; and (b) the progression of previously domestic market-oriented local firms into export activity. Foreign firms including Matsushita, Sanyo and NEC withdrew from joint ventures in the late 1970s as tax advantages were withdrawn (Hobday, 1994). Increasing labor costs further discouraged foreign investment.[78] Employment in foreign firms fell by one-third between 1976 and 1985.

This does not mean, however, that Korean firms became totally independent of foreign firms. By the late 1980s Korean firms still depended on Japan and the United States for technology, key components, capital goods, and material. What has changed since the mid-1970s was the nature of interaction between local and foreign firms.[79] Unlike in most other Korean industries, foreign investment in electronics seems to have been essential at the beginning.[80] But as Korean firms built technological capabilities, their reliance on foreign investments for technology transfer decreased.[81] Instead, Korean firms began to rely on original equipment manufacturers (OEMs) and technology licensing for technology acquisition.[82] For example, in the 1980s,

[76] By 1970 the proportion of bonded processing, a good indicator of the importance of foreign firms, was 80.8 percent for electronics exports, compared to 18.2 percent for all Korean exports. See Michell, (1988).

[77] The proportion of output exported rose from 33.9 percent in 1968 to 72.9 percent in 1976.

[78] The withdrawal of foreign firms was most apparent in subassembly operations, especially in the export processing zone in Masan, as foreign firms faced high labor costs. By 1980 a number of firms in Masan were idle (Michell, *ibid.* p. 141).

[79] Matsushita and NEC, for example, still retain technical links with their former joint-venture companies.

[80] Foreign direct investment in total capital formation in Korea has been low, but it was concentrated in technology-intensive sectors such as electronics. See M. Hobday (1993).

[81] Realizing this, the government appears to have "encouraged" foreign firms to leave by withdrawing tax advantages (Hobday 1993). As discussed below, such government action was accompanied by increasing government assistance to local electronics firms.

[82] During the 1980s some 50 percent to 60 percent of Korean electronics goods were exported under OEM arrangements (Hobday 1994). OEM deals appear to be much higher for products at an early stage of development. Until recently exports of computer terminals and telecommunication equipment were almost all on an OEM basis (Bloom 1991). In 1988 virtually all sales of 256K DRAM chips sales from Hyundai Semiconductors to Texas Instruments were on this

Samsung entered into several technology licensing agreements with Toshiba, JVC and Sony of Japan, Phillips of Holland, and General Electric of the United States to acquire technology in color TVs, VCRs, air conditioning equipment, and microwave ovens (Hobday, 1994). Some agreements were for production technology, others pertained to patent rights. Licensing was also used to acquire telecommunications technology from L.M. Ericsson (through Oriental Telecommunications), Alcatel, Toshiba, and Italtel in the mid-1980s. Leading Korean firms have started collaborating with international market leaders to develop new highly advanced technology (Hobday 1994).[83]

Table 3.1: Electronics Exports by Local and Foreign Companies, 1968-80 (millions of U.S. dollars)

Year	Local firms	Joint ventures	Foreign firms
1968	**4.0** (21)	**1.7** (8)	**13.8** (71)
1972	**41.1** (29)	**23.5** (17)	**77.6** (55)
1975	**151.8** (26)	**134.5** (23)	**295.6** (51)
1976	**318.2** (31)	**235.6** (23)	**483.0** (46)
1977	**354.1** (33)	**197.4** (19)	**512.2** (48)
1978	**525.3** (39)	**249.9** (18)	**584.0** (43)
1979	**839.2** (45)	**268.5** (15)	**737.7** (40)
1980	**954.1** (48)	**300.5** (15)	**749.2** (37)

Note: Numbers in parenthesis are percentages.
Source: Michell 1988.

In addition to formal modes of technology acquisition (such as foreign investment, joint ventures, licensing, OEM arrangements), firms have used informal channels to acquire

basis. In contrast, OEM arrangements account for about 30 percent of all Korean exports. As for technology licensing, electronics, electrical and communications equipment were responsible for 38 percent of the total value of licenses in 1987, as against 12 percent of all licenses in 1967-71 (Bloom 1991).

83 For example, in 1992 Samsung signed an eight-year agreement with Toshiba to develop flash memory chips, a leading-edge semiconductor for computers.

technology, recruiting foreign managers and engineers, recruiting local engineers with previous experience in foreign companies, sending technical staff abroad, and employing reverse engineering. Firm strategies, however, have varied. Hyundai generally avoided joint ventures when it entered shipbuilding, automotive industries, and semiconductors, preferring to employ foreign technicians or license technology (Bloom 1991). In electronics, however, Hyundai's strategy has involved joint ventures to acquire capability in advanced semiconductors and other IT products.[84] By comparison, Goldstar has relied on joint ventures - with Hitachi Cable (1969), Siemens (1970), Juji Electric (1970), NEC, Alps, AT&T, and Mitsubishi. Samsung has relied on joint ventures, licensing, and establishing or acquiring research facilities abroad.

Firms' means of acquiring technology for IT products - computers, semiconductors, and telecommunications equipment - have also varied, largely depending on their initial conditions. All *chaebols* have had crucial foreign links for technology licensing, OEM, or training although their individual strategies may have varied. The development of semiconductors, for example, owes much to technology and semiconductor manufacturing equipment from the United States and Japan (Bloom 1991). All four major semiconductor producers had initial links with leading U.S. firms, Texas Instruments (Hyundai), Intel (Samsung), AT&T (Goldstar), and Zymos (Daewoo). Korean firms have strategically changed their technological partners to acquire more complex technology. Samsung, for example, acquired 4-megabyte DRAM technology from IBM. The telecommunications industry owes a lot to U.S. and Japanese companies - ITT (Samsung), AT&T (Goldstar), Northern Telecom (Daewoo), and Sumitomo (Taihan Electric Wire) - especially for obtaining optic fiber technology.

2. Building Technological Capability in Computer Production

The local firms that entered the computer industry during its first three years, 1980 to 1982, had varying technological capabilities. Kim and others (1987) classifies them according to production capacity (the ability to operate and maintain production processes) and innovation capacity (the ability to generate and improve products and processes) (*table* 3.2).

[84] In 1986 Hyundai had a joint venture with Tandon to produce floppy disk drives. In 1989 Hyundai set up a joint venture with Allen Bradley to produce programmable logic controllers.

Table 3.2: Classification of Computer Manufacturers

Innovation Capacity	Production Capacity	
	High	Low
High	Industry dominators	Entrepreneurial innovators
Low	Original equipment manufacturers	Apprentices and imitators

Source: Kim and others, 1978.

Industry Dominators. The first group had both production and innovation capabilities at entry, and soon dominated the industry. These firms had more than 20 years' experience in consumer electronics. Capabilities gained in consumer electronics were applied to the production and innovation of computers.

The industry dominators, reluctant to copy foreign products, began investing heavily in acquiring technological capabilities in computer design and manufacturing to supplement capabilities in consumer electronics. They established high-tech outposts in Silicon Valley to design computers and chips, manned primarily by Korean-American scientists who had worked at American computer firms such as IBM, DEC, Bell Labs or Hewlett Packard. The California offices are "antennaes for information on research activities and training posts for scientists and engineers from R&D centers and manufacturing plants in Korea. The industry dominators were also the major beneficiaries of public R&D support, receiving more than 90 percent of the government's support for joint research. These firms also accounted for about 60 percent of foreign licensing through 1985. In other words, the industry dominators invested heavily in building relations with others who could provide critical technology elements.

Entrepreneurial innovators. The second group of firms, small in number, are, technology-based spin-offs from universities and public R&D institutes without production experience. Given their initial capability to innovate, they started with developing innovative systems and software for the industry dominators under subcontracting arrangements, and gradually accumulated production capability to manufacture their own systems. They relied less on licensing foreign technology but maintained relationships with their original organizations (universities and R&D institutes) to sustain competitiveness. Some have become important exporters. Cooperation among industry dominators and entrepreneurial innovators has accelerated learning for both parties, with the industry dominators strengthening their innovation capacity and the entrepreneurial innovators gaining production capability.

Original equipment manufacturers. The third group of firms entered the computer industry with some production experience in industrial electronics, but little innovative capability. These firms mainly engaged in producing computers and peripherals for OEM buyers. The firms benefited from technical assistance from OEM buyers but did not aggressively invest in acquiring capabilities. Some have intensified their R&D activities to diversify products and markets.

Apprentices and imitators. The fourth group of firms entered the computer industry with capability in neither production nor innovation. There are two different types of firms in this group -- "apprentices" and "imitators". Apprentices are large existing firms with no experience in electronics. Apprentices entered the computer industry as local sales and service agents for foreign mini- and microcomputers and gradually started manufacturing under foreign licensing. They acquired technological capabilities through heavy reliance on foreign sources, such as training at the supplier's site and training by foreign engineers at the recipient's site. By contrast, imitators are small new entrants with little capability in either production or innovation. These firms acquired technological capability by assembling a small number of eight-bit PCs through reverse engineering and gradually accumulated production experience. Apprentices grew rapidly by quickly acquiring technological capability. They used foreign assistance to supplement their own technological capability. But imitators could not compete in the mid-1980s when industry dominators began marketing innovative PCs.

The Role of Government in Promoting the Generation and Diffusion of Information Technology

In the 1960s and early 1970s, when the concept of information technology was not yet in vogue, the government focused on other areas of electronics, mainly consumer electronics. Attention to computers and semiconductors became more pronounced with the launching of the Fourth Five Year Plan of 1977-81.[85] In the late 1980s and early 1990s the government promoted not just the IT industry but also a major "informatization" of the Korean society.

A variety of policies have promoted Korean technological development: human resource development programs, R&D incentives, financial assistance to firms for investments in technology, and technology support services from public sector technology institutions.[86] Some

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85 According to some writers, the government played an even more active role in promoting computer and other micro-electronics related industries in the 1980s than it did for other industries in the previous two decades. See Kim (1987), p. 282-283.

86 A number of World Bank loans have facilitated these measures. The Bank's first involvement in Korea's industrial technology development was in 1979 with the "Electronics Technology Project" (Loan 1676-KO). This project sought to develop the capacity of the Korea Institute of Electronics Technology (KIET) to spearhead the Korean electronics industry into advanced semiconductors. The Bank also supported the Korea Technology Development Corporation with three loans totalling US$ 150 million between 1982 and 1988 (Loans 2112-KO, 2473-KO, and 2913-KO). The Bank assisted the Small and Medium Industry Promotion Corporation which complements the activities of KTDC by providing support to small and medium-sized firms (Loans 2215-KO and 2515-KO). In May 1983, the IFC invested W 750 million in the Korea Development Investment Company a venture capital company whose primary objectives include the provision of equity finance for commercialization of new technology. The Bank has also extended several education sector loans (Loans

policies targeted specific industries including electronics, some did not. Invariably, both the IT industry, as well as IT applications in other industries and services, have benefited from these policies.

A number of public technology and research institutes have led industry into new technological fields and products, imparted technological information, provided training, and coordinated research among public institutes, academia, and private firms. The most important of these institutions for IT have been the Korea Institute of Electronics Technology (KIET), Korea Advanced Institute of Science and Technology (KAIST), and Korea Electronics and Telecommunications Research Institute (ETRI).

1. The Overall Policy Context

Macroeconomic policies. There is little doubt that both the IT industry and IT applications have benefited from a macroeconomic environment conducive to private sector-led growth.[87] Well handled and largely predictable macroeconomic policies contributed to raising firms' own demand for acquiring, adapting, diffusing, improving and developing IT.

Industrial policy. The evolution of the Korean electronics industry, including the IT industry, has been influenced by industrial policy (*table 3.3*). The electronics industry is among those that have been favored by the government, now for more than three decades. Government policy within electronics, however, has changed over time from promoting assembly (mainly of consumer products) to more technologically sophisticated production (including advanced semiconductors).

The evolution of industrial policy has had four main phases. The first phase, from 1953 to 1961, was inward-looking, encouraging import substitution in consumer and intermediate goods industries. This policy soon reached its limit primarily because of the small domestic market. The government adopted an outward-looking strategy in 1962 that included trade reforms, currency devaluation, tax reforms, and price stabilization. During this second stage, industrial policy promoted labor-intensive, light industries such as garments, textiles, footwear, plywood, and consumer electronics.

Outward orientation continued in the third stage, in the 1970s, but the focus shifted to capital-intensive industries such as heavy machinery, shipbuilding, iron and steel, non-ferrous

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1800-KO; 2427-KO; and 3037-KO) to improve the quality of higher education in science and engineering, and to increase the supply of qualified Korean engineers, technicians and managers.

[87] A well managed macroeconomic environment is a key factor explaining the Korean "miracle". Although the late 1970s witnessed a macroeconomic crisis, a stabilization program launched in 1979 was successful in restoring stability (Dailami 1991).

metals, and petrochemicals. The government sought to move industry away from assembly operations to more complex technologies. The Fourth Five-year Plan (1977-81) called for a deepening of technological capabilities in electronics, involving a shift from assembly to more technology-intensive operations. In the 1980s, industrial policy shifted again, away from heavy industry toward knowledge-intensive, high technology industries such as precision machines, fine chemicals, biotechnology, and industrial electronics.

A key feature of the Korean industrial policy has been the way in which the government promotes selected industries. The government has favored infant and strategic industries over established, internationally competitive industries. Incentives for established industries are policy-neutral -- meaning that effective incentives are roughly equal to imports and exports. But, there has been substantial bias toward selected infant industries. Instruments have included tariff and non-tariff protection, preferential credit, tax incentives, and so on. Yet at the same time, the infants --generally limited in number at a given point --have been forced to export quickly.

Table 3.3: Evolution of Industrial and Technology Policies

	1960s	1970s	1980s	1990s
Goal of industrial policy	• Support export-oriented industry • Import substitution • Prepare for heavy chemical industries	• Support heavy chemical industries • Support large export firms	• Support strategic industries • Ready for high-tech industries	• Support high-tech industries • Prepare for information industry
Main sectors of industry	• Handicrafts • Light industries (food, textile, apparel, plywood, footwear)	• Light industry • Some heavy industries (petroleum, cement, steel, ship building)	• Heavy industries • Some high-tech industries (electronics, automobiles, computers, microchips)	• High-tech industries (new materials, life science industry, information)
Technology import policy	• Restricted	• Restricted (but ready to liberalize)	• Liberalizated	• Full liberalization
Institution building	• Ministry Of Science and Technology • Science & Technology information center	• Public research institutes	• Science & Technology commissions • R&D cooperatives	• Cooperative R&D
Main Policies	• Science & Technology institution building • Education and human resource development • Import foreign technologies	• Reinforce technological capability in strategic industry • Assimilation and modification of foreign technology	• National R&D programs • Liberalization of technology imports	• Large, composite R&D projects • International R&D cooperation Increase supply of high-tech manpower

Source: Sun Geun Kim, 1994: 3.

In addition to promoting selected industries, the government has also fostered favored business groups - *chaebols* - that have been at the forefront of Korea's industrialization.[88] In the early 1960s, electronics goods were produced by relatively small firms. Today electronics production is concentrated in a handful of *chaebols,* giant conglomerates.[89] Particular sectors and firms, including electronics, have had preferential access to working capital and low-interest loans from the government-controlled financial system. Selected sectors and firms have been protected from competition from imports and foreign firms located in Korea. At the same time, the government was willing and capable of enforcing performance standards on favored enterprises and disciplining them.

Science and technology policy. Beginning with the First Five-Year Plan in 1962 and continuing into the 1970s, science and technology policy was an implicit part of industrial policy. The main focus was on acquiring and absorbing imported technology and building the technological infrastructure to support that goal. But, as some spheres of Korean industry — including several areas of electronics such as microprocessors and computers — approached frontier technology, the government felt the need to encourage greater R&D for developing new technologies. Policy since the 1980s has focused on future-oriented, long-term, large-scale research. IT has a prominent position in such futuristic policy action.

At the forefront of science and technology policies during the 1980s and 1990s have been national R&D programs, including the Highly Advanced National (HAN) project launched in 1992. The first national R&D program, initiated by the Ministry of Science and Technology in 1982 supported high-risk research and research with important externalities. All projects were entirely government initiated and funded. Fields included information technology, new material technologies, core industrial technologies for import substitution industries, energy and resources technology, environmental and related technology, and marine and space technology.

The second national R&D program, implemented by the Ministry of Trade and Industry in 1987, focused on the development of industrial "seed" or "core" technologies that private firms could not handle alone. These projects were cofunded by the government and participating companies. They included relatively weak technologies in new materials, machine automation, electronics, information and communications, and textiles. In 1988 the Ministry of Energy and

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88 This strategy was based on the premise that large size was necessary to undertake the risks and costs of setting up internationally competitive industries involving complex technologies (World Bank, 1993). In addition, in the early years, Korea economized on scarce entrepreneurial resources (Mody, 1989; Ernst & O'Connor, 1992).

89 The average electronics firm in Korea is much larger than in Taiwan. In 1987, the average Taiwanese electronics firm had a production turnover of $3.5 million, compared to $15.1 million in Korea. In addition to economizing on scarce entrepreneurial and managerial resources, large conglomerates facilitated the adoption of increasing returns technologies as well. The Korean electronics structure is heavily weighted towards high volume, standardized products subject to sizeable scale economies -- color TVs, audio equipment, VCRs, and memory chips.

Resources launched a third national R&D program to develop alternative energy and the basic technologies necessary to use it. The Korea Institute of Industrial Technology annually surveys firms to determine which technologies they want to develop.

Perhaps what distinguishes Korea's government-initiated R&D programs from those in other industrializing countries is the government's willingness and ability to constantly evaluate its own R&D programs and change them. For example, the Highly Advanced National Project which focuses on strategic, demand-driven R&D, was the result of the Ministry of Science and Technology's internal evaluations, which concluded that its R&D programs had been more curiosity driven, rather than demand driven or strategic.

Science and technology policy has focused increasingly on collaborative research. As *Table 3.4* shows, cooperative R&D accounts for nearly 60 percent of the national R&D programs (Jin-Gyu Jang 1994). Eighty-seven percent of the Highly Advanced National project involves cooperative research. The government has encouraged joint research by R&D institutes, universities, and industry by enacting:

- the Technology Development Promotion Law in 1977, which established an industrial technology research union.

- the Industrial Technology Research Consortium Act in 1986.

- the Science and Technology Promotion Law in 1991, which guarantees the status and wages of exchange scientists.

- the Cooperative R&D Promotion Law in 1993, which provides funds, manpower, facilities, and information necessary for cooperative research (Jang 1994).

Table 3.4: Cooperative R&D in National R&D Projects (Percent)

Projects	Number of projects	Unilateral projects	Cooperative projects
Highly advanced national projects	**148** (100)	**19** (13)	**129** (87)
Strategic national R&D projects	**727**[a] (100)	**392** (54)	**335** (46)
Industrial seed technology projects	**173** (100)	**26** (15)	**147** (85)
Total %	**1,048** (100)	**437** (42)	**611** (58)

[a] *Note:* Does not include 17 industrial seed technology projects and R&D planning and evaluation projects.

Source: Jin-Gyu Jang 1994.

Cooperative R&D has the first priority among R&D projects for grants. Moreover, consortiums with more than ten research staff members are exempt from paying customs taxes on imported research equipment. The establishment of a Science Town in Daeduk —expected to house more than fifty institutes of research and education by 2000 -- will further expand cooperative research (Looncheol Lim 1994).

A number of developments in informatics have been attributed to cooperative R&D (Jin-Gyu Jang 1994). Among the most successful are TDX-1, TDX-10, 4M DRAM, 16M DRAM, TICOM1, and TICOM2, all implemented through an R&D consortia composed of ETRI and four private firms. For example, after TDX-1 was developed by the consortium, participating firms produced it.

2. *The Evolution of Korean Information Technology Policy: An Overview*

The Electronics Industry Promotion Act in 1965 was probably the first major step toward assisting the IT industry. This led to several policy measures including the Eight-Year Electronics Development Plan and the creation of the quasi-governmental agency, the Fine Instruments Center, responsible for implementing government policies toward the industry (Michell 1988). The Fine Instruments Center set up offices in New York, Tokyo, Bonn, and San Francisco to promote foreign investment, and offered feasibility studies to would-be investors on potential operations in Korea and provided market information. The center also organized the Korea Electronics Show, held for the first time in 1970. Though it is difficult to evaluate the center's contribution to attracting foreign investment in electronics, its activities demonstrated that the government was serious in offering "an initial entry point into what is, after all, a difficult country in which to invest because of innumerable regulations, mostly not translated to English and open to ambiguous interpretations" (Michell 1988).

The Fine Instruments Center also tested products and industrial equipment used by industrial firms, and qualified technicians. It negotiated agreements with foreign quality-control agencies to ensure that Korean exports met the quality and safety requirements of importing countries. The center conducted junior-college training and short-term courses for technicians and engineers in electronics. In 1979, the center was absorbed into the Electronics Association, to form the Electronics Industries Association of Korea, which has taken over all of the Center's former functions.

Another important government agency early on was the Korean Trade Promotion Corporation (KOTRA), established in 1962 (Michell 1988). It set up about a hundred trade centers around the world to supply foreign buyers with information, contacts, product samples, and publications (Hobday 1994). Much like JETRO in Japan, KOTRA representatives, working with embassy and consular officials, traveled the world exploring potential markets for existing products. KOTRA also advised manufacturers about products that could be developed. KOTRA organized the first international trade fair in Korea in 1968. It trained Korean salesman, advised them on foreign import laws, and provided legal advice. As *chaebols* developed their own trade information networks, the role of KOTRA changed, but it remains a key source of information for government and small and medium-sized industries, as well as for foreign importers seeking advice on manufacturers in Korea.

The Eight-year Electronics Development Plan ended in 1976 and was succeeded by the Fourth Five-Year Plan of 1977-81, a milestone in the evolution of electronics. The Fourth Five-Year Plan ranked electronics as the second most important sector after the machinery industry (Michell 1988). The plan envisaged a structural shift within electronics, from assembly operations to the production of basic components and parts. Export targets were set for 56 items selected "on the basis of product life cycles, and comparative advantage". This included a large number of IT products — semiconductors, computers and related items. In addition, the plan enunciated eight general policies toward:

- Boosting the industry as a leading export sector and diversifying markets;
- Promoting technical development and renovation;
- Developing products of superior quality;
- Developing domestic models and renovating designs;
- Standardizing products to reduce costs and achieve mass production;.

- Promoting foreign investment and international specialization;
- Improving manufacturing techniques and production processes; and
- Increasing the use of locally made parts and raw materials (Michell 1988).

The government, above and beyond employing its usual incentives, pushed higher value-added products embodying greater level of skill and technology. It established an industrial estate for semiconductors and computers. The Electronics and Telecommunications Research Institute, within the estate, set aside a $60 million fund to promote the importation and mastery of advanced technology.

The government also protected the domestic market.[90] A 1983 law restricted imports of computers and peripherals in both low and medium ends of the market. The law prohibited imports of most microcomputers, some minicomputers, and selected disk drives, printers, terminals, and tape drives (Harvard Business School 1985). As Korean producers began developing personal computers, imports were restricted. This provided a protected market for small local firms to enter and survive long enough to gain initial experience in computer manufacturing. The government, however, liberalized the market in 1987 under pressure from the United States. While restrictions were imposed on direct foreign investment in electronics, joint ventures were viewed favorably. Most of the big business groups in the computer field — Hyundai, Daewoo, Lucky-Goldstar and Samsung — entered into joint ventures.

Government policy since the mid-1980s has tried to respond to the information technology "revolution." As the concept of "information society" became popular, the government started emphasizing greater diffusion of IT. This does not mean, however, that its support for the local IT industry became less important. In fact, government efforts at diffusing IT were primarily linked to promoting the local IT industry. In addition, there have been many government-sponsored IT projects.

Growing government commitment to IT generation as well as diffusion is reflected in a long-term economic development plan announced in 1986 -- that highlighted IT's place in making Korea an advanced nation by 2000. The plan included prospects, goals and strategies for cultivating an information society. Among its goals were expanding high-quality communications facilities, popularizing the use of information, developing and diffusing new media such as

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[90] "As traditionally defined, semiconductors and computers hardly fell within Korea's area of comparative advantage, certainly not in 1976, when per capita income in Korea was only $459, about the same as Guatamala's. The fourth five-year plan therefore accelerated the import-substitution of such goods" (Amsden 1989).

teleconferencing and videotext, completing an online network for post offices, cultivating high-quality manpower (*table 3.5*), and fostering promising IT products and enterprises (Lee 1990). Several IT-related projects were launched in the late 1980s, including G-7, Electro 21, ISDN, KoreaSat, and a national computerization plan.

In the early 1990s the government appears to have intensified its commitment to informatics. An Information Industry Promotion Plan, announced in December 1992, was to bring Korea's IT up to the level of advanced countries by 2000. The plan stipulates goals for the four sectors — computer, semiconductors, communications, and software (*table 3.6*).

Kim Young-sam, Korea's first democratically elected president, has launched a very comprehensive technology policy, with greater emphasis on promoting IT. The electronics industry is expected to receive massive government funding through 1996. Under a plan announced in December 1992 (*box 3.1*) the government is expected to invest \$1.9 billion by 1996 in a computerized information network — an essential infrastructure for the IT industry. In addition, \$128 million a year is expected to be loaned to the four subsectors — communications, computers, software, and semiconductors — over the next three years.

The Highly Advanced National (HAN) Project, seeks to identify and develop strategic industrial technologies (Yooncheol Lim 1994) As noted earlier, this project recognizes a greater need for paying attention to the needs of industry. The project has two components: the Product Technology Development Project for specific products, and Fundamental Technology Development Project for core technologies deemed necessary for economic and social progress. IT occupies a significant place in both types (*tables 3.7* and *3.8*).

Table 3.5: Investment and Manpower Plans for the First Phase of IT Development, 1987-91

Technology	Objective	Investment (millions of U.S. dollars)	Manpower (persons)				
			1987	1988	1989	1990	1991
Computers	• Development of high-quality work stations • Development of multiprocessor systems	227	980	1,020	1,160	1,340	1,560
Software	• Establishment of software engineering environment • Language translation and voice recognition technology	491	940	1,260	2,120	2,670	3,050
Semiconductors	• 4/64-Megabyte DRAM development • VLSI design technology	435	1,100	1,150	1,310	1,450	1,910
Communications	• Digital communications network development	133	4,430	4,770	5,570	6,580	7,360

Source: Jae Beom Lee, 1990.

Table 3.6: IT Development Objectives: A Phased Approach

Technology	First phase (1987-91)	Second phase (1992-96)	Third phase (1997-2001)
Computers	Development of super-minicomputers	Establishment of the foundation for AI computer technology	Development of AI computers
Software	Establishment of software engineering environment	Development of systems software	
Semiconductors	Development of 4-Megabyte DRAM	Development of 16/64-Megabyte DRAM	64/256-Megabyte DRAM
Communications	Building digital communications networks	ISDN/Value Added Networks	Value Added Networks

Source: Jae Beom Lee 1990

Box 3.1
IT Development Master Plan - 1992

- *Computers*: increase the number of personal computers and terminals from 2.2 million to 10 million by 2001; increase the locally manufactured computer market share from 3 percent to 50 percent by the 2000s; and launch a special program to turn out 1,000 technical experts a year at information and science high schools and university departments.
- *Semiconductors*: develop 256-Mbit DRAM chips within three to four years.
- *Communications*: develop broad-band information services digital network (ISDN) and digitize wireless networks for cellular phones.
- *Software*: establish a center to map out a standard linking code Korean and other languages.

Source: *Electronics* 1993.

Table 3.7: HAN Project: Products Technology Development

Industry	Product Technology
Semiconductor industry	Highly integrated semiconductor
Communication industry	Integrated service and data network (ISDN)
Home appliance industry	High definition TV (HDTV)
Automobile industry	Electric vehicle
Computer industry	Intelligent computer
Fine chemical industry	Medicine and agricultural medicine
Mechatronics	Advanced production systems

Source: Yooncheol Lim, 1994.

Table 3.8: HAN Project: Fundamental Technology Development

Technology	Development Activity
New materials	Advanced materials in information services, electronic and energy industry
Machinery	Next generation transportation systems, including machines and parts
Bio-technology	Functional bio-materials
Environmental technology	Environmental engineering
New energy	Energy resources
Atomic power	Reactor design and verification
Human factors	Interface with electronics and robotics

Source: Yooncheol Lim, 1994.

A reorganization of government administrative structure is also on the agenda, to accommodate the growing importance of technology This would include a reorganization of the Ministry of Communications as the Ministry of Information and Communications so that the requirements of the emerging information society can be better met. Perhaps in keeping with his view that national power stems from science, technology and information (and not guns), President Kim has proposed to charge the intelligence agency, the Agency for National Security Planning, with gathering international economic and industrial information, and sharing it with business enterprises (Electronics 1993).

Policies for Promoting the Information Technology Industry

Some government IT policies and programs have been demand-side, designed to induce the private sector to produce IT goods. Two key demand side policies have augmented private efforts in computer production: protection of the domestic market for personal computers and peripherals, and government procurement. The government has also adopted a number of supply-side actions to help building technological capabilities of private firms, including: R&D tax incentives to the private sector, financing of IT-related research, R&D support from public sector technology institutions, development of technologies by public R&D institutions that are diffused to the private sector, cooperative R&D between public technology institutions and private firms, and IT-related basic research in universities.

1. Trade Policies

The Korean market is too small for cost-effective production of many consumer electronic products (Bloom 1991). But that does not mean that the domestic market has not been significant. The impetus to make consumer electronics originated with the protected domestic market.[91] To promote local production, the government imposed tariffs and quotas on imports. For example, for televisions, industrial assistance included an expansion of the broadcasting infrastructure and a ban on TV imports until the early 1980s, and foreign investments were restricted.[92] Potential foreign investors were strongly encouraged to allow local participation and management and to transfer technology. The government also imposed trade licensing and inspection requirements and used informal pressure to increase local content. When the facsimile market was opened in 1983, it was restricted to local companies, all of which depended on technical or joint-venture agreements with Japanese manufacturers.

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[91] Before 1969, electronics production was mainly for the domestic market (Bloom 1991).

[92] During the 1970s, the government appears to have even encouraged foreign firms to leave. However, recognizing the importance of foreign firms in improving Korea's technological capabilities, foreign direct investment and licensing policies were liberalized in the early 1980s.

This brief import-substitution phase had important implications for the development of technological capabilities. As Mody (1989) notes, the domestic market in Korea was not only a training ground for export-oriented electronics projects but also a source of demand.[93] Sales by domestic producers (Korean companies and foreign-owned companies in Korea) rose from approximately $400 million in 1976 to about $3 billion in 1984. The same pattern — domestic production leading to rapid exports — occurred with personal computers and telecommunications equipment (Bloom 1991).

The government began a phased liberalization of imports in the late 1980s, accompanied by a progressive reduction in import tariffs. By 1987 most consumer electronics products had been placed on an automatic approval list, and their tariffs had been reduced to 16 percent (Bloom 1991). For computers, however, the effective tariff amounted to 20 percent.[94] Since 1990 foreign companies have been allowed to bid for telecommunications equipment contracts of government-funded organization in selected areas. The government has, at the same time, tried to minimize the adverse consequences of liberalization by extending tax and financial support to vulnerable industries.

2 *Government Procurement*

The government has used procurement to promote innovation by guaranteeing markets for technology-intensive items.[95] The government first announces procurement items for the coming three years, including technical specifications and local content ratios. For, example, the government announced in 1982 that it intended to purchase 5,000 low cost personal computers for public schools in 1983 and increase the number in subsequent years (Kim 1987). The announcement attracted many entrants to the industry and induced investments in R&D and production. The announcement was a turning point for the computer industry and led to the development of 16-bit personal computers in 1984, which were exported in large numbers starting in 1985. Procurement needs for national information networks would provide another boost. Similarly, private sector development of TDX systems was encouraged by prospects of selling TDX systems to the government.

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[93] The Korean domestic market for electronics products grew from $ 1.1 billion in 1976 to $ 6 billion in 1984. This represents a much larger rise than in Taiwan where the domestic market for electronics products rose from $ 1.2 billion in 1976 to $ 4.3 billion in 1984.

[94] Products from different countries were treated differently. Some imports from Japan, including the 16-bit personal computer were banned until the late 1980s (Bloom, 1994). In 1988, an import ban on computer printers was removed -- except for those from Japan. For US imports, the tariff was 15 percent; imports from other countries faced a 20 percent tariff.

[95] Procurement policies were not particularly aimed at technological development until the 1980s. See Jin-Gyu Jang (1994).

3. *R&D Support*

On the supply side, the restructuring of industry toward technology-intensive production has been accompanied by substantial increases in both public and private sector investment in R&D. As *table 3.9* shows, R&D expenditures rose from won 280 billion in 1980 to won 4,158 billion in 1992.

Private investment in R&D has grown rapidly. In the 1960s and 1970s, public sector research institutes led industrial R&D; the private sector and the universities played minor roles. In 1980 the public sector accounted for 63.5 percent of R&D expenditures (*table 3.9*). This picture had reversed by the mid-1980s. While public investment in science and technology increased, the private sector share rose to 80.6 percent in 1990.[96]

The number of private sector R&D centers rose from 54 in 1980 to 1,551 in 1993 (*table 3.10*).[97] Most of the increase has taken place in electric and electronics sub-sectors.[98] As of June 1993, private research institutes in these two fields accounted for nearly 40 percent of the total.

As shown *in table 3.10*, research centers affiliated with small and medium-sized companies have increased, thanks to the 1985 Technology Development Promotion Law, which lowered from 10 to 5 the number of researchers required to establish an institution (Jin-Gyu Jang

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[96] The share of total R&D expenditure in GNP rose from 0.44 percent in 1976 to 2.02 percent in 1991 (Appendix 2).

[97] Young-Ho Nam, 1994: 24. Between 1971 and 1990 the number of R&D institutions multiplied by almost seven times, and the number of R&D personnel increased by about 14 times (Jae Whoan Lee, 1992: 141).

[98] Of 769 institutes established after 1990, 45.4 percent have been in electric and electronics sectors (Jin-Gyu Jang 1994).

1994).[99] Large conglomerates invest 2.1 percent of revenue in R&D, while small and medium-sized companies invest 3.8 percent (*ibid,* 16).

Table 3.9: National R&D Investment, 1980-91

(billions of won)

	1980	1985	1990	1991
Public Sector (Percent)	**178** (63.5)	**301.9** (24.5)	**647** (19.4)	**815** (19.6)
Private Sector (Percent)	**102.5** (36.5)	**930.2** (77.5)	**2,687.9** (80.6)	**3,343.4** (80.4)
Total (Percent)	**280.5** (100)	**1,232.1** (100)	**3,334.9** (100)	**4,158.4** (100)

Note: Numbers in parenthesis are percentages.
Source: Young-Ho Nam 1994.

Table 3.10: Number of Private Research Centers

	1980	1982	1984	1986	1988	1990	1991	1992	1993
Large firms			152	207	338	421	503	532	551
Small and medium sized firms			16	97	336	545	698	903	1000
Total	54	88	168	304	674	966	1,021	1,435	1,551

Source: Young-Ho Nam 1994; Jin-Gyu Jang 1994.

Korea's rising commitment to R&D has been necessitated by two related factors. First, maintaining industrial competitiveness by improving and upgrading products and processes had compelled industry to invest in developing new technology and products and reduce reliance on imported technology. Basic research became imperative, especially in IT. Second, as Korea

[99] There is some concern, however, that some companies which established research institutes had no specific goals about technological development or research; their sole intention was to receive financial and other support, including tax credits, from the government (Jin-Gyu Jang 1994).

approached world frontiers in several technological areas, it encountered barriers to acquiring technology from more developed countries, which are reluctant to continue exporting advanced technology to a competitor.

Investments in basic research has increased rapidly. Expenditures almost tripled between 1983 and 1987, although basic research as a share of total R&D expenditures has remained at about 17 percent. Nevertheless, this proportion compared favorably with the major industrial countries in 1986: United States 12 percent; Japan, 13 percent; Federal Republic of Germany, 19 percent; and France, 21 percent. It is expected that basic research will account for 20 percent of total R&D expenditures in Korea by 2001. Universities have the prime responsibility for basic research, in accordance with government policy calling for a rough division of responsibility between universities on the one hand (responsible for basic research) and research institutes and industry (responsible for applied and developmental research).[100] Although universities account for 49 percent of expenditures on basic research, it is industry that dominates R&D activity - accounting for 22 percent of expenditures on basic research, 56 percent on applied research and 79 percent on developmental research.

The rise in R&D expenditures from won 16 billion in 1973 to won 1.9 trillion in 1987 was accompanied by a smaller but still substantial growth in the number of researchers, from 6,000 to 53,000. This implies an increase in annual expenditures per researcher by nearly 14 times. The share of researchers with graduate degrees increased from 46 percent to 53 percent between 1977 and 1987, and the number of graduate degree holders more than quadrupled.

Although earlier R&D efforts were largely financed by the government, from the early 1970s tax and other incentives have encouraged private sector R&D. A "technology development allowance system," established by the 1972 Technology Development Promotion Law required firms to reserve up to 20 percent of pre-tax profits for R&D. Reserves must be spent within two years on any activity related to technology development, including assimilation of imported technology, acquisition of information, technical training, research facilities and donations to institutions. R&D expenditures were tax deductible. In 1973, 80 firms reserved won 3,000 billion, and used 23 percent within two years. In 1978, 153 firms reserved won 30,500 billion and used 80 percent within two years. Other measures encouraging technology development included a 10 percent tax credit on R&D expenditure, local tax exemptions on the purchase of real estate for research centers, income tax exemptions for foreign technicians, and low tariffs on goods imported for R&D activities (Jae Whoan Lee 1992). In addition to these general measures, private organizations engaged in "strategic" industries are exempt from local taxes and tariffs on R&D equipment, and their R&D employees are exempt from military obligations (Kim and others, 1987). Capital investments are allowed accelerated depreciation.

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[100] The universities do not focus exclusively on basic research. Expenditures by type of R&D in 1987 were: basic research, 77 percent; applied research, 18 percent; and development, 5 percent.

The Electronics and Telecommunications Research Institute and its predecessor have been at the forefront of IT-related technologies (*box 3.2*). The Bank also has contributed to Korea's technological capability in semiconductors through its electronics technology project (loan 1776-KO). This project, the Bank's first direct involvement in technology development, helped the institute lead industry in developing semiconductor technology, provide R&D support and technical training, and identify markets. The project set up a pilot wafer fabrication facility for large-scale integrated circuits in 1979, several years before private computer and semiconductor production. Unfortunately the project was slow to commence, and, according to the Bank's project completion report (PCR-10838), the rapid development of the private semiconductor industry in the early 1980s largely obviated the need for the services that the institute aimed to supply. The institute did not become a profit-making, self-financing institution with a leadership role as envisaged at appraisal. Nevertheless, it probably did play a useful catalytic role. Its acquisition and mastery of semiconductor technology in 1979-81 had a demonstration effect, and its training helped firms enter VLSI fabrication. The wafer facility was eventually sold to Goldstar.

National R&D programs, jointly financed by the government and the private sector, focus on strategic areas beyond the capacity of industry. A number of IT projects received priority funding. In 1983, the government contributed $28 million to 182 projects of 131 industrial firms. Seven additional projects in semiconductors and bioengineering received $40 million (World Bank 1987). Further, the Ministry of Trade and Industry subsidized the development of: frontier technologies such as 16M DRAMs and high definition television (HDTV); and more established technologies in which Korea was facing bottlenecks, such as heat treatment, printing, and molding technologies.

The Development of TDX. Digital switching technology is another area where the government played a decisive role, mainly as a coordinator of technological development.[101] Initiated by the government, TDX-1 and TDX-10 were developed through a strategic alliance between KTA, ETRI and four private manufacturers (*box 3.4*).

The core switching technology for TDX-1 was acquired from Ericson, but the capability acquired in this process enabled the indigenous development of core TDX-10 technology (*table 3.11*). This was evident from local firms' involvement in the product and process technology for TDX-10; their role in TDX-1 was limited to process technology. This also demonstrates that the role of the government can be phased out as private sector capabilities are developed. The TDX series is cost competitive with other internationally prominent switches.[102] Korea is now a net exporter of electronic switches.[103]

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[101] This review of the development of TDX draws extensively from Kim and others (1992).

[102] TDX-10 is expected to cost one-third less than AT&T's No. 5 ESS and will cost about the same as low-priced Japanese switches (Kim and others 1992).

Kim and others (1992) identifies several factors that contributed to this project's success: the gradual creation of a pool of knowledgeable researchers, stable financial support, and government coordination. Government-sponsored research institutes developed the technologies, and the government monitored their progress. Furthermore, the government persuaded companies to invest in the project.[104] The government also was astute and quick in addressing problems.

16-Megabyte DRAM. This project envisaged the establishment of a new government laboratory in collaboration with the three largest DRAM manufacturers, Samsung, Goldstar, and Hyundai. The project was expected to span three years and cost won 190 billion of which 80 billion was to be provided by the government, mostly in the form of a low-interest loan. But the three manufacturers were unable to reach consensus on their respective contributions to research. Each company has gone ahead on its own, yet the government is credited for initiating the effort.

Electro 21. Launched by the Ministry of Trade and Industry in 1992, this project aims to develop 51 key electronic parts in 18 fields during the period 1992-96.

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[103] In 1989 Korea had a $46 million trade surplus for electronic switches (Kim and others, 1992).

[104] R&D costs for developing TDX-1 and TDX-10 (including the projected budget for 1991) were $240 million. The Korean government and KTA together provided 45.2 percent ($109 million) and the rest was financed by participating private firms.

Box 3.2

Korea Institute of Electronics Technology

KIET was founded in 1976 as a public sector research institute to spearhead government efforts in computer and semiconductor technology. It was expected to provide a broad range of services to private industry reduce initial investment requirements of companies, and their entry into electronics. Services, expected to be available the early 1980s included:

(a) *Fabrication of Wafers for Industry.* This was expected to be KIET's major activity and the source of two-thirds of its revenues. The assumption was that private companies such as Samsung (already fabricating wafers) and other companies would produce wafers for simple devices and KIET would concentrate on more sophisticated products.

(b) *Supply of Mask-sets for Domestic Industry.* This service, which was to be needed for wafer fabrication within KIET, was also to be provided to private sector wafer producers so as to substitute imports and reduce turnaround time.

(c) *Supply of Integrated Circuit Designs for Industry.* The integrated circuit designs provided by KIET were to be "tailor-made" to suit the specific needs of individual firms.

(d) *Testing Services for Industry.* At the time KIET was founded, there was no local facilities for carrying out electrical and environment testing of semiconductor devices and system hardware, and such services were imported at a considerable expense.

(e) *Contract R&D to Industry.* KIET's pool of qualified personnel with substantial capability for the design and development of a wide range of microprocessors, mini computers and other digital systems, were expected to provide contract R&D to industry in a big way.

(f) *Provision of Other Supplementary Services.* KIET was expected to supply supplementary services such as printed circuit boards, hydrogen dioxide, and education services.

Source: World Bank, 1992.

Box 3.3

The VLSI Project

The VLSI project was one of the many high-priority national projects involving collaboration between private sector R&D laboratories and public sector research institutes. VLSI received enormous support from the government, including subsidized credit, and was generally known as the "Blue House Project," after the official residence of then-President Chun Doo Hwan. According to some analysts, presidential advisers convinced him that the only way to crack the world semiconductor market was to orchestrate a massive development project involving every important Korean company in the business.

"That's just what is happening now, and the goal is to position Korean chip-makers as major players in he world industry by 1991. This impetus came from the president, and the muscle behind the program is coming from the commitments of three of the largest Korean conglomerates --Hyundai, Goldstar and Samsung." (*Electronics*, 1987, quoted in Amsden 1989.)

Source: Amsden, 1989.

Box 3.4
Time-Division Digital Switching Technology (TDX) Development

Government interest in TDX technology dates back to 1971, when the Ministry of Communications requested Korea Institute for Science and Technology to develop TDX technology. Lack of technological expertise brought initial failure (Kim and other 1992). Two years later, KIST acquired from GTE (a U.S. telecommunications firm) the know-how to develop small-scale electronic switching. In 1977 the government created the Korea Telecommunications Research Institute (KTRI) to spearhead the effort, but progress was stalled until the government included the project in its national economic development plan in the early 1980s and provided stable financial and other support. In 1982 Electronics and Telecommunication Research Institute was separated from KTRI and dedicated exclusively to TDX development.

The TDX-1X project started as a pilot in 1981. A committee, of academic and business specialists made periodic recommendations to the government on how to develop TDX. The government electronic switching equipment and licensed core technology from an internationally recognized supplier -- LM Ericsson of Sweden. A technology licensing contract was signed between Ericsson and KTA, and researchers at ETRI were sent to Sweden to receive technical training.

By 1984, ETRI had successfully developed the TDX-1 system. Four private firms were selected as manufacturers of the technology. The TDX-1A, which has a maximum of 10,000 lines, was introduced in the local network in 1986. In 1988, TDX-1B with a capacity of 23,000 lines was developed. In 1989, the TDX-10 project was started to develop a large-scale system of 100,000 lines by the end of 1991. TDX technology was commercialized in 1985. The number of telephone lines supplied through TDX rose from 24,000 lines in 1985 to 1.33 million lines in 1990.

Source: Kim and others, 1992.

Table 3.11
TDX-1 and TDX-10
Technology Development

	TDX-1	TDX-10
Participants	ETRI and four Private firms	ETRI and four Private firms
Core technology	Ericsson	Self-development
Product technology	ETRI	ETRI and four private firms
Process technology	ETRI and four Private firms	ETRI and private firms
Medium of transfer	Document Technical training Technical assistance	Joint research
Order of development	Sequential Core --> Product --> Process	Simultaneous Core --> Product --> Process

Source: Electronics and Telecommunications Research Institute (1990).

IT Diffusion Policies

Recognizing the promise of IT in all kinds of industries and services, the government has taken a number of steps to enhanced the demand for IT applications (*table 3.12*). Measures include the creation of countrywide information and communications networks, improvement of telecommunications and high-speed data networks, and enhancement of satellite capabilities and incentives for encouraging IT application in manufacturing industries and services.

Table 3.12: IT Business Applications

	Application	Application policy	Status	Notes
Agriculture, fishing, forestry	• Office procedures	• Apply information system to production activity • Build systems connecting production, storage, forwarding, and management • Networking between cooperative unions	• Computer applications in office procedures	• Increase productivity
Industrial goods	• Production process • production, marketing	• Networking among industries (such as Value Added Network) • Control production costs	• Early stage of Management Information Systems • Introduction stage of FA	• Change quality and quantity of demand • Development of different types of industry
Consumer goods	• Production process • R&D and management procedures	• VAN • Networking distribution channels • Automated selling • Consumer market information	• Early stage of Management Information System	• Change the qualitative conditions of competition • Reformulate the distribution channel
Retailing	• Distribution online • Point of Sale introduction • Mail selling	• Shop at home • VAN • Use credit cards to collect consumer information • Control distribution channel	• Introducing Point of Sale system	• Qualitative change in conditions of competition • Change the functions of stores
Banking	• Online between headquarters and branches • Computerized network of banking industry	• Checking bank balances at home • Firm banking • Cash services	• Most banking procedures are automated • Computerized network is being constructed	• Change the functions of banks • Cooperation in financial services
Publishing	• OA (writing and printing) • Printing process	• Networking of distribution channel of published books • Provide information service via media such as videotext	• Introduction of FA	
Newspapers	• Production process • Building database of stories	• Use satellites • Electronic paper, paper via Fax	• Introduction of FA	

Source: Jae Beom Lee 1990.

1. Nationwide Information Networks

A main goal of IT application in government administration has been to achieve a high level of computerization that will diffuse into the private sector by the early 2000s. The computer-based integrated information systems project, launched in 1983, is geared to building a nationwide information and communications network by the mid-1990s. This network would include five basic networks: an administrative system linking central and local government offices, a financial information system linking about 140 banks, insurance companies, and other financial institutions, an education and research information system connecting more than 20 universities and research institutions, a defense information system, and a public health and social welfare information system among hospitals and social welfare institutions.

The networks are expected to contribute to the development of the Korean information industry (including hardware, software, and network technologies), improve public services, provide access to public information, and enhance coordination among organizations. This is expected to raise national productivity and narrow geographic gaps.

The first phase of the project established the National Administrative Information System and created demand for IT products worth more than $300 million (Yoon 1993). Computer hardware for the network is expected to include 80 main computers (each costing more than $1 million) in provinces and cities and about 5,000 workstations ($12 million total) in districts and towns (Kim and others, 1987). The first phase was completed in 1991 and the second stage is now underway.

The second stage includes information systems related to finance, health, social welfare, education, research and defense (*table 3.13*). Existing systems in each field are being expanded and integrated into one national system. Of significance is a computerized information network, linking ten science and technology centers owned by government-funded research institutes. Its goal is to provide the scientific community with more efficient science and technology information services.

Table 3.13
Distribution of Personal Computers in Educational Institutions and Projected Increase

Institution	*1987*	*1996*
Primary, middle, high school	5/school	30/school
University	1/100 students	1/10 students
Professors, researchers	1/10 persons	1/1 persons

Source: Jae Beom Lee 1990.

2. *Applying Information Technology in Manufacturing*

The government has augmented the use of IT in manufacturing by adopting or supporting human capital development policies, R&D tax incentives for advanced product and process technology, R&D support from public technology institutions, and cooperative R&D between public technology institutions and private firms. IT-specific support has included financing for developing IT-related production systems and prototypes, financing for locally produced IT goods, IT education and training programs, and telecommunications infrastructure improvements. These measures are detailed later.

Of particular importance for IT diffusion in manufacturing are policies that encourage greater automation: numerically controlled machine tools and industrial robots, CAD, CAM, programmable logic controllers and flexible manufacturing systems. In a recent survey, 25 out of 40 SMEs that had automated their factories received assistance from technology-support agencies.

The Korea Productivity Center is promoting micro-electronics-based factory automation, mainly through training in the use of technologies and technical assistance (Ernst and O'Connor 1992). The Center also has a flexible automation demonstration room for new technologies.

Cross-Cutting Policies

1. Human Capital

Korea's greatest resource is its people. It surpasses other newly industrializing countries such as Brazil, Mexico and other developing countries in almost all educational indices.[105] Its secondary and tertiary school enrollments (89 percent and 35 percent respectively) in the mid-1980s were comparable to those in developed countries. Dropout rates are low, and the quality of education, as measured by test scores, are good. Korea has impressive vocational training enrollments, and a significant proportion of Korean employees receive in-firm training.

Both the government and the private sector have invested heavily in education. The share of education in the government budget rose from 2.5 percent in 1951 to 22 percent in 1985. Yet government account for only one-third of expenditures on education; parents and business bear the rest. The government has offered incentives to encourage training at home and abroad and has established institutions to develop technical skills. Furthermore, between 1968 and 1989 government incentives induced more than 1,000 scientists to return from overseas, contributing to the country's science and technology development (World Bank 1993b; *box 3.5*).

In the early 1990s the government commenced a program of sending scientists and engineers abroad for training.[106] Some 10,000 people were sent to foreign enterprises, universities, and research establishments in the early 1990s. A high proportion of senior personnel in government, business, and academics have been exposed to foreign training, mainly in the United States under economic assistance programs (Mason and others 1980). The share of tertiary level students receiving training abroad has been twice as high in Korea as in Argentina, Brazil, and India (Westphal, Kim and Dhalman, 1985). Industrialists helped design science and technology education curriculum so that the education and training given to graduates are consistent with industrial needs.

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[105] Amongst NICs, Korea has the highest number of secondary and tertiary students as a percentage of the relevant age groups, science and engineering students as a percentage of tertiary enrollments, scientists and engineers per million people, and scientists and engineers engaged in R&D per million people.

[106] From 1982 to 1991, the Korea Science and Engineering Foundation sent 1,353 scientists and engineers with Ph.D.s to industrial establishments, research institutes, and universities in advanced countries to learn about advanced technologies. Another 1,000 or so scientists and engineers will be sent abroad for post-doctoral studies, through 1996 (Jin-Gyu Jang 1994).

Box 3.5
The Role of KIST in "Brain Re-draining"

KIST was successful in drawing back Korean scientists and engineers employed overseas -- the so-called "brain re-drain". The recruiting team, supported by Battelle Memorial Institute, sent recruiting letters to around 800 institutions in the world and received around 500 applications. From these applications, eighteen members were hired in the first round of recruiting. Almost all Korean scientists and engineers abroad were informed, and KIST had the opportunity to select the most appropriate researchers.

KIST, supported by Battelle Memorial Institute, adopted advanced management systems such as contract-based systems for project management and responsibility-accounting systems for planning and evaluation of research labs. For basic management training, thirty-six key members were sent to Battelle Memorial Institute, Columbus, Ohio, for six months to one year from 1966 to 1971.[107] These individuals had opportunities to observe and learn general project-management practices such as management of contract systems, research planning, facility management, project-cost accounting, and client relations. Their knowledge was used to operate and maintain the systems Battelle had set up for KIST.

As the Korean economy expanded, most of the original KIST members left for new positions. Their new jobs were mostly with universities or newly established public or private R&D centers. Through this personnel movement, knowledge about advanced project-management systems diffused throughout the national R&D systems. The understanding of these original members of R&D project management became a standard of Korean R&D management systems. This standardization, which made research centers in Korea more homogeneous, is one of the most influential but least-noted achievements that KIST provided to the national R&D systems.

Source: Young-Ho Nam, 1994.

[107] By 1973, 86 members had opportunities to observe and learn about advanced management practices at various research centers in nine developed countries -- the United States, Japan, the U.K., Australia, the Netherlands, Germany, France, Canada, and India.

Vocational training has been a key source of skilled manpower in Korea, and here again, the government played a significant role. Planning of vocational training began with the Vocational Training Law of 1966. This law led to the first set of public vocational training institutes. But their growth could not keep pace with rising demand for skilled workers, so the government began offering training subsidies to private schools in 1968. The private sector responded but when the subsidy was withdrawn (three years later), private sector training efforts declined.

In 1974 the government began requiring firms with more than 500 employees to provide six months of training in approved schemes. In 1976 it imposed a training levy on firms that did not fulfill the training requirements.[108] These laws had some drawbacks: some firms considered six months of training too long and opted to pay the levy (World Bank 1993b). The levy has not been effective particularly in promoting in-plant training, potentially a key source of capability development. Bureaucratic regulations involving the preparation and approval of training schemes made the levy system cumbersome, and expensive. Furthermore, the levy was determined annually by training costs in each industry, but data proved difficult to compile and maintain, so revenue fell well short of cost. Thus the levy came to be just another business tax. In 1986 the levy was again raised to cover about 75 percent of the training cost; from 25 percent in 1979. Some researchers have found that large firms undertook training regardless of the levy, whereas smaller firms found it an insufficient tax to encourage training.

Yet, the overall effect of such legislation on training appears to be positive. Under the 1974 law, many firms established their own vocational institutes, and trained about 10 percent of their workforce each year. The number of graduates increased from 31,621 in 1970 to 104,502 in 1980. The number has dropped since then, as the government relaxed the training requirement in response to a recession. More recently, the government simplified the levy from an amount based on training costs to a payroll tax. The change eliminated the need to survey costs, but its effect on training is not yet apparent.

In 1989, the vocational training system -- public and private institutes and in-plant training -- included 261 centers and trained 57,900 craftsmen.[109] Seven institutions trained 22,100 craftsmen, accounting for about 28 percent of the training institutions and 38 percent of output. Public sector training is undertaken in centers managed by central

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[108] The proceeds of the levy were placed in a Vocational Promotion Fund, which supports public sector vocational training.

[109] Public vocational training programs are from one to three years duration while private in-plant training lasts from 6 to 12 months and authorized training by other private institutions lasting around three to five months. Seven-hundred master craftsmen, 140 instructors and 4,435 supervisors were trained and 16,230 employees received additional training.

government departments and local government bodies but the most significant organization is the Korea Vocational Training and Management Agency (KVTMA). It was established in 1982 to centralize the administration of public vocational training institutions, acquire textbooks, develop curriculum, test skills, and prepare skill and industry-specific demand projections. The agency controls thirty three vocational training institutes which account for about 70 percent of public sector training.

The private sector provided 62 percent of trained craftsmen in 1989, up from 52 percent in 1983. The trend reflects the government's recognition that the private sector can more effectively identify needs and provide training more efficiently. Large firms invest heavily in skills training and maintain well-managed, generously funded training centers, accounting for about two-thirds of in-plant training. Smaller firms lack the resources to establish training programs, and their lower skill needs limit their use of such programs. Small firms, therefore, share training costs with similar firms or recruit trained workers. About half of the graduates of public training institutions are recruited by small and medium-sized firms.

Korea's vocational training system responded as industry evolved from labor-intensive, low-skill industries through heavy industry to technology-intensive fields. By the early 1990s, the vocational training institutes were focused on metal processing, transport and construction equipment and electronics and communications industries, which accounted for about half of the output of craftsmen in 1989. Courses serving textiles and wood processing accounted for only 12 percent of trained personnel. By contrast, during the Fourth Five-Year Plan (1977-81), metal processing, transport and construction equipment, and electronics and communications accounted for only 39 percent of the total output of craftsmen, whereas textiles and wood accounted for 40 percent. The World Bank has also contributed to Korea's expansion and upgrading of technical skill (*box 3.6*).[110]

[110] The Bank's positive role in Korea's education sector is documented in World Bank's OED Report No. 5950, 1985.

Box 3.6

World Bank Assistance to Education

The Bank has provided loan/credit programs to assist the training of technical personnel in Korea, which closely paralleled the increasing sophistication of the Korean economy.[111]

The First Education Sector Loan (1800-KO) concentrated on upgrading junior technical colleges and university departments of engineering and management with of equipment, staff development, and improvements in curriculum development, manpower planning, equipment maintenance, and academic accreditation. The Second Education Sector Loan (2427-KO) supported in graduate science and engineering, science programs in secondary schools and colleges, graduate research programs, improved sector management and manpower monitoring, and strengthened the financial base of private educational institutions.

The First Technology Advancement Project (Loan 3037-KO) combines assistance to improve science an engineering education with strengthening the R&D capacity of two national research institutes relating to metals and machinery, and electrotechnology. The recently approved Second Technology Advancement Project (Loan 3202-KO) has similar objectives and design and supports a graduate institution in science and technology and three national research institutes relating to genetic engineering, metrology and energy and resources.

111 The education projects were: Cr. 151-KO, Ln. 906/Cr. 394-KO, Ln. 1096-KO, and Ln. 1474-KO. See World Bank Staff Appraisal Report on Korea Science and Technical Education Project, November 15, 1993 (Report 12272-KO). p. 8.

Not everything is rosy with Korea's education and training system. Recent studies have highlighted a growing shortage of technicians and engineers in high-tech areas, and the rising unemployment rates that greet graduates of the general high schools and universities (Yen Kyun Wang, 1990). This mismatch is partly caused by insufficient expenditures on higher education.

To meet the growing human capital needs of an informatizing society, the government has undertaken steps to enhance IT-related education. The Korea Advanced Institute of Science (KAIS), which became the Korea Advanced Institute of Science and Technology (KAIST) when it merged with the Korea Institute of Science and Technology, was established in 1971 to meet the growing need for scientists, especially in electronics engineering, computer science, and telecommunications.[112] As indicated above, the institute has been a center for basic and mission-oriented applied research in new technologies. For example, KAIST developed prototypes of computers, robotics, and CAD/CAMs (Kim and others, 1987).

President Kim Young Sam has reiterated the government's commitment to scientific and technical education. The president has promised to raise the number of scientists and engineers from the current 180,000 to 320,000 by 1998 and to legislate an industrial technology education promotion law. As noted above, the information industry development master plan of December 1992 would turn out 1,000 IT experts a year from information and science high schools and university departments.

2. *Financing*

The government has used the largely nationally-owned banking system to provide subsidized credit to favored industries and firms.[113] Use of the banking system had two consequences: it enabled the government to direct investments into favored enterprises; it also made capital costs artificially low for those enterprises and biased investments toward capital-intensive activities and large ventures (O'Connor, 1989).[114] Until the early 1980s, borrowing costs of large firms were lower.

In 1976 the government expanded the scope of the Korea Development Bank to provide technology development loans for purchasing R&D equipment and commercializing

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[112] Since 1971 KAIST has produced 1308 Ph.D.s and 6939 M.Sc. (Jin-Gyu Jang 1994).

[113] A key method of promoting conglomerates has been channeling credit to favored firms.

[114] Contrasting financing policies for export-oriented industries helps explain the differences in industrial structure between Korea and Taiwan.

research results (World Bank, 1993a). These loans, however, were of limited scope, and the banks staff was not geared to appraise technology promotion projects. As a result, industrial firms faced difficulty in raising funds for technological development from financial institutions. Thus the Korea Technology Development Corporation (KTDC) was set up in 1981 with Bank assistance. As World Bank (1993a) asserts, KTDC's experience with venture capital activities served as a model for other venture capital institutions. According to the Ministry of Science and Technology, more than thirty institutions have backed technology investments.[115] Further, the government's special industrial technology research financing program, initiated in 1982, provided seed capital to corporative R&D projects between public and private sectors. Such joint projects help transfer technology among organizations. A more recent measure, the 1991 Korea Technology Banking Corporation Law, allows the Korea Technology Banking Corporation (KTB) to receive funds from government-supported institutions and other organizations and to operate a technology development lottery. This is expected to increase KTB's capital from $205 million to $684 million (Jin-Gyu Jang 1994).

Although large conglomerates have led Korean industrialization, small and medium-sized enterprises cannot be ignored. In 1988 they accounted for 57 percent of manufacturing employment and 39 percent of value-added. SMEs have preferential access to credit in commercial banks and are served by specialized financial institutions. In 1991 the compulsory lending ratio required that at least 35 percent of the loans of major commercial banks be directed to SMEs. For local and regional banks, the proportion of lending to SMEs was set at 80 percent. Financial resources for the SMEs are provided by the Small and Medium Industry Promotion Fund and two specialized banks, the Industrial Bank of Korea and the Citizens National Bank. There is also a loan guarantee scheme through the Korea Credit Guarantee Fund.

IT generation and diffusion have benefited from preferential financing available for production systems and prototype development and investments involving locally produced capital goods. For example, the purchaser of locally produced capital goods such as numerically controlled machine tools can obtain preferential financing for up to 90 percent of the purchasing cost.[116]

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115 Ministry of Science and Technology, 1990.

116 Kim and others, 1987, P. 285.

3. *Telecommunication Infrastructure*

Telegraph service was introduced in Korea in 1885, but systematic investment in telecommunications did not begin until 1962, when the first five year plan for economic development was launched (Choi 1990). During the 1960s and the 1970s telephone facilities grew at a moderate rate, but government could not keep up with the demand. In 1982, there was a backlog of more than five million orders for telephone lines (Kim and others. 1992). Businesses were demanding more diverse, advanced and specialized telecommunications services.

In the early 1980s the government launched a major expansion of telecommunications facilities, including investments in land, buildings, and equipment, mainly through the Korea Telecommunications Authority (KTA); technological developments through government-sponsored research institutions, which fostered cooperation between the government, businesses, and academic institutions; and measures such as the liberalization and internationalization of telecommunications, incorporation of public common carriers, and the separation of telecommunication policy formulation from the provision of services. The telephone network has grown by one million lines per year since the early 1980s, eliminating the chronic backlogs and waiting lists of the 1970s. Investment in telecommunications by the government and public common carriers during the 1980s was enormous. At its peak in 1983, investment in telecommunications was 1.83 percent of GDP, and it has remained above 1 percent since then.[117]

Until the early 1980s the Ministry of Communications was responsible for both policy and operations, which led to inefficiency and limited accountability. The government then placed the provision of telecommunications services with several new public common carriers under the KTA, an autonomous, flexible decision making body that has dominated telecommunications ever since.[118] KTA has formed subsidiaries for specialized telecommunications services; some have substantial private participation. Data Communications Corporation of Korea was formed to develop data communication services. Korea Mobile Telephone Corporation and Korea Travel Information Services Corporation were established as common carriers to provide specialized services including mobile services (car phones, portable phones, pagers), marine communications, and travel information services. The Ministry Of Communications is responsible for making telecommunications policies, regulating telecommunications business operations, supporting research activities, and promoting communications equipment manufacturers and installation companies.

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[117] According to Kim and others, this ratio is about twice as high as the highest level reached by advanced industrialized countries in the last two decades. See *ibid*, P 1830.

[118] See Kim and others. 1992 for a lengthy discussion of this topic.

The government promoted the data base industry through telecommunications related organizations such as the KTA, Data Communications Corporation (DACOM), and Korea Research Institute for Telecommunications Policy (KISDI). Using telecommunications lines leased from Korea Telecom, DACOM has worked as an intermediary service agency to connect foreign databases to domestic users.[119] DACOM also has provided economic and industrial data from domestic databases through its Chollian I and II systems since 1986 (Lee 1992).

Super High-Speed Information Network. Like projects in the United States, Japan, and the European Union which have invested in constructing high speed information networks, this project is expected to build a nationwide fiber optic network that could handle the flow of a large volume of information, at very high speed.[120] Furthermore, Korea Telecom, under the Ministry of Communications, aims to provide broadband ISDN service to Korea by 2000 (*table 3.14*). In addition, KoreaSat - a $400 million project started in 1987 - is expected to acquire critical satellite system capabilities from foreign countries and launch a communications satellite by 1995.

[119] Foreign database vendors available through DACOM's online service include DIALOG (the largest U.S. database vendor) since 1983; GSI-ECO (a French vendor) since 1984; JOIS (a Japanese vendor) since 1985; Questel (French) since 1985, and LEXIS/NEXIS (US vendor) since 1990.

[120] The United States has announced its plan to construct an Electronic Highway, while EEC countries are installing a high speed administrative network interconnecting member countries. In Japan, a fiber optic cable network is being installed throughout the country under the New Social Infrastructure Construction Plan.

Table 3.14: The Integrated Circuit Digital Network Project

Stage	Goal	Agenda
First phase (1987-1991)	Narrowband Integrated Circuit Digital Network Project	• Circuit switching • Packet switching • Common channel signaling system
Second phase (1992-1996)	Mediumband Integrated Circuit Digital Network Project	• PABX for Integrated Circuit Digital Network • Multiplex communications
Third phase (1997-2000)	Broadband Integrated Circuit Digital Network	• Broadband image signaling • Wideband exchange

Source: Byung-Il Choi 1990.

4. *Promoting an IT-Oriented Culture*

Despite Korea's success in generating and diffusing IT, constraints stand in the way of future developments, including public resistance to new IT, lack of qualified manpower, and the regulatory environment (Choi 1990). The government is campaigning with industrial firms to change public perceptions. In 1988 it established an "information culture center" to carry out public campaigns, cultivate a workforce that can deal with IT, and gather information on advanced foreign technologies.

Conclusion

Korea has made impressive strides in both the development and use of IT. It is now one of the world's leading manufacturers of computers and advanced semiconductors and is among the most informatized societies of the industrializing world.

It was indeed the private sector that was at the forefront of the IT industry. The private sector adopted a very aggressive strategy to acquire and build technological capability, through joint ventures, technology licensing, foreign training, or even setting up their own research entities abroad. Yet at the same time, the government played a key role in facilitating and sometimes leading the private sector. This case study illustrated how informatics have benefited from general, as well as IT-specific policies.

Perhaps what is most remarkable about the evolution of IT policies in Korea has been the willingness and the ability of the government to evaluate its own policies and programs and undertake appropriate changes in a pragmatic manner. The government itself has learned over the years, and intervention has been based on a strategic vision of the nation's dynamic comparative advantage. Policies were quickly changed in response to emerging local capabilities, domestic market potential, and external circumstances. This is true of almost all policies - be it towards foreign investment, import competition, national R&D programs, or *chaebols*[121]

As the private sector began to invest in R&D, the government's technology push began to lose justification. At the same time, one of the traditional roles of government research institutes -- absorbing technologies from abroad and transferring them to domestic industries -- has been challenged by private R&D centers. These changes have encouraged the government to reduce its tight controls. An interesting example of the government's changing role is how the focus of the national R&D programs were changed towards more demand-driven, rather than curiosity-driven research.

Constant evaluation of policies and the ability to undertake reforms in an agile manner also helped avoid big policy mistakes. Unlike many industrializing countries that followed inward-looking development strategies, the duration of protection for a given infant industry was limited, and government assistance to selected firms was linked to meeting performance standards or to pursue a "strategic intent" such as building long-term markets and new competencies. Private firms were subject to strong government pressures to export quickly -- in return for favorable treatment.

Another significant lesson is the importance of government-private partnerships. Korea has demonstrated the need to see beyond a state/market dichotomy. The development of switching technology (through the TDX project) clearly shows what can be achieved through collaboration. The government provided the institutional framework, coordinated efforts, persuaded companies to invest, and quickly addressed problems based on the recommendations of a committee of academics and business specialists.

All this, however, has not been without friction. The most significant barrier to cooperative R&D has been a concern about revealing business secrets. There have been

[121] In addition to liberalizing trade and telecommunications, the government is now trying to reduce the power of *chaebols*, by restricting their foreign and domestic borrowing, making equity the main means for raising funds for companies (thereby diluting the controlling equity of founding families), and limiting cross-shareholdings between group companies.

disputes over the distribution of research outcomes, excessive competition, and lack of information on the manpower and technology of partners. The 1993 Cooperative R&D Promotion Law to reinforce cooperative R&D by removing some of these barriers.

Finally, it should be noted that despite Korea's success in IT, its future is somewhat constrained. As OECD countries are making concerted efforts to restore their competitive advantage, Korean firms face a difficult transition from a strategy based largely on low-cost mass production of electronic hardware, marketed under international brand names, to one involving greater product differentiation and a greater reliance on their own brand names and marketing (O'Connor). Equipment shortages in the universities have hampered the quality and quantity of research. Boundaries between the three key public agencies concerned with IT are blurred, and firms are confused about what to do in several important cases. Finally, public resistance to new technology remains a barrier. The government is in the process of examining ways to alleviate these problems.

Appendix 1: Economic Statistics, 1962-91

	1962	1967	1972	1977	1982	1987	1991
GNP							
Billions of dollars (current)	2.3	4.3	10.7	36.8	71.8	128.9	281.7
Billions of Korean won (1985 constant)	11,215.8	13,864.2	28,504.7	46,135.4	59,322.2	99,611.6	141,659.4
Population (millions)	26.5	30.1	33.5	35.4	39.2	41.6	43.3
Per capital income							
Dollars (current)	87	142	39	1,012	1,824	3,110	6,498
Thousands of Korean won (1985 constant)	423	568	850	1,269	1,516	2,403	3,273
Gross investment (percentage of GNDI)	9.9	17.0	17.7	28.4	25.2	32.3	36.2
Gross savings (percentage of GNDI)	11.0	15.4	17.2	27.6	24.2	36.2	36.3
Exports (millions of current dollars)	54.8	320.2	1,624.1	10,046.5	21,853.4	47,280.9	71,870
Exports (percentage of GNP)	2.4	7.4	15.0	27.2	30.7	36.7	25.5
Imports (millions of current dollars)	421.8	996.2	2,522.0	10,810.5	24,250.8	41,019.8	81,524.9
Imports (percentage of GNP)	18.3	23.3	23.6	29.4	34.0	31.8	28.9
Industrial structure (percents)							
• Agriculture, forestry and fishing	37.0	30.6	26.8	22.4	14.7	10.5	8.0
• Mining and manufacturing	16.4	21.0	23.5	28.9	30.4	33.0	27.6
• Other	46.6	48.4	49.7	48.7	54.9	56.5	64.7
Heavy industry in manufacturing (percents)	28.6	34.7	36.1	49.2	452.8	57.0	64.9
Heavy industrial goods in exports (percents)	na	8.7	21.3	32.8	50.8	52.9	57.7
Employment structure (percents)							
• Agriculture, forestry and fishing	63.1[a]	55.2	50.6	41.8	32.1	21.9	16.7
• Mining and manufacturing	8.7	12.8	14.2	22.4	21.9	28.1	26.9
• Other	28.2	32.0	35.2	35.8	46.0	50.0	56.4
Unemployment (percents)	8.2	6.2	4.5	3.8	4.4	3.1	2.3
Nonagricultural unemployment (percents)	16.3[a]	10.9	7.5	5.8	6.0	3.8	2.6
Absolute poverty (percents)	na	40.9[b]	na	14.8[c]	9.8[d]	na	na

[a]. 1963 data [c]. 1976 data
[b]. 1965 data [d]. 1980 data

Note: na=not available GNDI=gross national disposable income

Source: Jin-Gyu Jang 1994.

Appendix 2: R&D Indicators (billions of won)

	1976	1981	1987	1988	1991
R&D expenditures	60.90	293.13	1,878.0	2,343.4	4,158.4
• Government	39.18	121.73	383.18	522.94	815.84
• Private sources	21.72	171.40	1,495.0	1,931.2	3,342.60
• Government: private	64:36	42:58	20:80	21:79	20:80
• Manufacturing	16.70	111.17	1,114.70	1,473.36	2,533.71
• R&D/sales	0.36	0.67	0.83	1.61	1.69
GNP	13,881	45,126	106,024.4	126,230.5	206,681.2
R&D/GNP	0.44	0.65	1.87	1.94	2.02
Number of researcher[a]					
• Government/public	11,661	20,718	52,783	56,545	76,252
institutions	3,592	5,065	9,184	9,581	10,529
• Universities	4,811	8,488	17,495	18,665	20,680
• Private sector	3,258	7,165	26,104	28,299	45,043
• R&D exp/researcher (thousands of won)	5,223	14,149	35,580	57,715	5,580
Researchers/1,000 population	0.33	0.54	1.27	1.35	1.76
Corporate R&D laboratories	12	65	455	604	1,201

[a]Does not include research assistants, technicians, and other support personnel.
Source: Jin-Gyu Jang 1994.

Appendix 3: Government Supported R&D Institutes and Foundations

Organization	Field	City & telephone
Korea Institute of Science & Technology (KIST) • Systems Engineering Research Center (SERI) • Genetic Engineering Research Center (GERC) • Science and Technology Policy Institute (STEPI)	Research and development of national projects Development training and education of computer manpower Development and dissemination of genetic engineering technology Analysis of technology development trends, policy studies and evaluation of National R&D Projects	Seoul (02) 962-8801 Daejeon (042) 869-114 Daejeon (042) 860-4114 Seoul (02) 962-8801
Korea Advanced Institute of Science and Technology (KAIST) • Korea Institute of Technology (KIT)	Engineering graduate program of M.Sc. & Ph. D. holders Gifted students program	Daejeon (042) 868-2114 Daejeon (042) 861-1234
Korea Atomic Energy Research Institute (KAERI)	Research and development in atomic energy	Daejeon (042) 868-2000
Korea Institute of Geology, Mining and Materials (KIGAM)	Development and use of technology of resources	Daejeon (042) 868-3114
Korea Institute of Machinery and Metals (KIMM) • Korea Research Institute of Ships and Ocean Engineering (KRISO) • Korea Aerospace Research Institute (KARI)	Development of technology for machinery and metals R&D in shipbuilding and ocean engineering Aerospace related technology	Changwon (0551) 80-3000 Daejeon (042) 861-7401 Daejeon (042) 860-2114
Korea Research Institute of Standards & Science (KRISS) • Korea Astronomy Observation (KAO) • Korea Basic Science Center (KBSC)	Establishment of national standards and development of technology in space Science and Astronomy Facilities in basic science to universities	Daejeon (042) 868-7201 Daejeon (042) 861-1501 Seoul (02) 554-9256
Korea Research Institute of Chemical Technology (KRICT)	Research and development in chemistry	Daejeon (042) 860-7114
Korea Electric Technology Research Institute (KERI)	Development of technology pertaining to electric power	Changwon (0051) 80-1112
Korea Institute of Nuclear Safety (KINS)	Regulations on nuclear safety	Daejeon (042) 868-2000
Korea Science & Engineering Foundation (KOSEF)	Support of basic research and manpower and development	Daejeon (042) 869-6114
Korea Ocean Research and Development Institute (KORDI)	Basic and applied research to promote the efficient use of ocean resources and continental shelf	Banwol (02) 863-4770
Korea Institute of Energy Research (KIER)	Development of energy technology and exploitation of energy	Daejeon (042) 860-3114
Korea Science Foundation (KSF)	Development of science and technology culture	Seoul (02) 555-0702
Korean Federation of Science and Technology Societies (KOFST)	Foundation of science and technology policies, fostering of societies and organizations	Seoul (02) 553-2181
Korea Technology Banking Corporation (KTB)	Providing industries with financial and extensive support services	Seoul (02) 782-7600

Source: Ministry of Science & Technology; Cited in Jin-Gyn Jang, 1994: 48-49.

Appendix 4: International Indicators of IT Usage, 1989

	Telephone lines per 100 persons	Per capita sales of telephone and telegraph services (U.S. dollars)	Mainframe computers per one million persons	Per capita sale of data communications services (U.S. dollars)	Per capita sales of information processing services (U.S. dollars)
South Korea	28.32	92.87	222	10.70	9.4
United States	50.58	442.35	8,287	39.06	414.0
Japan	42.05	304.75	4,693	46.31	380.7
West Germany	45.90	309.58	na	33.26	191.2
United Kingdom	39.00	165.65	na	9.76	188.5
France	46.98	248.10	3,834	65.50	261.0
Singapore	36.55	285.19	na	97.17	na
Thailand	2.08	14.53	na	0.71	na
Malaysia	7.35	33.54	na	3.63	na
Philippine	0.95	8.44	na	0.43	na
Brazil	6.00	8.40	na	1.61	na
Colombia	6.72	19.40	na	1.85	na

Note: na = not applicable.
Source: Reproduced from World Bank 1992, p. 1831.

Appendix 5
The Significance of Hardware and Software Industries in Total Production

	1984	1985	1986	1987	1988	1989	1990
GNP (US$ Million)	809	862	922	988	1,060	1,135	1,212
Hardware	3.5	4.4	5.5	6.8	8.2	9.8	11.8
Software	0.53	0.73	1.06	1.2	2.08	2.91	4.07

Source: Jae Whoan Lee, 1992.

Appendix 6
Sales of Data Communications Services (million $)[122]

Service	1988	1989	1990	Service providers	Service contents
Data processing	74,370	120,520	154,940	STM, KICC, KOTIS, SDS., etc.	Credit card, check, travel information
Data base domestic	970	1,550	5,300	DACOM, KIET	Data retrieval
International	6,070	9,370	11,680	DACOM, KIET	Data retrieval
Electronic data interchange	na	100	460	DACOM, KIET, YONHAP, MAE-KYUNG	Inter-firm electronic data interchange
Electronic mail	110	360	590	DACOM, SDS	Electronic mail BBS
Simple data exchange	880	1,120	15,590	DACOM	na

Source: DACOM (1990).

[122] Intra-firm transactions are not counted. Data Communication Corp. (DACOM) STM: System Technology Management, KICC: Korea Information Company SDS: Samsung Data System. KIET: Korea Institute for Economics & Technology.

CHAPTER 4: INFORMATION INDUSTRY IN TAIWAN

Introduction

The rise of the information industry in Taiwan, China has been extraordinarily rapid and largely focused on the manufacture of computer products for world markets. Since designating the information industry as a strategic industry in 1980 and launching a ten-year information industry development plan (1980-90) in 1982, the government has been a forceful advocate for growth in output, productivity, and technological mastery.

The state's concerted effort has borne fruit. For example, before 1980 there were only some keyboard and terminal exports, and by 1982 the export value was still only United States $106 million. But by 1985, only three years after the governmental initiative began, exports had climbed to $1.22 billion, representing 3.9 percent of all exports and some 1 percent of worldwide market share.[123] In 1992, computer products accounted for 42 percent of the economy's exports and 67.4 percent of the world market for mother boards, 40 percent for monitors, 70 percent for scanners, 70 percent for mouse devices, and 22 percent for notebook computers.[124] In addition to the growth of information technology (IT) production, governmental and industrial user community has expanded as well, largely the result of a concerted diffusion policy effort.

Profile of the Information Industry

Between 1975 and 1985, Taiwan had the biggest jump in electronics output as share of gross domestic product (GDP) of any major manufacturing country. By 1985 only Japan had a higher percentage of electronics in manufacturing output (SRI International; *table 4.1*).

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[123] Information Technology Policy and International Cooperation in Asia, 1991.

[124] Reuter Textline, 1993.

Table 4.1: Information Product Manufacturing in the Republic of China

	1985	1986	1987	1988
Total production value (millions of U.S. dollars)	1,260	2,134	3,839	5,157
Total export value (millions of U.S. dollars)	1,220	2,063	3,701	4,999
Share of total export in ROC (percent)	3.9	5.2	6.9	8.2
Export industry ranking	11	7	4	3
Worldwide ranking	9	7	7	6
Worldwide market share (percent)	1	1.5	2.4	3.1
Share of total electronic exports (percent)	25	29	34	38
Export dependency (percent)	93.8	96.6	96.4	96.7
Share of top 20 exporters (percent)	74.4	57.4	53.7	53.7
Share of components to total exports (percent)	28	34	40	40
Share of microcomputers to total exports (percent)	19.7	19.0	20.5	23
Share of exports to the United States (percent)	64	57	51	45

Source: MIC, Institute for Information Industry, Republic of China.

By 1987 Taiwan had joined the top seven countries in terms of information industry production value, behind the United States, Japan, United Kingdom, France, West Germany, and Italy. The mix of production indicates the dynamic growth of personal computers, monitors, and components -- two million personal computers were exported in 1988, (*table 4.2*).

Table 4.2: Production Mix of Republic of China Information Industry, 1985-88
(millions of United States dollars)

IT Products	1985	1986	1987	1988	Growth rate, 1987-88 (percent)
Minicomputers	-	-	1.8	2.6	44
Personal computers	240	398	759	1,151	52
Disk drives	42	71	97	111	15
Printers	45	41	44	43	3
Terminals	225	317	414	505	22
Monitors	303	500	847	1,089	29
Peripheral NES	256	44	80	81	1
Components	109	697	1,458	2,016	38
Total	1,220	2,063	3,701	4,999	35

Source: Institute for Information Industry, Republic of China.

Finally, the spread of high-tech manufacturing and the diffusion of information systems across government agencies and institutions drove the expansion of the information services industry in Taiwan, which amounted to $458 million in 1987.

Table 4.3: Information Services Industry in the Republic of China, 1987-88
(millions of United States dollars)

Information Service Segments	1987	1988	Growth rate (percent)
Information services revenue of multinational corporations	96.0	160	60
Package software	26.7	60	124
Professional services	20.6	34	65
Data processing services	14.5	19	31
Network services	2.3	6	160
Integrated systems	105.0	179	70
Total	265	458	73

Source: Institute for Information Industry, Taiwan, Republic of China.

The Government's Role in Information Industry Development

From 1971 to 1976, the growth rates of the leading sectors of the economy -- textiles, transport equipment, electrical machinery -- slowed considerably and new leading industries such as electronics did not develop fast enough to substitute. The government responded with a dual strategy: upgrade (or informatize) traditional sectors like textiles and stimulate strategic industries such as computers and telecommunications (Engelbrecht 1988).[125] The government's role in information industry development has thus evolved as part of a broader strategy aimed at raising the productivity and technology of manufacturers.

1. Policy Framework

The government in Taiwan, like Japan's in an earlier phase, has been a strategist and market leader. Technology-intensive exports were only 31.5 percent of the total in 1982, as compared with Japan's 70 percent in 1973, but the government decided that technology-intensive manufacture was the future.

In the industrial development plan of 1982, the government designated strategic industries: energy, basic metal, shipbuilding, automatic machinery, electronics, chemicals, and

[125] Engelbrecht, Hans-Inergen, "The Primary Information Sector of Taiwan," in *The Cost of Thinking: Information Economies of Ten Pacific Countries*, edited by Jussawalla Meheroo, Ablex Publishing Corp. 1988. p.196.

textiles. The machinery and information industries were given priority. They were guaranteed long-term loans at favorable interest rates and given tariff protection and technical and managerial assistance to explore new markets.

The government used both defensive and offensive tools to foster industrial and technological development. Defensive tools -- aimed at protecting local producers and suppliers of technology -- included import controls such as tariffs, import licenses, and local content regulations. Offensive tools included measures to develop local technological agents, engineering firms, capital goods producers, and research and development (R&D) institutions. *The Statute for Encouragement of Investment in Productive Enterprises* (the Statute), first promulgated in 1960 and regularly amended since, has been a major tool. The Statute has the following incentives:

- A five year tax holiday or accelerated depreciation of fixed assets for new enterprises.
- An investment tax credit for locally made (15 percent) or imported (10 percent) productive machinery and equipment.
- A maximum business tax of 22 percent on annual taxable income for key capital and technology intensive productive enterprises and 25 percent for other productive enterprises and trading companies.
- Duty-free import of machinery and equipment by export-oriented high-technology industries, and tax breaks and accelerated depreciation to encourage research and development, quality control, and efficient energy use.

The Statute makes no distinction between foreign and local companies. In fact, foreign investment has played an important role in the development of certain industries.

As exports of technology-intensive products have become important, so has domestic R&D capability and demand has increased for scientists and technicians. But science traditionally has been weak in Taiwan. Some observers relate this to the strong dependence on imported technology, as manifested in the Statute. The need for original research has been recognized, and government and private spending on R&D has increased. In 1983 the national expenditure on R&D was 0.73 percent of gross national product (GNP), about $363 million. By 1989, R&D expenditures had grown to 2 percent of GNP.

Since 1968 science policy in Taiwan has been based on four-year plans. The 1982-85 plan reflected R&D policies linked to the development of export industries. The plan had eight priority areas for research: materials science, information technology, automation, genetic engineering, lasers, hepatitis prevention and therapy, and food processing. Still, because of the small resources that traditionally have been allocated to long-term research, Taiwan has suffered brain drain. About four out of five students studying abroad stay after completing post-graduate training. The government has tried to lure back some engineers and scientists. The science-based industrial park in Hsin Chu is intended as a magnet for such high skills.

The government also tried to increase private R&D. But it faces a major constraint -- the dominance of small and medium-size companies, which lack the resources to carry it out. As a result the government has been induced to develop technologies and then transfer them to private companies. The Industrial Technology Research Institute (ITRI) of the Ministry of Economic Affairs, is an important umbrella organization for research. There are five research organizations under ITRI: Union Chemical Laboratory, Mechanical Industry Research Laboratories, Electronics Research and Service Organization, Materials Research Laboratories, and the Center for Measurement Standards.

ITRI is semi-governmental, meaning its R&D is sponsored by both the government and the private sector. ITRI develops technologies and disseminates them in several ways: joint development projects are carried out with one or more clients, technology is transferred after the completion of in-house projects, or venture companies use the results of ITRI research. ITRI also promotes joint ventures among foreign and local industries and cooperates with universities and other institutions.

A further step in creating a favorable climate for companies to invest in R&D was taken in 1980 with the establishment of the Industrial Science Park in Hsin Chu. The park offers investment incentives to companies that use advanced technology to make high value-added products. The incentives include tax and duty incentives that correspond to those in the Statute. They also include low-interest loans and low rents on factory buildings. Investors may use their patents or know-how as equity shares in government joint ventures.

2. *Development Policy*

The chronology of information industry policy includes:

1974	establishment of Electronic Research and Services Organization (ERSO) for integrated chip R&D
1979	establishment of *the Institute for Information Industry* (*III*), whose 10 year objectives included technology transfer services and development support for software, public sector computerization and training IT professionals
1980	organization of the first Information Week activities and designation of IT as a strategic industry
1982	passage of Information Industry Development Plan (1980-1989) and establishment of the Steering Committee for the Development of Information Industry in the Executive Yuan
1984	start of a Five-year Manpower Development Plan and setting up of Marketing Intelligence Center (MIC) in III
1985	collaboration between MIC and Arthur D. Little, U.S.A.
1986	revision of copyright law to protect software and organization of a study group on intellectual property right protection
1987	start-up of the Taiwan Semiconductor Manufacturing Corporation, a joint venture between ERSO, local Industry and Phillips to produce integrated circuit masks for local and international clients
1988	initiation of the Software Engineering Environment Development (SEED) project and opening of the Information Service and Technology Exhibition Center (ISTEC)
1989	initiation of planning the new 1990-2000 Information Industry Development Plan

Source: Institute for Information Industry 1992; and Dahlman, 1993.

This chronology does not capture the governments and the private sector's strategic pursuit of productivity and competitiveness in information technology products. During the 1980s the government promoted Taiwan as a low-cost computer manufacturer for multinational corporations, funneled financial and technical resources to local industrial extension activities to enhance IT subcontractor capabilities and to spread IT to traditional manufacturer sectors, and laid the groundwork for basic R&D infrastructure in government as an aid to small and medium firms delivering IT products to world markets. In the 1990s, Taiwan's strategy is shifting upstream. It is encouraging firm concentrations for heightened competitiveness in global market niches; innovation in IT products, and strategic alliances and investments that enhance innovation. This evolution in government IT strategy can be tracked through its interventions.

3. *Diffusion Activities*

Government IT diffusion activities have had several objectives to establish advanced telecommunications infrastructure: to stimulate and standardize government demand for computer systems to improve information sharing and use, enhance domestic competition in information services, accelerate local information industry development, and spread the productivity-enhancing benefits of IT across industry, both to upgrade traditional industries and to spur continuous innovation in high-technology industries.

4. *Public Sector Diffusion*

Telecommunications: Telecommunications in Taiwan has been dramatically improved as a result of the 1985-1990 Telecommunications Modernization Plan launched by the Directorate General of Telecommunications (DGT), which runs the country's public networks, and the Ministry of Communications, which regulates telecommunications activities. the DGT invested $1.6 billion in this period to install 2.7 million local switching lines, 145,000 trunks of digital toll switches and local exchanges in every township. In addition, ISDN beta sites were established at the Taipei World Trade Center and Hsinchu Science based Industrial Park.

DGT is currently in the midst of its second development initiative, the 1991-1996 Telecommunications Development Plan which is budgeted at $14 billion for the whole period. This plan seeks installation of 10 million switching lines, 100% digitalization of the toll switching system and the national implementation of an ISDN for commercial use. This latter effort is viewed as a crucial element in attracting and retaining multinational corporations who rely on high speed high volume global data transmission. In addition to the mainline installed base, over 138,000 channels of fiber optic cable were brought on-line in the three year period (1988-1991) to lay the groundwork for these ISDN "Intelligent Network Services."

Taken together, these two telecommunications development plans have transformed the social infrastructure in Taiwan, bolstering the mainline penetration rate from 27.6 per 100 population in 1989 to 36.1 per 100 population in 1993 and raising the percentage of households with phones from 86% to almost 100% in the same period. The pervasiveness of telecommunications infrastructure has also enabled the proliferation of major private networks for social development, such as the National Health Administration Network which connects 18 mainframes and 200 terminals for country-wide sharing of health and medical data. (Taiwan Country Study Pyramid Research, Inc., Cambridge, Massachusetts, 1992, pp. 220-260).

The historically tight control over the telecommunications infrastructure maintained by DGT and MOC is only recently starting to loosen. In March 1992, in response to complaints about capacity shortages, MOC announced that domestic private companies will be allowed to establish and generate cellular phone (CT-2) services - the first step toward privatization of any segment of the Taiwanese telecommunications infrastructure (Pyramid Research, Asia, March, 1994, p. 11).

In 1982, at the suggestion of the Institute for Information Industry, a high-level steering committee for the information industry was established in the Executive Yuan composed of all ministers and agency chief executives. The committee has five sections (Chou 1990):

- *Overall planning section.* Plans the nation's administrative information systems and standardizes information codes for government application, evaluates and schedules every government-sponsored computerization project, and promotes government automation to upgrade quality and service.

- *Information industry development section.* Implements government incentives for the software industry, assists the Software Association to join the Asian/Oceanian Computing Industry Organization, encourages local software makers to participate in government-planned, large-scale software projects and to transfer software technology from abroad, and develops software copyright protections.

- *Screen section.* Simplifies government computer acquisition procedures, audits information systems operations across agencies, and allocates and plans annual government computerization budget.

- *Data communications section.* Plans and implements nationwide data communication networks, videotex, telex, and value-added database services.

- *Information manpower cultivation section.* Provides information and education to students in high schools, vocational schools, colleges, and universities, promotes enrollment in information-related departments in junior colleges and universities, and evaluates information professionals' capabilities and skills.

The steering committee has set 133 standards in information and communications systems, including Chinese interchange codes, product bar codes, nation codes, currency and foundation codes, and keyboard inspection methods. It has completed five drafts governing portable operation systems interface formats and other standard communications protocols. And it has promulgated regulations for computer security regulation, personal data protection and the like (Lee 1993).

Box 4.1
Strategic National Information System:
Cargo Clearance Automation

Contract Distribution Services (CDS) is an automated warehouse and distribution center located just outside of Taipei. It handles all aspects of physical transport -- pack-up, warehousing, delivery -- for imported finished goods that travel as sea freight. The warehouse contains over 10,000 pallets and handles both bonded and unbonded goods. In many cases, freight forwarders must subcontract parts of the delivery process if they do not operate their own warehouse and transport system, but CDS integrates all of the services. It uses on-line computer systems to convey information on delivery, transport, inventory, orders, and customs clearance. CDS can receive, load, and deliver an order within 24 hours. CDS also uses internal computer systems to track the location of goods, special storage needs such as temperature, and the order in which goods are packed for shipment. By integrating services and monitoring the flow of goods, CDS enables companies to reduce or forego their own distribution systems.

Source: Reinfeld 1993.

As the spearhead public sector institutional mechanism for IT diffusion, the steering committee has presided over an explosion of computer use. Mini and mainframe computer installations have risen from 1,298 in 1982 to 7,436 in 1988, with government and government-owned businesses accounting for 1,013 of the total. On average, these public sector installations cost NT$21 million. Major public-sector applications include:

- *Centralized processing applications for national taxes.* All national tax data is submitted to the data center of the Ministry of Planning for processing. This computerization has led to a rise in income tax revenue from NT$15 billion in 1960 to NT$42.1 billion in 1987, with more than NT$5 billion collected through cross-checking by the center, and a rise in business tax revenue of NT$330 million in 1987 alone due to cross-checking of suspicious cases.

- *Interbank on-line system:* The Ministry of Finance brought on-line the first nationwide interbank operation system in 1987 to allow users to conduct financial transactions anywhere in the system using a single identification card.

- *Automobile registration and driving license record information management.* This system has increased operational efficiency five-fold and decentralized operations to rural areas (Choi 1992).

Other indicators of civil service computerization include:

- The Taiwan provincial government which has completed more than sixty large information systems, with another ninety projects underway.

- The Taipei municipal government which has completed more than forty computerized systems, including commercial registration, land administration, and construction administration.

- The Kaob Sung municipal government which has completed more than thirty computerization programs, including business management, land ownership, and election affairs.

- As of June 1992, three-fourths of the 359 towns, villages, cities, and district offices in the country had been equipped with computer facilities. Applications include civic affairs, property management, construction, agriculture, budget and accounting, citizen appeal, and work follow-ups (Lee 1992).

The diffusion of IT to traditional industries in Taiwan also has been impressive. In the woodworking or case goods industry, numerically controlled machines have slashed equipment change-over time from two days to two minutes between 1987 and 1992, allowing Taiwan to remain a world leader (Brackett 1992). In the weaving industry, shuttleless loom technology using highly sophisticated microelectronic controls represents 23.3 percent of total installed loom capacity (*table 4.4*).

Table 4.4: Shuttleless Loom Technology in Total Installed Loom Capacity, 1987

Germany	37.2
Taiwan	23.3
Indonesia	4.4
Malaysia	2.7
China	0.1

Source: Ernst 1992.

In addition to production automation, ninety-six firms participated in a government-assisted program to computerize management activities in 1984-87.

The China Productivity Center, which receives half its funding from the government and half from nongovernmental organizations and industry, has delivered automation technology through free consultancy services, government-subsidized loans and other assistance. Through the factory automation task force established in 1983, the productivity center has planned and brought on-line the quality control, plant layout, production planning, activity scheduling, and work measurement practices that prepare companies for automation. With the help of productivity center "doctors," many companies go on to adopt IT-based automation systems, such as flexible manufacturing systems, robotics, computer-aided design/computer-aided manufacture *(box 4.2;* Badiru, and Jen-Gwo 1992).

Box 4.2
Government Technology Extension Programs from the User's Perspective: Survey Findings of Taiwanese Software Companies

A survey of 120 computer software firms was conducted to evaluate the performance of technology institutions. Among the findings:

- Information services are the most frequently used. The Institute for Information Industry, the Industrial Association, R&D departments within firms, and relationships with customers and suppliers business contacts all provided quick and easy access to information and technology, and help with new product development and design. However, the Institute for Information Industry was criticized for its lack of quality technical personnel, slow response and high fees.

- Of government policies, government procurement policy is the most frequently used. Government is a major customer for the Chinese-language word processing and applications packages these firms produce.

- Training is the second most frequently used service. The Institute, the China Productivity Centers, R&D departments within firms, and private consulting firms are key providers.

- Support for formation of technical networks was the least frequently used service, indicating the "maverick" attitude of these companies.

Source: San Gee 1994.

5. *Development Activities*

In the three years following the launch of the 1980-90 development plan, government R&D budgets focused on IT development and factory automation. In 1983 information and automation accounted for 51 percent of the NT$6,615 million provided to the eight special technologies designated by the government; they were 57 percent of the NT$9 billion R&D budget in 1985 (Yuan 1990). That year, 4,413 of the 7,577 government R&D personnel in the eight special technology areas were working on information and automation.

An emphasis of government R&D was mastery of advanced techniques and then their promulgation across industry. ERSO's Center for Common Design Service was instrumental in acquiring and diffusing integrated circuit technology. Another ESRO initiative, the Taiwan Semiconductor Manufacturing Company (TSMC), was begun in 1987 overcome technology barriers and move into large-scale chip production. The $200 million project was an alliance between the government, which controls 48.3 percent of equity, Phillips International NV of the Netherlands (27.5 percent), and a consortium of Taiwanese companies. Phillips provides integrated circuit technology for high-volume, low-cost production as its equity contribution. TSMC supplies local semiconductor design companies, manufacturing 10,000 wafers per month to fill contracts with companies such as Toshiba, NEC, and Apple.

Indicating the shift upstream in strategy and capability, the Industrial Technology Research Institute announced a palmtop computer break-through. In alliance with nine firms, all based in Taipei or the nearby Taoyun Industrial Zone, ITRI developed a one-half kilogram palmtop that had most of the functions of an IBM desktop and could be operated for 20 to 40 hours on two AA batteries and retain memory for up to six months. The unit, developed after fifteen months of R&D, will compete against Hewlett-Packard and Sharp Electronics products (*Electronics* 1993). By the end of 1993, Taiwan's first microprocessor was to be available as a result of ITRI research (Reuter Textile 1993).

Another instrument of government -- private sector collaboration is the Hsin Chu Science Park (*box 4.3*). Its advanced infrastructure facilities have been used to lure home Chinese scientists and engineers, to attract technology-driven startup companies, and to combine the flexibility and entrepreneurship of small and medium-size enterprises with the economies of scale of shared R&D and facilities.

Box 4.3
Hsin Chu Science-Based Industrial Park:
The Pulse of Entrepreneuralism

Hsin Chu Science Park was established in 1980 as a magnet to bring back brain power from abroad. Today its 2,500 acres, an hour's drive from Taipei, are home to 13,000 researchers from four of six Taiwan's national laboratories and universities. It also hosts 150 companies, half of which are run by returned entrepreneurs. Nine-tenths of the sales from companies based at the park computers, chips and telecommunications products.

Hsin Chu has many benefits. Prefabricated factories are available, firms get five year tax exemptions and generous grants imported tools are duty-free, exports are zipped through an automated customs system, and innovation prizes are constantly awarded to let the public know jobs and economic wealth are built on research successes at the park.

Since 1980 the Taiwan Government has invested $500 million. The companies based there have a combined annual turnover of $5 billion, a very high return on investment for the country.

Driving this growth are scientists like Hsu Wenhsing, a professor at the National Tsing Hua University in Hsin Chu. His vision and advice led to a start-up called Startek that is commercializing automatic fingerprint verification. The custom-made scanning unit that translates the fingerprint into digital images, with the speed and convenience of a card-key swiped through an automatic reader, was developed in Taiwan. New markets in credit card verification, computer network access automation, and medical insurance claims sorting are opening for it, and Startek sales are expected to climb.

Source: Economist 1994.

In addition to direct investment in local R&D, Taiwan also has engaged in worldwide technology search and investment. For example, the Bank of Communications established a $328 million venture fund to "get a window" on advanced technologies and transfer them back to Taiwan (Ministry of Finance 1988).

To compensate for its weakness in software, the government is using its Institute for Information Industry to establish an alliance with IBM. Through the joint venture, Taiwan expects to acquire advanced software technology and diffuse it to private software companies. The government is providing, various R&D and incentives to develop software packages in the Chinese language. This is critical to wide diffusion and provides opportunities for applications and export to other Chinese markets.

As part of its effort to encourage innovation, the government has revamped its international property laws. The patent law was revised in 1986, reversing the burden of proof to the alleged infringer and raising the penalties for infringement. In 1991 a new fair trade law strengthened trade secrets protection. Copyright law also is being revised (Braga 1993).

6. *Human Resources Promotion*

The Five-Year information manpower development plan of 1984-89 expanded training of information professionals. Some 45,000 people were in various training programs in those five years.

At the high-school level, every student now takes two computer courses. In college, every student can take two to six credit hours of computer application courses. To train teachers, three national universities work with the Institute for the Information Industry.

Finally, a nationwide IT engineering examination was put into place to qualify software engineers and programmers. The exam has defined skill standards for information personnel.

The Private Sector's Role in Information Industry Development

By all accounts, the distinguishing characteristics of the Taiwanese information industry's development has been the large number of relatively small firms. In 1985, a survey of 2,000 electronic firms by the Council for Economic Planning found that only 136 had sales above $10 million (SRI 1992). That year the average firm had twenty-four workers.[126] The computer products sub-industry, with 650 manufacturers in 1989, has likewise been characterized by small firms. Taiwan's top five firms accounted for $3 billion in sales; Korea's top three accounted for $15 billion in sales (Hobday 1993).

The small size of Taiwanese information industry producers has been a two-edged sword. On one side, there is flexibility and strength in learning about markets and exploiting emerging niches before larger competitors can act. On the other side, smallness implies lack of organizational infrastructure and financial resources for advanced production and technology, training, and R&D, deficiencies for which the government has tried hard to compensate.

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126 Hobday 1993, p.16.

At the firm level, an accelerated production and marketing learning curve exists among Taiwanese IT producers. Hobday (1993) has outlined a process spanning from complete dependency on foreign buyers -- mainly the large Japanese trading houses in the 1970s to gain exposure to international markets; then a reliance on "original equipment manufacture" for these traders and U.S. multinationals; then "own design and manufacture" programs in which high-reputation local firms appropriated value and produced products to their own specifications that were sold and resold under the brand of the foreign firm. Ernst (1993) noted that as Taiwanese producers cut into the market shares of IBM and IBM-PC-compatible suppliers, they were forced to increase R&D to stay competitive. As Ernst notes: "Intensifying external pressures (for example, as a result of trade frictions with the United States) as well as stiff competition among themselves has forced them to become less imitative and more innovative. To be able to design new products quickly, they have come to rely increasingly on the customization of their integrated circuits components. They have been able to take advantage of the substantially reduced cost of designing such circuits with new automated design tools and methods. The demand generated by this dynamic group of integrated circuits user firms has given rise to a whole new class of 'supplier' firms in Taiwan, firms which specialize in the design of application specific circuits (ASICs). They do not make the chips themselves, but work closely with customers to devise a 'camera-ready' chip design tailored to user requirements, which are then sent to a "silicon foundry" for processing (that is, the joint venture foundry between Phillips and the Government of Taiwan)."

The growth of the IT products industry -- from small subcontractor and OEM manufacturer to larger original design and manufacture company to innovative, vertically integrated transnational production and marketing company is encapsulated in ACER, the largest computer firm in Taiwan. In 1976 the company had eleven employees and $25,000 in capital. In 1988 the company had 4,400 employees and $550 million in sales, with overseas subsidiaries in Silicon Valley (California), Europe, Tokyo, and Hong Kong engaged in high-tech production, R&D, and venture capital investing. In its first five years, ACER imported advanced technology and focused on short-term profits from forty OEM products and developing design skills. It used employee stock option programs and other employee financing to grow. In its second five years, ACER plowed resources into R&D, nurtured its own brand names, and initiated a "periphery to the core" marketing strategy, that is, it entered smaller markets to gain experience before taking on the United States. In late 1986 ACER followed Compaq and introduced 32-bit 80386 personal computers that were widely hailed for their price and technology. From 1986 onward, ACER has concentrated on global expansion, building regional offices and worldwide R&D and production (Infotech 1992). More recently, ACER has focused on enhancing both technological flexibility. Its "chip up" concept -- chip upgradeable motherboards -- is an example of this organizational effort, as is its attempt to turn overseas production units into stand alone units run by local managers.

ACER's response to a dynamic and increasingly competitive global IT industry is not unique; Taiwanese firms are rushing to acquire innovative technology and new distribution channels for their products. In fact, the whole production structure is changing dramatically. The small, family-run computer business that has characterized the Taiwanese IT production sector is disappearing. From 300 brands of computers produced by a plethora of firms, only ten brands remain, and the Taiwan products promotion company predicts soon there will be only three or four (Reuter Textile 1993).

The next stage of expansion will find these larger, more vertically or laterally (given the scope of recent international alliances) integrated computer makers at the center of fast-growing regional production networks focused on mainland China. Many of the island's computer companies are ignoring laws that prohibit investment in China and taking production partners on the mainland. The Taipei Computer Association, for example, is trying to convert a one-square-mile swamp in suburban Shanghai into an industrial park for Taiwanese computer companies and open showrooms in Shanghai and Beijing to promote sales of the island's IT products. Taiwan is thus becoming the organizer of a high-tech production and trading system. In recognition, Microsoft has renamed its office in Taipei the "Greater China Office" (*BusinessWeek* 1992).

Perhaps we can anticipate the emergence of Greater China-based IT conglomerates in the late 1990s, whose managerial and R&D centers will be in Taiwan, whose production facilities will be sprawled across the Chinese mainland and whose outputs will be marketed around the world through joint ventures and alliances.

Conclusion

There has been dynamic and staged growth in the Taiwanese IT-production complex. Growth first focused on local manufacturing in the private and public sectors. Government emphasized industrial extension and finance, building basic R&D capabilities to support small and medium-size firms and launching international business promotion and recruitment. Private sector emphasis was on subcontracting with multinational companies, absorbing technology and market know-how from abroad, and internalizing design capabilities. The second stage has been characterized by firm consolidations, more self-contained R&D and technology development mechanisms; more sophisticated international technology and marketing relationships, such as alliances rather than subcontracts or licensing and regional production organizing, as in the coming mainland China computer production network; and a decline in direct government intervention, as demonstrated by the 20 percent reduction in the $200 million budget of the Industrial Technology Research Institute in July 1993.

A conscious and stepped progression toward technological mastery has been accelerating. This has been Taiwan's strategic intent, in which the private and public sectors have acted as a focused, interactive business system aimed at global competitiveness in IT.

Recent political reforms have called into question the lockstep pace with which the private and public have moved to execute industrial policy, and these questions have resulted in funding cutbacks of ITRI. But there is evidence of a new phase of more strategic and flexible interactions between the government and a more liberated business community. For example, in February 1993, the Ministry of Economic Affairs agreed with AT&T to establish a regional telecommunications consulting service. It began negotiations with Motorola to establish a software center and an R&D center on wireless communications as part of a long-term plan to enter the mainland China market. These developments indicate the strategic awareness of public sector leaders and their determination to assist the private sector in the transition of Taiwan into a leading regional managerial and research center for IT. Thus the partnering modalities in the Taiwanese IT public-private business system may evolve, but the system itself will surely remain.

CHAPTER 5: INFORMATICS IN HONG KONG

Introduction

Of all the cases in this report, Hong Kong has had the most laissez-faire approach to information industry development. The government has franchised to the private sector all ownership and operations of state-of-the-art telecommunication infrastructure and services. Market forces, particularly Hong Kong's gateway functions to China for financial services and for capital and know-how in manufacturing, have driven information industry expansion. Only when the market has blatantly failed -- as in shortages of information technology professionals to serve the banking, finance, and insurance industries -- has the government stepped in to execute targeted IT policies. Recently, however, government involvement in industrial policy is increasing as concern grows over the hollowing out of electronics manufacturing.

Profile of the Information Industry

Hong Kong's information industry is two-tiered: a declining electronics manufacturing base that is redeploying physical assets, investment capital, and managerial skills to the provinces of China, and a booming information services market led by banks, trading houses, and insurance companies involved in gateway transactions to China or other international deal-making. The transition of Hong Kong from a center of relatively labor-intensive consumer goods manufacture to high-tech trading and services is reflected in that, from 1982 to 92, manufacturing as a share of gross domestic product (GDP) dropped from 25 to 20 percent and as a share of the labor fell from 40 to 29 percent (Greenfield 1992).

The electronics industry, while in decline, nevertheless provided 23 percent of the total manufacturing output and 26 percent of total exports in 1990. IT products include electronic games, printed circuit boards, and liquid crystal displays. While still mostly an original equipment manufacturer for United States and Japanese firms, local firms have some development and design successes in fax machines and liquid crystal displays (Hobday 1993). These successes have been few, however, and, shortage of engineers and lack of government research and development (R&D) have contributed to many firms moving to nearby Shenzen, where wages are one-sixth of those of Hong Kong (SRI 1992). China is now home to three-fourths of the manufacturing workers employed by Hong Kong firms and, in one province alone -- Guangdong -- 28,000 Hong Kong-backed factories employ 3 million workers (*Economist* 1993).

These factors have resulted in a considerable drop in Hong Kong's share of overseas IT export markets. Between 1983 and 1987, Hong Kong's share of the United States electronics market dropped from 5.9 percent to about 3 percent. Both the rapid buildup of electronics companies in the 1970s and the stagnation of the sector in the 1980s are illustrated in *table 5.1*, which shows that Hong Kong had the most number of computer companies but the slowest average annual company growth rate among the countries surveyed.

Telecommunications infrastructure is provided by two private companies, the Hong Kong Telephone Company and Hong Kong Telecom International, operating under exclusive license from the government's telephone authority. The companies provide public telephone service, telex, fax, data transmission, and leased circuits. In addition, a diverse group of telecom companies provides mobile communications, electronic mail, value added networks, and the like, in a loosely regulated, highly competitive environment. There are six major non-exclusive service operators in addition to the two exclusive telecom franchises, and fifteen international value-added network services operators (Greenfield 1992).

The information services market in Hong Kong was valued at about HK$5.5 billion in 1989, with software products and services constituting about 30 percent of that total. Given that the value of software and IT services produced in Hong Kong was about HK$1.04 billion, of which about 9 percent were local software products that were exported, IT services have been imported from abroad to meet the demands of the key banking, insurance, and trading house sectors (Reinfeld 1993).

More recently, joint ventures and alliances have been created by Hong Kong firms to develop domestic information technology service capacities and to capture value-added from these activities. For example, Infolink Asia and the Sing Tao Publishing Group acquired ACS, a Hong Kong computer services company, to market and support business systems and data networking skills that the company developed in Australia (*Australian Financial Review* 1990).

Table 5.1: Computer Companies in Selected Asian Countries

Country	Number of companies	Density[a]	Average annual growth rate (percent)	
Republic of China	760	0.040	1981-85:	28.9
Hong Kong	2,354	0.428	1980-85:	27.3
India	2,073	0.003	1982-85:	105.8[b]
Indonesia	826	0.005	1980-85:	32.4
Republic of Korea	661	0.016	1981-85:	30.6
Malaysia	1,450	0.092	1980-85:	36.7
Nepal	36	0.002	1984-85:	111.8
Pakistan	244	0.003	1983-85:	47.6
The Philippines	1,438	0.026	1980-85:	27.8
Singapore	1,828	0.703	1980-85:	39.3
Sri Lanka	268	0.017	1981-85:	55.4
Thailand	684	0.013	1980-85:	30.2

[a]Companies per thousand population.
[b]Extremely high growth rate reflects, in part, better coverage of the survey in 1985.
Source: Asian Productivity Organization, 1990.

On the other hand, telecommunications and information services are growing rapidly (*table 5.2*).

Table 5.2: Growth in Telecommunications in Hong Kong

Phone Lines	1,988,524 (1987)	2,800,000 (1992)
Lines per 100 people	35.1	47.0[a]
Outgoing international calls (minutes)	64 million (1984)	234 million (1988)
Outgoing international fax usage	Increased by 24 times between 1984 and 1988	

[a]Surpassed in region only by Japan and Australia.
Source: Economist 1993.

The Government's Role in Information Industry Development

1. Policy Framework

The major public vehicle for promoting technology policy has been the Committee on Science and Technology, established in 1988 to promote economic growth and competitiveness. Public and private forums sponsored by the Committee have helped define new directions. The November 1992 Technology Roadmap Conference brought together academics, manufacturers, and politicians to discuss how Hong Kong could move beyond its role as an exporter of consumer goods. The Roadmap group targeted biotechnology, materials technology, environmental technology, and IT (*South China Morning Post* 1992). Another group, the Guangdong-Hong Kong Association for the Promotion of Technology Enterprise, was founded by businesses, industrialists, and academics who shared a vision of growth in technology enterprises in Hong Kong and China (*South China Morning Post* 1991)."

Evolving from these public-private forums was the Technology Center, an incubator concept borrowed from Singapore and Taiwan to generate business startups. The center represents an intense and direct new governmental involvement in industrial policy.

2. Development Policy

Hong Kong still lacks a comprehensive information industry development policy as in Singapore or Taiwan. Until 1989 the government had no formal strategy for its own IT investment and adoption. Policy reforms are evolving.

Public sector diffusion. In the public sector, the Government Data Processing Agency was reinvented as the Information Technology Service Division to stimulate strategic, non-data processing activities and consolidate IT strategic planning among departments. A government systems architecture, with procurement and hardware/software standards, now guides all departmental purchasing of IT. Between 1987 and 1989, the value of computers in the government doubled to HK$644 million; more than 30 minicomputers and 2,000 microcomputers were installed. Governmental expenditure on IT services increased from HK$180 million in 1987 to HK$500 million in 1990. Applications have emerged for hospitals, customs control and shipping registry, and land registration.

Extension to the private sector. Concern over manufacturing sector slippage has motivated the expansion of the Productivity Council, funded by the government with HK$120 million between 1989 and 1992, to develop and diffuse computer-aided design and automation technologies. This new round of funding followed surveys that showed only 5.9 percent of the manufacturing sector (2,854 companies of 48,750) used computers and only 2.3 percent used CAD (Howe 1990). The government also is making grants to companies to train engineers in application-specific integrated circuits (ASIC) design. Finally, it is considering whether to build IT technology transfer centers and a management training center.

Among public-private service promotion transactions, the electronic data interchange project (SPEDI) was launched in 1984 by the Trade Facilitation Council to lobby industry to adopt United Nations standards for electronic data interchange (EDI) and government to process electrically its trade documents and exchanges with banks, insurance, and trading companies.

Box 5.1
Automated Warehouses

An application of advanced infrastructure under development is automated warehouses. Hong Kong Air Cargo Terminal Limited (HACTL) and Tait's Contract Distribution Services (CDS) have enhanced the speed and reliability of cargo handling. They integrate formerly disparate activities through IT-enhanced physical infrastructure and services.

HACTL is a private company that handles, stores, builds up, breaks down, and documents air cargo for the 60-plus airlines that use Hong Kong International Airport. It operates 24 hours, and serves up to 280 flights and 3,500 tons of cargo per day. Whereas airlines elsewhere operate their own warehouses and employ several intermediaries, HACTL integrates these services for all airlines under one roof. HACTL uses computer networks to track internal operations and link cargo handlers, airlines, customs officials, and local cargo agents. For example, HACTL's loading docks assess volume and weight of a consignment and send this information into a computer network that calculates air freight charges for the airlines. The system ensures that aircraft will be loaded safely and provides HACTL with an internal tracking record.

HACTL's mishandling rate is a scant one in 6,500, versus the one in 20 consignments that arrive mishandled from the airlines themselves. Similarly, HACTL's "dwell times" -- from the moment cargo arrives until it departs -- of 19 hours for exports; and 40 for imports are among the best in the world. Its performance is a result not only of HACTL's efficient cargo handling systems but of Hong Kong's status as a free trade area and the limited customs restrictions.

Source: Reinfeld 1993.

Hong Kong, like other Asian newly industrialized countries (NICs), is exploiting IT to develop advanced infrastructure for trade, finance, and manufacturing. These infrastructures include enhanced physical facilities and common value-added service applications that improve the flow of cargo and information and enhance responsiveness to user needs (*box 5.1*). Although Hong Kong's infrastructure is among the best in Asia, it is less supportive of manufacturing than of services such as trade and finance. It has less developed common value-added services (such as EDI) for manufacturing than Taiwan or Singapore.

The slow development of advanced infrastructure may be explained by the following:

- The nature of the products and markets served by Hong Kong manufacturers, generally do not employ logistics management. Many companies that do have satellite operations have located them in southern China and therefore do not rely on advanced infrastructure to communicate with those facilities.

- Hong Kong's manufacturing industry is dominated by small and medium-sized companies that lack the resources to develop value-added services.

- The government is laissez-faire, but its support is needed to develop advanced physical infrastructure and value-added services, particularly where industries are dominated by small companies, initial costs are high, or returns to suppliers and operators are too low to attract them.

Nevertheless, there is a growing awareness that for Hong Kong to stay competitive -- as a manufacturer and as a regional center for manufacturing industries -- improvements in advanced infrastructure, particularly in value-added services are needed. Government and quasi-government organizations are encouraging development of value-added applications, among them the Industrial Development Board (the government's thinktank on industry and a mover in technological development), the Hong Kong Productivity Council, the Industrial Technology Center, the Federation of Hong Kong Information Technology, and the Federation of Hong Kong Industries.

Human Resources for Information Technology

Demand for graduate-level IT professionals is increasing at about 10 percent a year in Hong Kong (*South China Morning Post* 1991). The rise in demand, coupled with a brain-drain of engineers and other IT workers to Canada and Australia, is creating shortages. The government has launched a plan to add more than 1,000 IT-related places in tertiary institutions by 1994-95. Other IT technical training activities are underway *(table 5.3)*.

Table 5.3: IT Training Programs

Program	Description
Information Technology Training Center (ITTC) of the Vocation Training Council	ITTC offers fifty free IT courses ranging from one day to fourteen weeks on subjects from desktop publishing to finance and insurance. There is a full-time fourteen-week, basic IT course to help graduates of disciplines other than computers become IT workers. In 1991, there were 3,500 students served by the ten training officers.
IBM Hong Kong/Hong Kong Government Training Partnership	To help the government modernize its IT functions, IBM has provided $6.2 million in hardware and software and 25 man-years of human resources to transfer IBM technology and experiences to government officers.
Hong Kong Productivity Council	This government organization researches IT applications, and through extension, training, and funding support helps small and medium enterprises acquire IT.

Source: *South China Morning Post* 1991.

The Private Sector's Role in Information Industry Development

Telecommunications and services have driven information industry development in Hong Kong. The two exclusive telecom franchises have led the installation of one of the world's largest optical-fiber networks, linking all major urban telephone exchanges and handling half of all calls. Their zero-cost local calling charges have promoted widespread use of fax machines and other peripherals and stimulated several firms to pioneer the strategic use of IT.

Probably the leading IT user has been Hong Kong and Shanghai Bank (HSBC), whose 1993 earnings topped $2.5 billion, making it the most profitable bank in history (*Wall Street Journal* 1991). With a $1 billion information technology budget and global information network developed in-house, HSBC has been in the forefront of IT. Having recently acquired the Midland Bank, the UK's third largest lender, HSBC is installing a 1,700 branch information network in Midland over five years that it expects will save $100 million a year in operating expenses. Bank Chairman William Purvis says the combined resources of HSBC and Midlands will provide the capital and economies of scale to speed decisionmaking by hooking global management into one database" (*BusinessWeek* 1993).

Another innovative IT user has been the publishing industry. More than 200 publishing houses use the latest in equipment and multimedia. One firm, Interoptica, produces a multimedia program called "Astonishing Asia." It provides interactive full-motion video and on-line data selections for users to "tour" the region in cyberspace (*Economist* 1993).

In manufacturing, vanguard users have been clustered in the apparel sector, where EDI has long been important. Liz Claiborne's international network has linked clothing factories in China, Hong Kong, Korea, the Philippines, Singapore, and Taiwan in an EDI system linked to headquarters in New York. This system coordinates fifty steps between raw goods delivery, and final product, reducing sample approval and production changeover time from days to hours (*New York Times* 1989). EDI systems have enabled Hong Kong's clothing manufacturers to remain competitive. Reinfeld (1993) describes such computer-based international activities, including digital transmission of patterns and color schemes from New York designers to laser engravers and international work sessions with customers via video conferencing (*box 5.2*).

Box 5.2
Hong Kong Garment Manufacturer

A Chinese garment manufacturer, with twelve factories in Asia and a network of high-fashion retail customers throughout the world, is an example of the direction that successful firms in this industry are taking. It is a family-run business that began as a "job shop" for large United States department stores before quotas, when buyers came looking for cheap labor. As market conditions changed, the company had the foresight to respond, continuing to capitalize on cheap labor and its favorable market position. The founder's son, who had been educated in modern business management, quickly apply technology and strategies emerging in more industrialized countries.

The company still manufactures in Hong Kong but moved most of its production to China, Malaysia, Philippines, and Sri Lanka. Supplies come from the Caribbean, China, Egypt, Pakistan, Taiwan, and the United States.

"The garment industry cannot survive without cheap labor," this manufacturer said. "Labor costs in Hong Kong are now twenty times greater than those in Sri Lanka. Therefore we have moved most of our manufacturing activities to other countries in the region and have kept only the central service functions and specialized manufacturing in Hong Kong."

Its activities in Hong Kong are computer-oriented and rely on advanced infrastructure, particularly in dealing with the market. For example, New York designers transmit patterns and color schemes to laser engravers. This company also conducts international work sessions with customers via video conferencing and depends on time-specific delivery of higher-valued goods to market. T-shirts with in-style prints must be manufactured, and delivered to retail outlets quickly, since the market can evaporate as quickly as it appeared.

The production of higher-value or time-sensitive products are done only in factories that can employ IT. This, in turn, depends on the availability of advanced infrastructure and trained manpower. Products that have no requirement but cheap labor are left to those countries that have no advanced infrastructure or IT capabilities.

The outlook for the industry, according to this company, is that Hong Kong will become a headquarters and service center and that the factories will relocate to areas where labor remains competitive and where it is possible to find advanced infrastructure. If otherwise Hong Kong firms will be unable to compete with North American Free Trade Agreement (NAFTA) and European Economic Community (EEC) industries for Western markets.

The company finds that infrastructure is better in Hong Kong than in Asia, but that local industry needs to do more to develop EDI.

Source: Reinfeld 1993.

Conclusion

As a regional gateway with IT overlaying its dynamic trade, investment, and production coordination patterns, Hong Kong has exhibited remarkable growth and resiliency with minimum government intervention. Early on, government franchised out core IT infrastructure creation to the private sector and withdrew to a monitoring function.

This approach, coupled with a competitive telecom equipment and information-service supplier market, expanded supply and helped ease the demands of banks and insurance companies. On the other hand, manufacturing was allowed to atrophy. A shortage of IT professionals in manufacturing and a lack of government attention to IT diffusion led to a loss of manufacturing quality and competitiveness. Similarly, the government's laissez faire posture has encouraged the private sector to invest in infrastructure and value-added services but has impeded riskier and more complex developments that required clear policies and standards. Although Hong Kong's advanced infrastructure is among the best in Asia, it is more supportive of services industries such as finance and trade, than manufacturing. The physical infrastructure supports manufacturing but has less developed common value-added services for this sector than Taiwan or Singapore. Only recently has the government moved to stem the bleeding, with business training, technology extension and incubator programs, and accelerated policies to exploit IT for advanced infrastructure development.

Despite the erosion of manufacturing, Hong Kong will continue to provide regional leadership in the use of IT in facilitating trade, finance, and producer support services. As the source of two-thirds of Chinese foreign investment (*Fortune* 1993), Hong Kong should remain an "intelligent" hub in global business networks well into the next century.

CHAPTER 6: SINGAPORE INFORMATION INDUSTRY DEVELOPMENT

Introduction

Singapore has leaped from a poor entrepot to a global hub for high-value information technology production and use. Without natural resources and with a small, zero-growth population, Singapore has relentlessly pursued technological solutions to productivity and competitiveness problems and has positioned the island as a strategic node in the advanced global manufacturing and service schemes of multinational corporations.

Through conscious, staged policymaking, government decisionmakers helped lead the economy rapidly upstream. They made two critical decisions in the 1970s. First, they invested in communications, increasing capital outlays for telecommunications services 239 percent from 1974 to 1980 in anticipation of demand for data networking capacities by corporations. Second, the National Wage Council in 1979 let wages rise 20 percent, which forced many multinationals either to automate production and "flee upstream" to more intensive use of new technology or to relocate assembly jobs to lower-wage factories in Malaysia and Thailand. These two decisions set the stage for dynamic growth for the information industry.

In the 1980s government strategy focused on inducing foreign investment. The Economic Development Board aimed its promotional resources at computer and software companies that could benefit from and contribute to the island's communications and high-skills infrastructure. One clear measure of success: in 1981 the computer industry had revenues of $40 million; by 1988 Singapore had become a major producer of computer equipment, exporting $3.8 billion to world markets (*Financial Times* 1990). With firms like Connor & Seagate flourishing, the island became the world's largest manufacturer of diskdrives, exporting $2.4 billion in drives in 1988, and $4.1 billion in 1991 (Fern 1991, Hobday 1993). Another major thrust of the 1980s was accelerating the adoption and diffusion of information technology (IT) among key user communities. The creation of the National Computer Board in 1981 and its generation of a national IT plan five years later were milestones. Among the Computer Board's achievements have been nearly 200 application systems installed across the civil service, with an estimated cost/benefit ratio of S$1.71 for every dollar spent, some 8,000 software professionals trained, and revenues from local software and services increased from S$69 million in 1981 to S$1.1 billion in 1988 (*Financial Times* 1990).

As the 1990s unfold, Singapore is shifting. It is seeking to leverage IT resources in industry, government, and the universities to become an "informatized" society, an "intelligent island." The IT 2000 and national information infrastructure report of the National Computer Board in April 1992 envisioned an effort among agencies such as Singapore Telecoms, the Singapore Broadcasting Corporation, and the Ministry of Communications to create a national high-speed data highway for voice, image, data, and live video. It is the next frontier: a unified software architecture reaching every building in the central business district by 1995 and every building on the island by the year 2005 (*Economist* 1993).

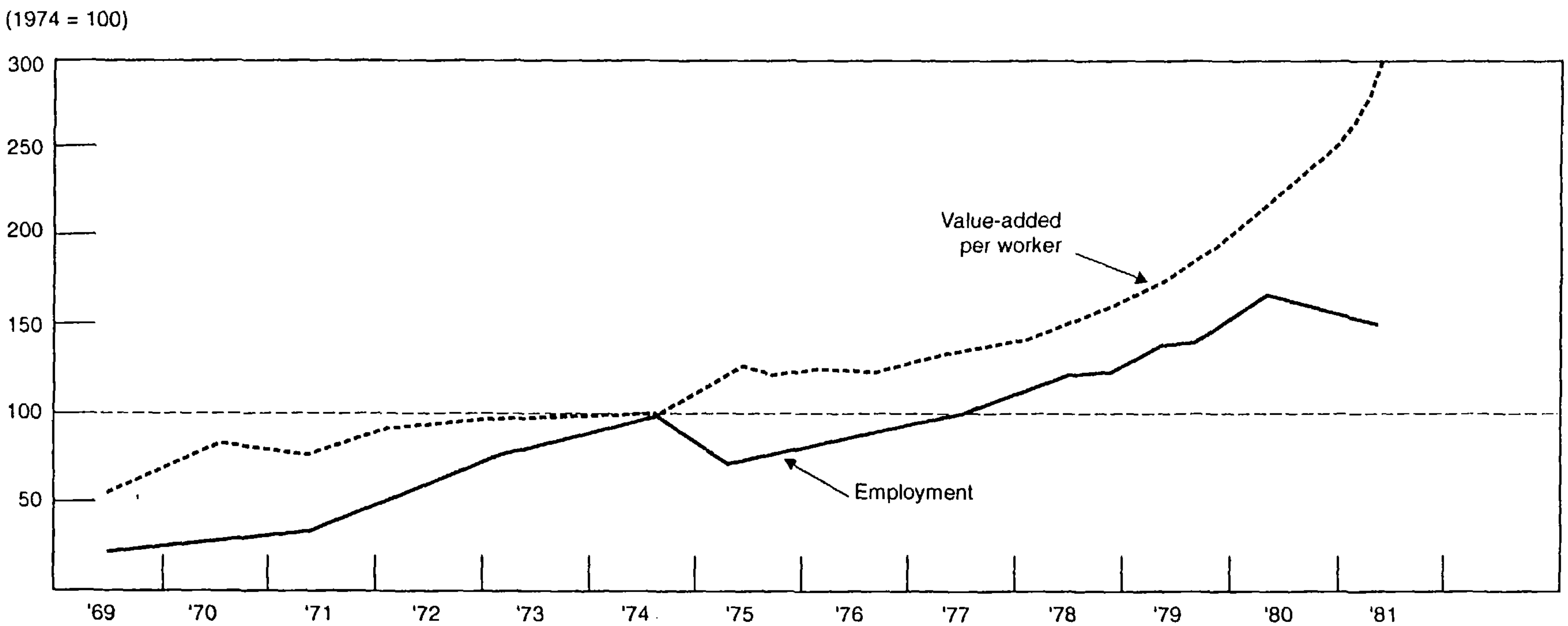
Such an architecture would facilitate diverse electronic interactions and "virtual partnerships" among manufacturers, suppliers, and distributors, between financial institutions and their clients, between government agencies and their user-communities, between education institutions and the public, and between households and a universe of services. Singapore's plan for an informatized society puts it in the vanguard of IT as the year 2000 approaches.

Profile of the Information Industry

The information industry (computer hardware, software, and IT services) was an outgrowth of the local consumer electronics industry, which took hold in the mid-1960s. This small, domestically oriented production sector gave way to labor-intensive semiconductor manufacture, led by United States multinationals that migrated to the island and, by 1971, made Singapore into the largest semiconductor manufacturing center in Asia outside Japan.

By 1973, however, the labor market had tightened. The government discouraged investors looking for low-wage, unskilled labor for the electronics industry and raised the minimum wage. By 1974 the transition to higher-technology, higher value-added electronics sectors was underway. As Crawford (1984) noted, from 1969 to 1974 electronics jobs increased faster than value-added per worker -- an average of 40 percent a year for jobs, compared with a 9.5 percent for value-added. Between 1974 and 1981 the trend reversed: value-added climbed at a 16 percent rate, while employment increased at only a 7 percent pace. The shift to higher value-added industries was accelerated by the National Wage Council's 1979 decision to let wages rise 20 percent, is shown in *figure 6.1*.

Figure 6.1: Transition to a High Value-added Electronics Industry, 1969-81



Source: Crawford 1984.

Crawford, Morris, "Use of Information Technology in Third World Industrial Policy: The Case Study of Singapore, Malaysia and Indonesia," program on information resources policy, Center for Information Policy Research, Harvard University, Cambridge, Mass. February 1984, p.19.

Although the high-wage policy accelerated investment in higher-technology and higher value-added electronics products, in 1985 Singapore experienced a severe recession. In response the government reduced labor costs by cutting employer contributions to the central pension fund, amounting to a 12 percent wage cut. The government positioned its labor force to attract multinationals and yet move up the value-added ladder by adjusting its cost, upgrading its skills, and experimenting with financial incentives (Liepziger and Thomas 1993).

Multinationals from the Japan, Europe and the United States continued to set up operations on the island in the 1980s, upgrading their testing and assembly operations and building new capabilities in advanced water fabrication, diskdrive manufacturing, advanced consumer electronics production, and industrial electronics, design and manufacture. This ongoing shift to higher value, technologically-intensive is shown in *table 6.1*.

Table 6.1: Electronics Industry, 1971-89

Year	Output (US$ Million)	% Mfg	Number of Workers	% Mfg	Value-added Per Worker (US$)	% Mfg
1971	92	6	11,847	8	3,563	111
1972	188	9	20,121	12	4,455	120
1973	368	11	29,537	15	4,829	93
1974	546	10	32,780	16	5,452	78
1975	519	10	24,351	13	6,969	93
1976	697	11	35,756	17	6,310	82
1977	876	12	41,245	19	6,393	76
1978	1,139	13	47,455	19	7,614	82
1979	1,826	16	63,201	23	8,753	80
1980	2,497	17	71,727	25	10,872	78
1981	2,715	16	69,358	25	11,109	68
1982	2,476	15	60,760	22	11,416	72
1983	3,326	19	65,954	24	13,736	80
1984	4,556	24	73,271	27	13,999	98
1985	4,172	24	66,646	26	19,737	103
1986	5,271	31	70,863	29	24,475	111
1987	7,857	36	85,750	31	27,933	113
1988	10,879	39	112,822	35	27,951	102
1989	12,443	39	115,837	34	31,091	104

Source: "Economic and Social Statistics of Singapore 1960-82," Department of Statistics, Singapore; "Yearbook of Statistics Singapore 1989," Department of Statistics Singapore.

By 1989 electronics production was driving the manufacturing sector, contributing almost 50 percent of output and employing 34 percent of the workforce. Within the electronics sector, computer equipment and peripherals become a significant portion of production. For example, of the $10.8 billion in electronics production in 1988, computer equipment and peripherals accounted for $3.4 billion. Manufacture of diskdrives comprised almost a third of computer and peripherals production, followed by microcomputers at 6 percent of production (Fern 1991). In addition to production for exports, there was intense local demand for computers and peripherals (*table 6.2*).

Table 6.2: Computer and Peripherals Production and Demand (millions US dollars)

	1986	*1987*	*1988*
Production	1,330	2,299	3,482
Imports	349	493	872
Exports	1,470	2,482	3,836
Total Domestic Demand	209	310	518

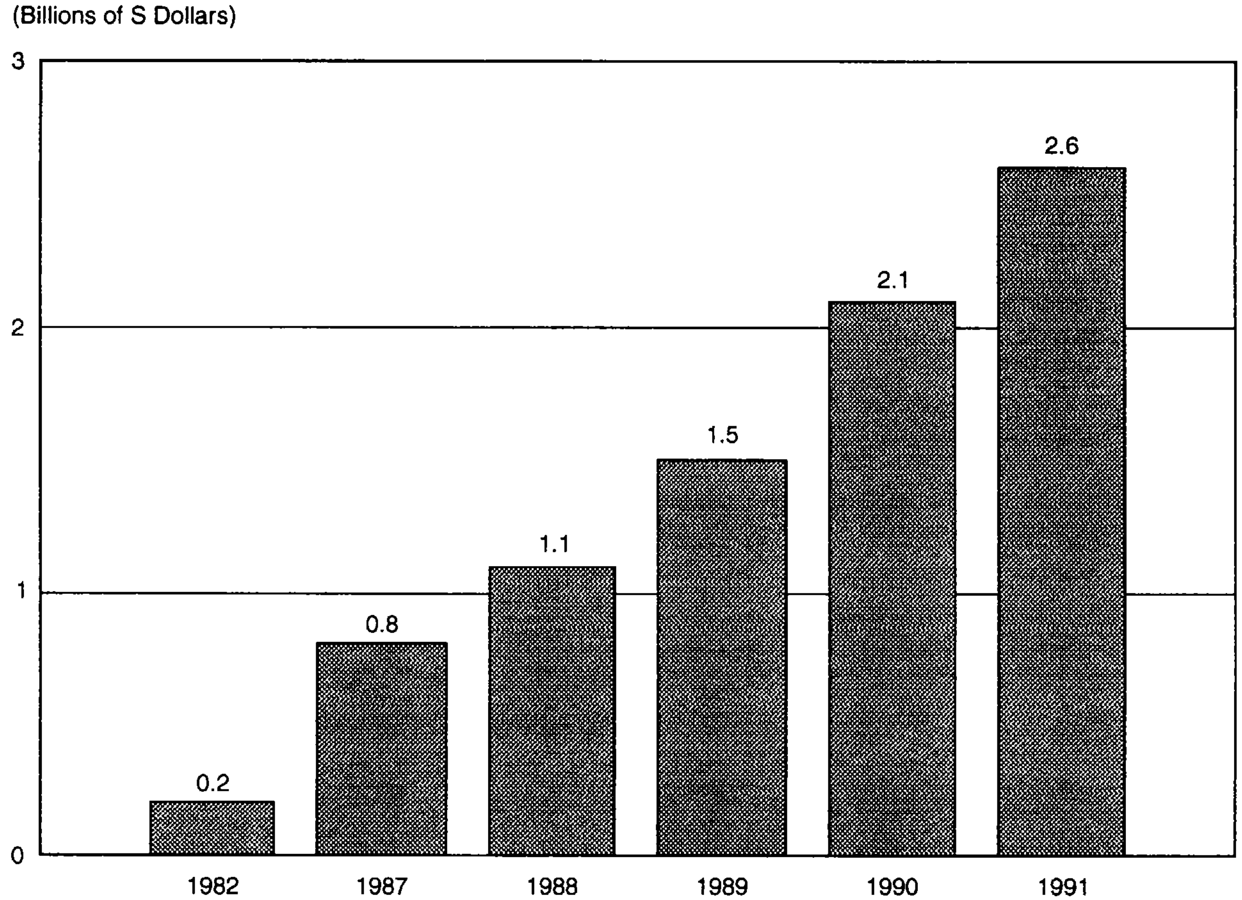
Source: Fong Loo Fern 1991.

A recent study of developing economies ranked Singapore as having the highest intensity use of IT products per capita among the economies surveyed (Dahlman 1993). It has been fueled by multinational, and financial houses spending on information systems and by public sector computerization, and it has stimulated the growth of an IT services complex providing systems and management support to local and regional institutions. The complex has been watched by government, which tracks its revenues as a way to monitor its incubation and competitiveness and to determine next steps in an evolving IT strategy.

Between 1982 and 1989 local IT industry revenue grew fivefold, from S$286 million to S$1.5 billion. Exports of software and IT services grew sevenfold, from S$50.5 million to S$357 million (National Computer Board 1991). See *figure 6.2*.

Given the consensus on creating an "intelligent island," the IT industry's 126 computer hardware manufacturers, 76 software companies, and 57 IT consultancy services -- should grow in numbers, output, and productivity in the 1990s.

Figure 6.2: Total IT Industry Revenue



Note: Includes sales of hardware (complete computer system), software and IT services.

Government's Role in Information Industry Development

1. Industrial Policy

The National Computer Board has developed a strategy to acquire, diffuse, and generate a next-generation of IT products and services that is almost without precedent. The strategy's aims and directions are firmly grounded within larger industrial policy dating to the 1960s.

As a small city-state dependent on external investment, Singapore has consistently championed the right "context" for capital accumulation. In the 1960s Singapore's economic strategy shifted away from entrepot mercantilism to the recruitment of offshore manufacturing industries. To create the proper climate for business, the government created agencies to supply core services and incentives. Within a brief period (1961-63), the Economic Development Board was established to provide foreign companies with industrial real estate and technical and financial incentives, the Public Utilities Board and Port of Singapore Authority were established to modernize electricity and shipping transport systems, and the Telecommunications Authority was created. By the late 1960s a flourishing, labor-intensive manufacturing sector led by food products, textiles and garments, wood and metal products, electronics, and oil refining contributed 18 percent of gross domestic product (GDP).

By the early 1970s, however, it was obvious to some government officials that competition from lower-cost countries in labor-intensive manufactured products and industrial-country protectionism would erode Singapore's comparative advantages. In 1972, for example, Foreign Minister Rajaratnam stated that Singapore must become a "global city" and a regional center for international trade, finance, transportation and communication (Gayle 1986).

It was not until 1979, however, that a coherent shift was declared. The 1980-90 development plan was to restructure the economy and create a "second industrial revolution" based on new knowledge-intensive products and services. In essence, the plan merely recognized reality: by 1980 Singapore's trade in "invisibles" -- telecommunications, financial and technical, business consultancy services, tourism, and air and port operations -- accounted for 1 percent of world trade in invisibles and placed Singapore third, behind only Switzerland and Norway, in per capita earnings from invisibles. The service sector accounted for two out of three jobs and two-thirds of GDP (Seow 1980).[127]

The promotion of high-technology, skill-intensive services and products has been and remains a major government strategy. In the twenty-first century, Singapore should become a

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[127] Seow, Greg. "Economic Restructuring and the Service Sector In Singapore," *Singapore Management Review*. Vol.2, No.1, January 1980. p.4.

service-oriented economy not unlike New York and London. Labor-intensive manufacturing will have moved to the hinterlands of Asia. Said the prime minister, "We should become a technopolis in the region" (Yew 1988).

To implement its strategy, the government has streamlined and upgraded central ministries and infrastructure facilities and established mutually reinforcing tax and fiscal incentives and business recruitment support programs. We will focus on their effects on the information industry.

2. *Development Policy*

IT policy has evolved consensually, with ministerial and statutory board executives acting through the Committee on National Computerization. The committee was convened in 1980 to respond to the 1980-90 development plan's call for a second industrial revolution. It brought together the heads of the Education, Trade and Industry, Finance and Defense ministries, and the executives of the Economic Development Board, Singapore Telecom, the Science Council and key universities. Its first achievement was the establishment of the National Computer Board. The Board and its committees on national IT, policy research, standards and applications and research and development (R&D) involved the private sector and outlined three objectives: computerizing the civil service, training software professionals, and building the local IT industry to expand software and services (National Computer Board 1991).

In 1986 the National Computer Board (NCB), Singapore Telecom, the Economic Development Board, and the National University of Singapore wrote a national IT plan (NITP). The plan called for accelerated use of IT to lift the economy out of deep recession. It urged expansion of civil service computerization, diffusion of IT in selected industries to raise productivity, improvement of alliances with international software firms to build engineering skills and local IT industry segments, installation of fiber optics and integrated services digital network capabilities, and promotion of IT culture through events like IT Week.

In April 1992, with the release of NCB's IT 2000 report, Singapore began, in the words of Tan Chin Nam, NCB's chairman, "the next lap, the improvement of economic competitiveness and quality of life through a service-rich multimedia information infrastructure linking businesses, schools, factories, home consumers and government agencies and people on the move." The leap to an informatized infrastructure will allow the island to:

- Organize and support electronic links among manufacturing firms for procurement, subcontracting, payments, and digital exchange of engineering designs and specifications,

- Re-engineer the trade sector and set up an integrated cargo community system, an extension of the trade information network (TradeNet) already in place, and support central warehouses that employ electronic ordering, automated route planning, generation of shipping notices, and other IT applications that can position Singapore as a regional distributor,

- Create a multimedia leisure information and reservation system that can help travel agents showcase Singapore's attractions,
- Provide easy-to-use gateways and knowbots or intelligent software systems that help users navigate databases to generate customized information, so that the national information infrastructure is truly accessible,
- Sustain a community telecomputing network to provide low-cost access to public information services twenty-four hours a day, seven days a week,
- Support "one-stop non-stop" government/business services for obtaining licenses and permits electronically,
- Cashless transactions through a common stored value card or "electronic purse" in banking and shopping,
- Telecommute more easily,
- Improve better health care through an electronic medical records system enrolling each person and allowing remote monitoring of patients (*IT Focus* 1992).

It will not be easy to implement a comprehensive IT national infrastructure. A special "open and modular software architecture" is being proposed that will enable replacement of software components with more advanced technologies without rendering the system obsolete (National Computer Board 1991). The heart of this staged approach is the creation of a high-bandwidth communication testbed called the Collabrium, which will link together IT R&D centers and showcases (intelligent offices, homes, factories, and classrooms) to test technologies before wide dissemination.

To plan and guide this massive undertaking, a national information infrastructure division of NCB was established, with an application and promotion department to promote IT diffusion in business and study specifications for IT 2000. A planning and infrastructure department is to designing a masterplan, building a network and application infrastructure, setting and promoting standards and research IT policy. The division's initial nine-month study encompassed eleven sectors of the economy -- construction, education, finance, government, health care, IT industry, manufacturing, media, publishing and information services, retail (wholesale and distribution), booking and transport -- and involved 50 NCB officers and 200 public and private senior executives.

In addition to the NCB's new resource configurations for the support of IT 2000, the Committee on National Computerization was reconfigured and renamed the National IT Committee to help implement IT 2000 programs across agencies, including the NCB, the ministries of Information and the Arts, Trade and Industry, and Finance, National University of Singapore, Singapore Broadcasting Corporation, National Science and Technology Board, and the Economic Development Board. The three phases of national IT strategy are shown in *Figure 6.3.*

These phases have led to the development of a national IT policy infrastructure (*figure 6.4*).

Figure 6.3: Evolution of IT Strategy of Singapore

Phase I: 1980-85
Government computerization

- Plan civil service computerization
- Develop government users and initials IT professional
- Develop public applications
- Develop initial base for local production (through multinationals)

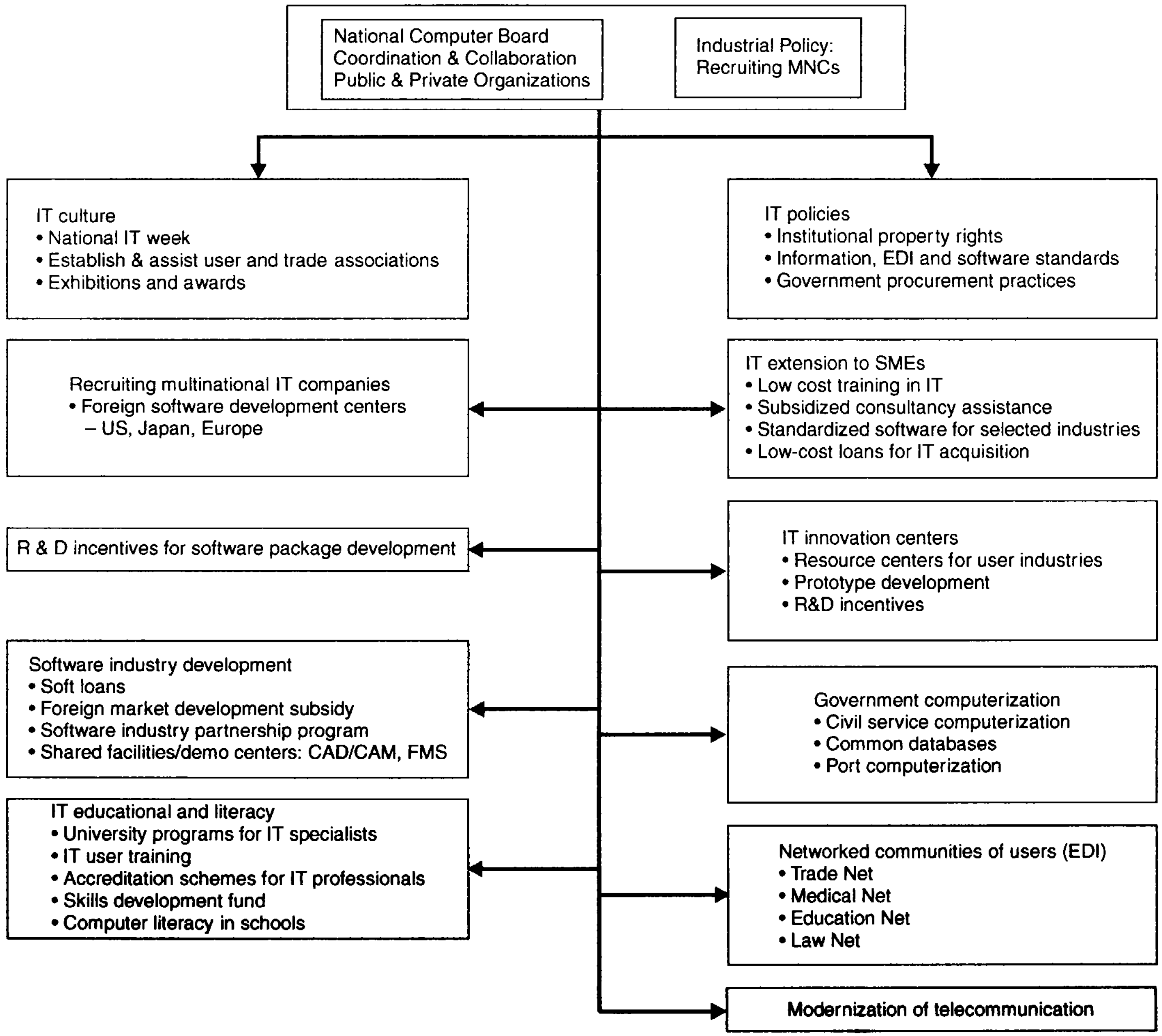
Phase II: 1986-90
National computerization

- Develop national plan
- Develop common business applications
- Develop skilled IT workface and business users
- Consultation for SMEs
- Develop production capabilities for local use

Phase II: 1986-90
Informatization of society

- Develop global plan
- Develop IT entrepreneurs, advanced users, and professionals
- Develop strategic IT applications
- Develop networked communities
- Develop international links
- Develop export capabilities in IT

Figure 6.4: IT Infrastructure



IT Diffusion

IT diffusion activities have had two central aspects: investing in government information systems and promoting private investment in and use of information systems.

1. Government Information Systems

The launch of the civil service computerization program in 1981 signaled a drive to diffuse IT across government agencies to raise productivity and, importantly, mobilize demand for IT and therefore expand the local IT industry. The number of application systems developed under this program is shown in *figure 6.5.*

Among the major applications and their effects:

- A computerized system at the Registry of Businesses has resulted in a 200 percent reduction in turn-around time to respond to correspondences for 95 percent of replies.

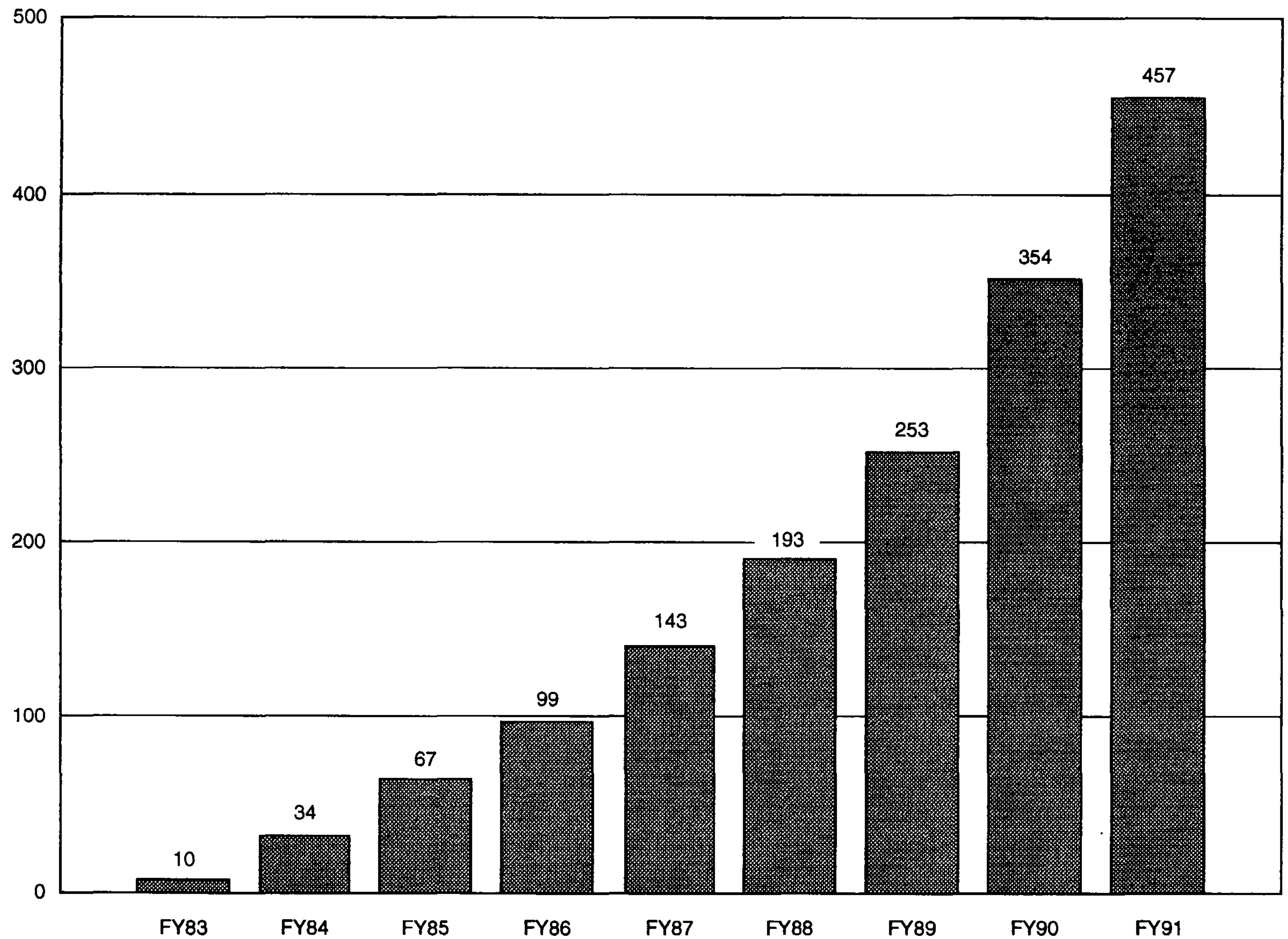
- A central personnel information system was developed for the personnel and wage information of 70,000 civil servants; its twenty-seven sub-systems can handle the entire administrative record of a civil servant from composing the letter of hire to computing pension benefits.

- A certificate of entitlement system (for certificates to operate vehicles -- open to competitive bids in space-poor Singapore) is available through 400 automatic teller machines. Electronic bidding has dropped the cost per bid from S$8 (for a bank cashier's check) to S$2 and saved the consumer travel and queuing time.

- An IDNet has linked the computer systems of thirty ministries and agencies and eased data sharing and shared software use for 2,000 users.

These applications span more than 120 mainframes and minicomputers and 10,000 workstations, with 800 information systems officers managing functions. Improvements underway include a data center to integrate mainframes in the ministries of Finance, Trade and Industry, Health, the Judiciary, and the Internal Revenue Authority. The data center's processing volume represents almost half of that of the civil service. A software center is being constructed to integrate requirements of selected ministries and achieve economies of scale (NCB 1991).

Figure 6.5: Application Systems Developed for the Civil Service (cumulative total)



Source: National Computer Board 91/92, 0.14.

A second initiative for public diffusion is Singapore Network Services, a private enterprise created in 1988 whose shares are controlled by the Trade Development Board, the Port and Civil Aviation Authorities, and Singapore Telecom. SNS is to establish specialized IT utility backbones for user-communities to facilitate economic and social transactions. Singapore Network Services manages Medinet, which allows government and industry to access health information; Lawnet, a database of statutes; Autonet for information on automation services and hardware; Biznet, for commercial databases; RedNet, a database on real estate; Schoolink, to connect all schools and the Ministry of Education; Portnet, a data interchange that links shipping lines and container ports to speed cargo clearing time from a day or more to thirty minutes (Reinfeld 1993); Orderlink, a network that allows manufacturers, suppliers, distributors and retailers -- the entire value-added chain -- to exchange data and accelerate just-in-time production and realign demand-sensitive retail stocking; and, finally, TradeNet.

TradeNet has improved government-service-user relations. Traders can complete and transmit by modem trading requests twenty-four hours a day to the Trade Development Board. Using artificial intelligence, the request is electronically routed to the right agency among the eighteen that approve trade transactions. Approvals can be transmitted to the trader within fifteen minutes of receipt of the request, customs and other fees are electronically debited from the trader's bank accounts, and permits to accelerate the clearance of goods are sent to the Port and Civil Aviation Administrations. TradeNet has helped save Singaporean trade a billion (U.S.) dollars a year in paperwork and waiting time (Sisodia 1992).

A third vehicle of IT diffusion is the targeting of key infrastructures for IT-based modernization. The modernization of the Port of Singapore is an example of the strategic application of IT (*box 6.1*). In developing the long-term plan of the Port, the contribution of IT was explicitly and systematically explored. The systematic application of IT led to dramatic productivity increases in port operations, with significant demonstration effects. It further developed a key component of an emerging national information infrastructure, in line with Singapore's vision to become a regional hub and an intelligent island.

Box 6.1
The Port of Singapore

The Port of Singapore is the busiest seaport in the world, serving more than 700 shipping lines from 80 countries. Over 38,942 ships with a total freight tonnage of 430.7 million used the Port in 1989 alone. This growth has been spurred by a reputation for efficiency that is second-to-none. The Port has the fastest "turnaround" time in the world, able to load or discharge container ships in quick order. To a great extent, such efficiencies have been the result of long term strategic investments in information technology.

Since the 1960s, the Port of Singapore Authority (PSA) has made major efforts to use IT to economize on labor and effectively manage large traffic volumes with reduced turnaround times. In 1967, PSA set up a Data Processing Department that has become a local leader in software development and professional skill formation. Between 1980 and 1989, IT personnel rose from 140 to 289 and total IT spending increased from S$2.4 million to S$22.7 million.

Applications are focused in two major areas: port construction and development; and port operations and management. In the former category, an Integrated Surveying and Hydrographic Information System was developed to provide computer-aided navigation, quality control of survey data and realtime acquisition of hydrographic data, and computerized navigation charts. In the latter category, two major IT projects CITOS (Computer Integrated Terminal Operations System) and CIMOS (Computer Integrated Marine Operations System) automate container terminal operations to maximize equipment and yard space use and apply expert systems and realtime databases in port navigation management.

The application of IT to port operations has had numerous benefits. The closing time for receiving containers was cut from eight hours to three hours; electronic data interchange links have cut the costs of preparing and processing a Shipping Note from S$12 to S$2.69; and an automated self-service cargo registration system has reduced transaction time from seven minutes to two minutes. Such systems have provided the Port of Singapore with real competitive advantages over other regional ports.

Source: Tan and Eric (1992).

A final vehicle for public sector IT diffusion has been the technological initiatives of the fifty statutory boards that run key enterprises, such as Singapore International Airlines. A good example is the Spectrum Air Cargo electronic data interchange network, developed and operated by Cargo Community Network, a subsidiary of the airline. To accommodate a five-fold increase at Changi Airport in air cargo agents and a leap in the number of airlines from 35 to 57 over the past decade, Spectrum lets cargo agents, airlines, and government agencies efficiently move electronic mail, trade declarations, billings, cargo statistics, shipment status data, space reservations and airway bills among themselves (Reinfeld 1993).

Thus, through direct government action to computerize operations of its ministries, spinoff corporations and statutory boards, Singapore is diffusing IT and creating demand for the local IT industry.

2. *Extension to the Private Sector*

A major governmental vehicle for IT extension to the private sector is the NCB's Information Technology Application Division (ITAD), which promotes IT in each industry sector, provides technical assistance for computerization and technology systems. In addition, the Economic Development Board (EDB) manages incentives for IT adoption by firms. Finally, Enterprise Promotion Centres Private Limited, a consortium of seven chambers of commerce created through EDB's initiative and funding, helps provide IT diffusion to 30,000 members (*table 6.3*).

Table 6.3: Programs to Promote IT Diffusion to Industry

Program	Scope
Small Enterprise Computerization Program (ITAD/NCB)	For enterprises seeking first computerization programs; or those firms using IT that wish to expand computerization. Client firms go through a process that includes the following: (1) Requirements assessment service (RAS). Visits the company and recommends functions for computerization, suggests configurations of hardware/software, and estimates costs and benefits. (2) Computerization assistance. The client may obtain technical assistance (National Computer Board advisor or approved consultant can conduct feasibility studies, specify requirements, evaluate hardware/software needs, and help implement), financial assistance (RAS subsidy, grants of up to 70 percent for advisor or consultant fees, grants of up to 50 percent of consultant fees for system implementation, and low-interest loan for hardware/software purchase), tax incentives (100 percent depreciation for computer hardware in the first year, 30 percent investment allowance for hardware, if eligible), and education (computerization seminars on site).
Software Quality Improvement Program (NCB)	Aims to strengthen the quality assurance practices of software companies and provides 70 percent of the cost of external consultants (up to $250,000) to review and recommend quality systems that meet international standards. Eligible companies must have at least 30 percent of shares held by local citizens or permanent residents.
IT Program for Office Workers (NCB)	Training program to equip office workers with fundamentals of word processing, spreadsheets, database management, office automation, and desktop publishing. Up to 70 percent of the course fee is reimbursed.
Small Industry Technical Assistance Scheme (SITAS)(EDB)	Provides up to 50 percent subsidy to engage advice for companies to solve technical problems, automate or computerize functions, and make management improvements.
Investment Allowance Scheme (EDB)	Tax incentive of 10 to 50 percent of investment for new machinery and equipment against taxable income.
Local Enterprise Finance Scheme (EDB)	Low-cost financing program, involving thirty-three participating banks and financial institutions, to help local enterprises establish new business, automate production, expand capacity or diversify products.
Enterprise Promotion Centres Private Limited (EPC)	EPC-Net allows, through a single connection, all local enterprises to access bulletin boards from government agencies, chambers of commerce and industry associations, search for products or services, compile trade/business statistics, and apply for government incentives and assistance.

Source: IT Directory of Singapore 1991.

3. *Highlights of Government Extension Programs*

Between 1989 and 1992, the Requirements Assessment Service conducted 442 consultancies for firms; 254 firms were undergoing computerization and $2.3 million was awarded in consultancy grants under the Small Enterprise Computerization Program. Seventy percent of participants in a recent survey said the program had been helpful. Some cases follow (IT Directory of Singapore 1991):

Apparel Industry Computerization. To help local manufacturers, NCB and six member companies of the Textile and Garments Manufacturers Association developed an integrated management system in 1989. The system, developed in modular form, automates and tracks the entire firm-level process: sales quotations, sample making and fabric testing, purchasing, production, and shipping. The seventeen applications modules contain interfaces for electronic data interchange, factory automation, and computer-aided learning.

Lea Hin Powder Manufacturers. This producer of industrial epoxy powder and polyester powder had rapid growth in 1982-87, leading to an eight fold increase in paperwork and a 25 percent increase in personnel. In 1987 Lea Hin sought help from the Small Enterprise Computerization Program to defray the costs of a computer consultant. By 1989 all software and hardware systems were in place, including manufacturing and inventory control, order entry and invoicing, accounts receivable and payable, and general ledger modules. With computers generating invoices, there are fewer errors; with computerized inventory control, stock values are instantly revised; and because paperwork has been reduced, staff can be assigned to other important areas like planning.

Microtronics. This producer of industrial controls and automation products tapped the expertise of program consultants to better manage its business. The company engaged a Coopers & Lybrand consultant with program support and designed an integrated management information system (MIS), as well as several modules of factory floor automation and thus is better able to manage its growth.

Ooi Clinic. A multi-clinic medical practice serving corporate and industrial clients, Ooi Clinic used a program consultant to develop requirements for an integrated management system, then took a loan under the small industries finance scheme to cover 80 percent of the cost of system hardware and software. The clinic installed a fully integrated system with patient records, drug dispensing and visits summary, inventory, and accounting, corporate billing and management reports. Now staff can do lab work instead of paperwork and the doctors are happy because the system can accommodate different styles of dispensing and case note-keeping.

Information Technology Development

Development activities are focused on incentives and programs to encourage IT-related R&D to stimulate new products and processes, specialized R&D institutions, and mechanisms to encourage new IT businesses.

1. Stimulating R&D

R&D incentives include:

- A product development assistance scheme, which provides a dollar-for-dollar match on new product development, can be applied to electronics products.

- A software development assistance scheme provides a 50 percent subsidy to local IT companies and to foreign/local joint ventures for designing and producing high-quality software for the global market.

- A double deduction of research and development incentives, which had applied only to manufacturing, now extends to service firms. It allows companies to deduct against taxable income twice what they spend on R&D for information and computer software services.

2. Specialized Research and Development Institutions

The National Computer Board's R&D is led by the Information Technology Institute (ITI). With 129 research engineers working in expert systems, parallel computing and neural networks, ITI has had a number of successes. Its research has led to advanced products sold internationally, such as POSE (picture-oriented software engineering), a highly advanced CASE product; Pro-Fax, a facsimile card for personal computers; Audit Pro, an expert system for auditors; and a ship planning expert system, which won the 1988 innovative application award of the American Association for Artificial Intelligence, beating the team that developed the NASA space shuttle mission control system. ITI is investigating financial data visualization, a digital crystal ball for financial managers, and multimedia applications. With forty-five projects with industrial partners in 1991-92, ITI is supporting many new products.

Another major R&D institute is GINTEC, whose efforts focus on computer-integrated manufacturing and data networking. With management and advisory boards composed of various industrial representatives, government agencies, and international experts, GINTEC has helped many companies innovate.

For example, GINTEC helped Phillips develop a software package to schedule the inputs into circuit board production. The software enabled Phillips to slice the time required to reschedule its manufacturing process from twenty-four hours to three minutes. GINTEC has designed a system for Digital Equipment to organize concurrent engineering teams and a computerized conveyor and bar-code system for Sanyo (Reinfeld 1993).

Key factors of these public R&D institutions include inviting private user and industrial suggestions for their management, engaging in cooperative research with industrial partners, specialization, and attracting and rewarding good staff.

3. Stimulating New Businesses

To encourage the formation of new businesses in IT, the government has employed several mechanisms:

Tax Incentives. "Pioneer status" can be awarded to new companies that are locally or foreign owned or represent strategic alliances between overseas and home investors. Pioneer status reduces taxes on profits by forty percent for five to ten years and has spurred creation of alliances. Two examples in telecommunications are:

- Softech 1 (Software Technology Singapore) is an alliance between a government corporation in mainland China, called China Software Technique Corporation, and a consortium of Singapore companies (Computer Processing Services Inc., Coopers and Lybrand, Far East Computers, Information Engineering Services, Singapore Computers Systems, and Systems Education Center). Softech is intended to pool Singapore's strengths in applications software with China's computer professionals and provide information services worldwide.

- Softech 2, created in 1988, a year after Softech 1, links the seven Singaporean companies in Softech 1 with Japanese companies to develop and market information technology products and services worldwide.

Venture Fund Investment. Since 1983 the Economic Development Board promoted venture capital funds that invest in emerging technologies and companies worldwide. Currently $400-500 million dollars are being invested through government-sponsored or -supported venture funds. Examples include SEAVI (South East Asia Venture Investments), which has put $50 million in thirty-six companies in Europe, Malaysia, Singapore, and the United States, mainly in communications, electronics, and computers; VIS-1, which has invested $14 million in twenty-six companies, of which the telecommunications sector accounted for 24 percent of the fund; and Transtech, which has committed 38 percent of its $27 million to telecommunications.

These tax and venture capital mechanisms are in sharp contrast to more passive approaches focused on short term job-creation through "informatization by invitation." Singapore appears likely to generate new products and services and not merely be a remote data-processing service site for large corporations, such as Ireland's.

Policies to Link Production and Use of Information Technology

The two primary forces for supporting and linking producers and users of IT have been rapid development of the communications infrastructure and specialized education and skills.

1. Communications Infrastructure

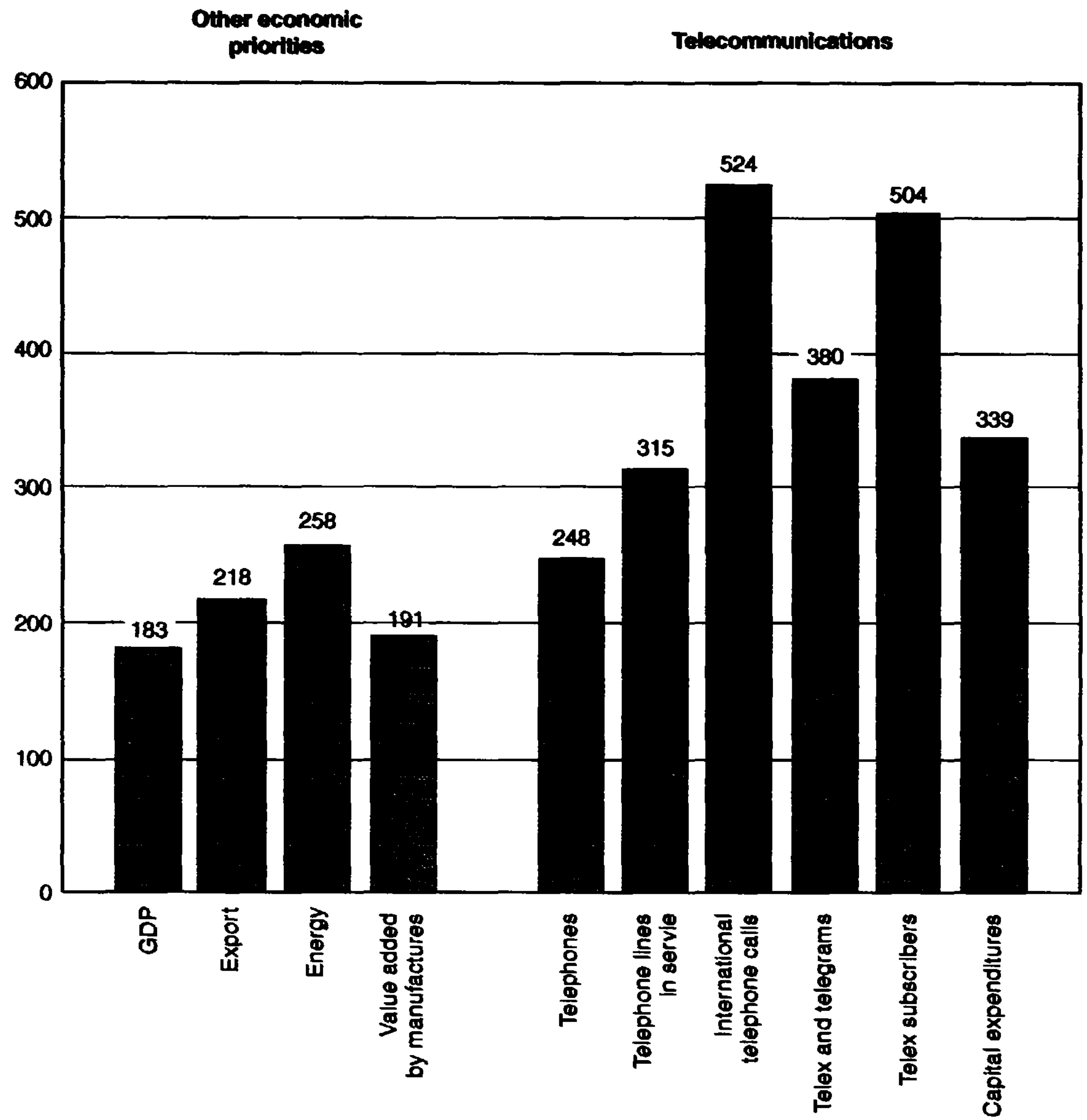
The government has committed to building a public telecommunications infrastructure, allowing the island to become a regional communications hub and setting the stage for the information society.

The history of telecommunications in Singapore began with the introduction of the telephone in 1879, three years after Alexander Graham Bell patented it. From 1881 until 1955, local telephone service was operated by the Oriental Telephone and Electric Company Ltd. under government license. In 1962, the Singapore Telecommunications Authority was established to guide the development of telecommunications and postal services.

A study by the International Telecommunication Union between 1961 and 1971 suggested that Singapore, despite its burgeoning manufacturing program and economic progress, nevertheless had a low telecommunications "utilization factor" (defined as number of telephones per $100,000 of GDP) (Saunders 1993). This simply meant that at least until 1971, Singapore's economy was not telecom-intensive.

This under-use of telecommunications advances concerned policymakers. Between 1974 and 1980 they committed to a massive investment in telecommunications infrastructure. Legislation in 1974 allowed Singapore Telecom to price services so as to self-finance expansion and arrange its resources to provide businesses the support services needed for corporate accounting and finance data systems. The expansion of telecom operations in relation to other factors highlighted in *figure 6.6.*

Figure 6.6: Telecommunications in National Economy Comparative Performance, 1974-80 (1974 = 100)



Source: World Bank 1982; Statistical Yearbook for Asia and the Pacific 1978; Telecoms Annual Report 1981-82.

By 1987 Singapore had 1.2 million private telephones and 20,000 public telephones, or 43 phones per 100 people. (This was about the same level as France's in 1981.) The growth has come not only because of a shift in industrial structure but because of an ambitious strategy begun in 1974. Its key features have been:

- Automate local exchange areas. Currently, all twenty-six national exchanges are automated.

- Provide expanded user services. Innovative services include Phone Plus, introduced in 1985, which allows abbreviated dialing, auto redial, call transfer, and three-way calling. The service had 80,000 subscribers within two years. Telefax is available by subscription to specific locations in forty-two countries or on an administration-to-administration basis to fifty-five countries. Teleconferencing enables customers to confer with nine other parties worldwide.

- Provide worldwide links to continue to diversify services. Singapore is now a regional submarine cable hub linked to Australia and Indonesia, the Philippines, Malaysia, and Thailand, and south east Asia, the Middle East and Western Europe. Apart from promoting cable links, Singapore is connected worldwide via Intelsat and the Palapa satellite system. Cable/satellite network communications development have allowed an even greater range of services, including Telpac, a packet-switching service for overseas remote computer access, and Datel, for high-speed data transmission and worldwide private networking.

- Pass on to the consumer, cost-efficiencies from new technology. In 1987, for example, international direct dialing rates to Australia, Japan, Korea, and Taiwan were reduced 17 percent, one of a series of price reductions by the Telecommunications Authority to spur demand (Ministry of Communications and Information 1987).

Through its strategy of rapid infrastructure development and user incentives, the Telecommunications Authority has laid the basis for growth of the information industry in Singapore.

2. *Education and Training*

In 1979 the Curriculum Development Institute installed three microcomputers in each school and declared its intention to procure twenty-four more for each school. In 1981 a flurry of activity unfolded. The government sponsored 260 mainframe and minicomputer installations and established major regional data-processing training center in cooperation with Japan. Its commitment led to a tenfold expansion of microcomputer purchases between 1981 and 1982, and the idea of an informatized society took hold (Gayle 1986).

The government also set up numerous schemes to train private sector workers in information technology:

- EDB began a skills development umbrella fund in 1979 to support companies to upgrade skills of their workers "in line with Singapore's restructuring program." This fund gives grants of 30 to 90 percent of training costs.

- A basic education for skills program was established in 1981 to mandate employer financing of basic mathematical and literacy education. By 1983, 9,000 workers in sixty companies were studying remedial mathematics and English.

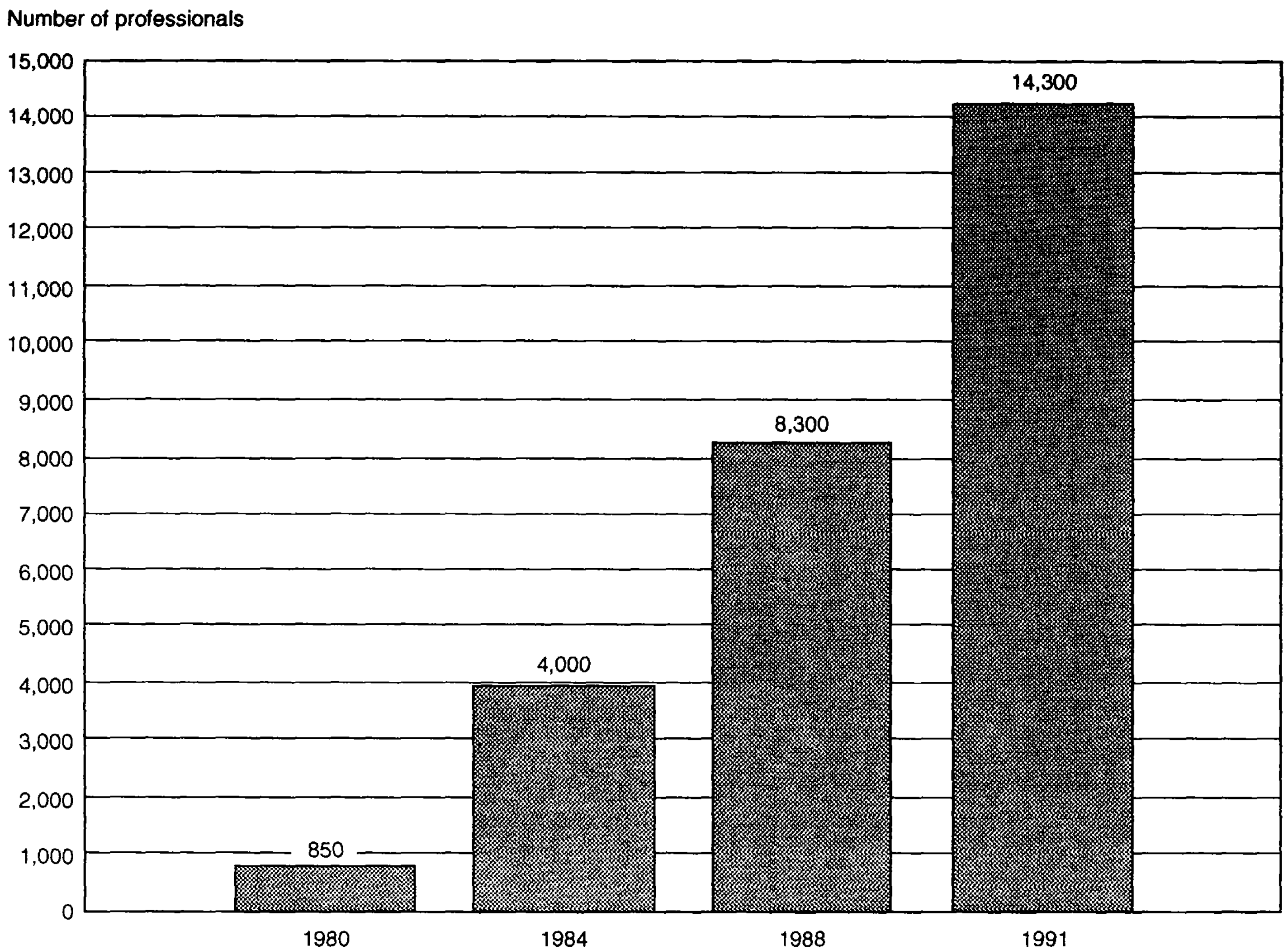
- The Initiatives in New Technologies scheme (InTech) was begun in 1984 to train professionals and scientists in optical and laser technology, engineering science, and automation and robotics.

- Universities began offering IT degrees, such as the National University of Singapore's B.S. in computational science. Singapore's polytechnics offered IT diploma courses for Ordinary Level (a British system post-high school certificate) applicants.

- Joint-venture training institutes in artificial intelligence (Japan/Singapore AI Center) and in communication technologies (Bell Labs/NCB Institute) were set up in 1991 to develop technology skills at international best-practice levels.

These programs have rapidly created a core of informatics professionals and increased the general workforce capacity to handle a variety of information-handling activities crucial to the telecommunications/informatics revolution. The rapid accumulation of IT skills in the workforce is highlighted in *figure 6.7.*

Figure 6.7: IT. Professionals



Source: National Computer Board.

A pool of 35,000 IT professionals will be needed by 2000. A rise in IT study in tertiary institutions and continued attraction of IT professionals from abroad is expected to help fill the projected shortfall.

The Private Sector's Role in Information Industry Development

Singapore's ability to attract foreign investment and retain multinational corporations has been a cornerstone of its industrial development. More than 650 multinationals are producing or operating out of Singapore, and more than 40 percent of foreign investment is reinvestment from existing firms, indicating the stability of the island's business relationships (Wells and Wint 1990).

Reinvestment has been a key to the steady climb to IT mastery and higher productivity -- a process often described as "strategic intent." At the industrial sector level, strategic intent can be seen in the staged adoption by firms of key IT innovations (*table 6.4*).

Table 6.4: The Corporate Climb Up the Information Technology Ladder

Application	Adoption
Batch processing in business environment	1962
On-line systems (banks and airlines)	1975
MIS in all sectors	1975
Word processing	1981
End-user computing with personal computers and terminals to mainframe systems	1984
Decision support systems	1984
Computer-aided design/manufacturing	1984
Medicine and health care	1984
Office automation systems	1985
Robotics	1986
Expert systems in business	1987

Source: Raman 1990.

NCB's 1992 IT usage survey found that computerization for companies with ten or more employees reached 84 percent, up from 68 percent in 1989. The main users are the financial sector, with one-fourth of the computer base, followed by computer vendors, manufacturers, and commerce/trading firms. Even locally owned sectors have attained high levels of computerization (*table 6.5*).

Table 6.5: IT Adoption by Locally-owned Sectors

Sector	Companies Using Computers (percent)
Retailers (ten or more employees)	**64**
Wholesalers (ten or more employees)	**76**
Advertising agencies	**89**
Survey and real estate	**94**

Source: NCB Yearbook 1991.

A few IT company cases demonstrate strategic intent. Connor's disk drive production in Singapore began in the 1980s as a simple assembly operation; by the late 1980s, it had become the company's world manufacturing center and a seedbed for process-technologies that were sent to plants in Scotland and Malaysia; AT&T's Singapore operation has progressed from offshore consumer product assembly to its world design and manufacturing center for cordless telephones (Hobday 1993; Magaziner 1990, *NewsWeek* 1993). Texas Instrument's integrated circuit production on the island began as an unskilled, thousand-person, manual wire-connecting assembly line, progressed to an automatic production line run by skilled technicians, and has become a $330 million silicon water fabrication joint venture with the government to guarantee a supply of application specific integrated circuits (ASICs) to Singapore's information industry. It is similar to the Phillips/Taiwan government venture described elsewhere. Apple is another example of corporate strategic intent (*box 6.2*).

Box 6.2
Apple's Climb Up the Technology Ladder

In 1980 Apple decided to install a simple factory in Singapore to assemble computer circuit boards, with automatic component insertion machines attended by low-skilled technicians. The factory was seen as a way to gain a foothold in regional markets and little else. With the help of the Economic Development Board, initial production of finished boards began less than two months after startup.

Production ran so smoothly, that senior management decided to go beyond building boards to manufacture computers. This meant upgrading and reconfiguring the assembly line and the workers. Apple paid for workers to attend government institutes for training in process-control and electronics. The production process was redefined and production began. Soon senior management became aware that the trained workers were not just running the line but innovating and improving the process. To overcome one problem -- boards suddenly falling out in the middle of manufacturing -- workers developed a unique automated board test system for the Apple II.

In 1985 the plant adopted just-in-time manufacturing, cutting inventories in half within three months and resulting in 60 percent of all parts arriving and departing in finished computers the same day. In early 1986 John Sculley, then Apple's president, came to Singapore to announce the construction of a $25 million world-class manufacturing facility for computer components.

Source: Magaziner 1990.

Local startup IT firms show signs of moving upstream. Two of them, CSA Holdings and Singapore Computer Systems, went public and were listed on the Singapore stock exchange, and both were oversubscribed. Elsewhere, Rahmonic Resources, a pioneer status firm in 1988, today produces Cepstra, an imaging and parallel processing system used by Apple for PC board inspection and others. Strategic Information Systems, which grew four-fold in one year, produces the Pacer engineering management information systems for oil, gas, and petrochemical industry clients in Asia, the Middle East, and Europe; and Business Computers Ltd. (BCL) developed an advanced hotel management system that allows guests to use interactive television monitors to buy concert tickets and request reservations.

Thus both large-scale foreign firms and small local pioneer companies show increasing technological mastery. It is firms' long-term, committed, learning curve that will drive IT industry expansion in Singapore.

Conclusion

The Singaporean model of IT development is dynamic and proactive and has evolved largely in response to perceived national weaknesses. Lacking a large indigenous entrepreneurial or technical pool capable of capturing and adding value to technologies from abroad, Singapore pioneered an industrial promotion infrastructure to attract multinational production activities and to upgrade its technical workforce and local enterprises. Quantitative and anecdotal evidence suggests that high levels of corporate reinvestment and inward technology transfer have indeed taken place.

Corporate willingness to undertake such transfers has certainly been positively influenced by Singapore's rigorous attitude toward intellectual property protection, as expressed by a 1987 revision of its copyright law. The revision expanded its scope and increased penalties (Wallerstein 1993). A high comfort level of foreign companies operating in Singapore came through in a 1991 survey of major U.S. companies concerning their attitudes about technology transfer toward sixteen countries *(Table 6.6)*.

Table 6.6: Perceptions of Intellectual Property Protection

Countries	Too weak to permit licensing of newest or most effective technology	Too weak to permit transfer to subsidiaries of newest or most effective technology
Brazil	39	28
Indonesia	31	23
India	44	43
Mexico	28	20
Philippines	26	24
South Korea	29	26
Taiwan	37	27
Singapore	20	14

Note: Based on a survey of major U.S. firms.
Source: Mansfield (1991).

The findings reinforce the view that Singapore has created a sound business climate to nurture the inward transfer of advanced information industry activities by multinationals.

Government planners, however, are well aware of the limits of this approach to technology acquisition. They have realized that multinationals will always restrict to home markets the most advanced proprietary R&D and technology. Such behavior can constrain technology development in Singapore and keep local companies behind industry frontiers. Singapore lacks Taiwan's huge pool of expatriate scientists and technologists in the United States and Canada. It has had to circumvent restrictions on acquiring the most advanced technologies through skillful use of its foreign reserves (some $46 billion in 1993) to invest in high-tech companies and venture funds, so as to gain windows on successive generations of technologies and to select which technologies to bring to Singapore. But this approach has likewise had limitations, largely related to historically deficient local technology capture and improvement mechanisms. Singapore's R&D funding as a percentage of gross national product (GNP) doubled between 1981 and 1985 (to 0.6 percent), yet still represented less than half of South Korea's R&D expenditure as percentage of GNP; and Singapore had only 20 scientists and engineers per 10,000 labor force, compared with 33 in Taiwan and 70 in Japan (1985). With these limitations, one can appreciate Singapore's intensive cultivation of information industry workforce, companies, and research centers, and the monumental tasks that lie ahead.

It is certainly useful to keep a historical perspective when reviewing the intelligent island concept. Unlike Taiwan, Singapore favors local ownership of IT infrastructure rather than of the means of production. Through Singapore Telecom, and the like, local value-added is in technology development activities attendant to infrastructure creation. But the creation of the information infrastructure will depend on attracting leading-edge service and technology providers and getting them to share frontier technologies, often before they are even tried in Western markets. As NCB officials state, "We don't want technologies already being tested in the United States by big providers like AT&T. We are trying to down-focus to something more unique, and make the Collabrium information infrastructure testbed a showcase."[128] Clearly, even in local value-added and technology development, foreign firms will be significant.

It might even be argued that the intelligent island scheme, with its incremental implementation, modular or open systems approach, geographic restriction in early stages to the fiber-optic wiring of the central business district, and modest testbed network of smaller factories and classrooms is a powerful promotional tool. It will attract multinationals and high-tech companies to compete for development contracts, infrastructure software installations, and hardware upgrades, and to field-test their latest technologies for export and dissemination to other information infrastructure projects throughout Asia. Singapore has an international network of university and industry research advisors, corporate information system and financial management executives, and access (through EDB joint ventures) to technology investment houses, such as Advent International. The concept of a vanguard information infrastructure might have less to do with serving domestic infrastructure needs than with offering up a powerful organizing tool to such

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[128] Author discussions with NCB officials, December, 1993.

foreigners to lure technology. Up and down the value chain, from new carrier network software and data transmission/compression technologies, to user-friendly multimedia applications for school and home--Singapore will try to internalize the production of innovative product lines from abroad and develop wholly new regional export platforms for the information age.

In essence, the information infrastructure project is a message intended for the region, the world, and key corporate and institutional decision-makers: "We are the vanguard, the testbed."

Whether Singapore will live up to the expectations created by its pronouncements remains to be seen. Its local entrepreneurial and research base -- though much improved -- may still be thin. Competition may be too great. Taiwan is making a determined effort to become a regional IT testbed, as its recent deals with Motorola and AT&T signify. China also is using its enormous market to try to do the same. Hong Kong has better telecommunications links and a longer history of gateway activities in Asia and, despite its laissez-faire style, might be poised for a more formal IT hub role under the direction of China as its anointed capitalist catalyst for IT trade dealings. All these initiatives surely pose a threat to Singapore's reach for IT leadership, despite the comfort the island engenders with international technology companies. Another restraining force on Singapore's ambitions could be the real logistical and financial difficulties associated with infrastructure development and the ever-present threat that the vital technology needed to make the infrastructure work could be withheld by suppliers, thus delaying or blocking development.

Yet, Singapore is a growing regional industrial financier and production system coordinator. The government is spending $3 billion on industrial parks and tourism facilities in Indonesia, and $200 million to develop a 27-square mile industrial site in Suzhou, 50 miles from Shanghai (*BusinessWeek* 1993). With the crucial role IT will play in coordinating all aspects of its regional system, Singapore has many compelling reasons to accept the risks and reach for leadership as an IT user.

CHAPTER 7: CONCLUSIONS: NATIONAL STRATEGIES FOR EXPLOITING INFORMATICS

Three Perspectives on IT

Japan and the East Asian NICs studied here recognized IT as a strategic industry, a generic technology and an advanced infrastructure.

1. As a Strategic Industry

East Asian countries, except for Hong Kong, have targeted the electronics industry for promotion and technology capability acquisition. They have viewed IT as a strategic industry, continuously developing more technology-intensive segments -- computers and telecommunications. Over a decade, the industry's growth and competitiveness have increased dramatically.

Electronics has been considered strategic for several reasons. Changes in microelectronics and software and associated IT technologies have transformed the economics of computing and communications and led to new opportunities for products and services. Consumer electronics provided a suitable entry point for late industrializers to exploit their low-wage advantage, enabling them to the fastest growing and largest global industry.

At any time there are few high-value-added, fast-growing global industries. Missing out on them can mean losing potential long-term growth and higher living standards. IT is the latest example.

IT should be measured not only by its contribution to exports or balance of payments. As Laura Tyson has argued, "A dollar's worth of shoes may have the same effect on the trade balance as a dollar's worth of computers. But the two do not have the same effect on employment, wages, labor skills, productivity and research -- all major determinants of long term economic health."[129](Tyson 1994.) Moreover, because technology-intensive industries provide a disproportionate share of the nation's R&D, they presumably generate positive externalities for the rest of the economy.[130] The IT industry also offers linkage externalities -- locally adapted services, lower costs, higher quality inputs -- for downstream user industries. Certain segments of the IT industry, such as application software and application-specific integrated circuits, require intensive adaptation and shared learning between producers and users, and production and

129 Tyson 1992.

130 According to new growth theory, technological change and innovation associated with knowledge intensive industries are more important determinants of long-run growth than saving (Grossman and Helpman, 1991 and Romer 1986).

technological capabilities in such segments may enable other industries and services to become advanced users of this generic technology. Thus the assumption that "it doesn't make any difference whether a country makes potato chips or computers chips"[131] is misleading.

Japan, Taiwan, Korea and Singapore have recognized and demonstrated the importance of the IT industry.[132] Within a decade or so, each of these countries became one of the largest global producers of key segments of the IT industry. To realize its vision, each orchestrated technological learning and built competitive advantages high value-added industries.

2. *As a GenericTechnology*

The case studies also indicate that IT is a generic pervasive technology. In Japan micro electronics were incorporated into capital and durable goods such as machine tools and cars, enhancing product quality and performance. IT was incorporated in production processes, cutting costs and response time. IT contributed to established Japanese practices of continuous improvement and "lean production."[133] It was also guided by an appreciation of the strategic significance of building new competencies in IT use among key industries and small enterprises.

Japan's lean production practices, pioneered by Toyota, have spread to the Asian NICs, and even to U.S. and European companies. These practices enhance flexibility, reduce inventory and other costs, customize products, and shorten product development time, and still, maintain the economies of mass production. Lean production requires intensive coordination along the supply chain, (Womack 1991.) Japan and subsequently other countries have shown that lean production practices should come before IT-based process automation. Their experience is embodied in the process reengineering that is sweeping industries and services in the U.S., Europe and Japan.

The diffusion of IT as a generic technology among the Asian NICs supports the new organizational imperatives of just-in-time, total quality control, continuous process improvement (*Kaizen*), and other features of lean production (Mody 1992). NICs have been quick to recognize these managerial innovations in adopting IT. The NICs' close ties to Japanese firms have helped them adopt best-practices in IT.

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131 Statement is attributed to Michael J. Boskin, former chairman of US Council of Economic Advisors.

132 Tyson's in-depth study of the semiconductor segment that "the semiconductor industry, wherever it has developed, has been an explicit target of industrial policy--whether in the guise of military policy in the United States or in the guise of commercial policy elsewhere in the world." Tyson, op. cit., p.85.

133 Lean production was first coined by the MIT study of the automobile industry. See Womack, Johnes and Ross, *The Machine that Changed the World*, Harper Perennial, 1991.

Other forces have driven diffusion in these economies, including subcontracting to SMEs. IT enhances alliances among SMEs, vertical links to domestic and foreign contractors, and access to information and other external resources. The desire to exploit economies of scale has encouraged diffusion, and it is behind Singapore initiatives such as TradeNet and government-sponsored software development for the garment industry. Similarly, Taiwan invested in the diffusion of IT to SMEs. In Japan local governments, large contractors, and industry associations have targeted IT for diffusion to SMEs. In Hong Kong, despite a laisse fair posture, IT adoption (CAD and EDI) has been recognized, as essential to the apparel industry.

Singapore and Hong Kong have demonstrated IT in modernizing services and IT-intensive services in technology transfer.[134] The literature of technology transfer has concerned manufacturing and ignored services. Yet services have become the dominant sector of many economies. Business services, in particular, have changed dramatically, because of IT innovations. They also have become a source of competitiveness in manufacturing, as competitiveness is increasingly based on flexibility and product innovation. Singapore's vision as an intelligent island and a regional hub is based on exploiting IT as a generic technology for services.

3. As an Advanced Infrastructure

Japan and Asian NICs have used IT to modernize traditional infrastructures, such as transportation and communications, and build a national information infrastructure. A generation of intelligent infrastructure has emerged, to meet a wide array of specific user needs. Industries and services increasingly want to use such infrastructures to produce higher value-added services and products with ever shorter development and production cycles and to serve markets that are demanding in price, quality and response. Examples from the NICs include EDI applied to clearance at airports and seaports (Singapore's TradeNet and PortNet and Taiwan's TradeVan), intelligent warehousing (Hong Kong, Taiwan), and EDI applied to procurement and production systems for industry transactions (Singapore's OrderLink and Hong Kong's EasyLink). The increasing productivity and responsiveness of Singapore's infrastructure provided the model for Hong Kong and Taiwan. Compared to Singapore, however, Hong Kong's advanced infrastructure is more supportive of finance and trade services than manufacturing.

The NICs have used IT to attract global industries and services. Singapore, Hong Kong and Taiwan, are developing advanced infrastructures to become "intelligent" and gateways to the rest of East Asia. They aim to coordinate regional inputs within the emerging global

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[134] The focus here is on producer services (such as design, logistics, information, management counselling, accounting, software support) and public services (such as banking, transportation, education, health, government administration), where IT is transforming both products and processes.

network of production and distribution. Intelligent infrastructures have helped attract foreign investment and supported regional and international strategic alliances.

As a national information infrastructure, informatics is the life blood of a modern economy. It reduces the transaction costs of monitoring and coordination.[135] Efficiency in a competitive economy depends on access to information which improves decision-making at all levels. It aids effective public policy, accountability and governance. It is key to organizing and learning. It reduces the time needed to shift resources to higher productivity and market opportunities.

The Asian NICs have used IT to adapt to market conditions. And since the 1980s they have exploited IT to build an advanced information infrastructure. Their development is information-based. Information practices are embedded in institutions and social processes, including agencies specialized in market information and brokerage services, such as the general trading companies of Japan and Korea. Group-directed quest for information and knowledge is a key strength of Japanese management.[136] These practices are also reflected in the information (social) structure of firms and the organization of work: flexibility in job duties, teamwork, horizontal communication, job rotation, quality circles, just-in-time delivery, and dense contractor-supplier networks.[137] Recently, the NICs have built on these strengths by using IT to modernize information-based transactions and services.

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[135] According to the New Institutional Economics, economic performance is the result of the costs of economic production and exchange. Production costs include transformation and transaction costs. Transformation costs are the physical costs of combining inputs to produce output and depends on the technology in society. The **transaction costs** of production are the indivisible **costs of production**. They **include**: (1) **monitoring labor**; (2) **coordinating** the physical factors of production; (3) **monitoring the use of the physical and financial capital** of the residual claimant. The transaction costs of production are the result of the institutions in a society and technology. Technology affects the transaction costs of production in a variety of ways. Technology reduces the direct costs of monitoring by better surveillance, and by reducing the need to monitor machines, and standardizing the production process. In addition, technology influences the **transaction costs of coordinating** production; no doubt the computer is largely responsible for the observed horizontal integration in commercial banking in the past decade.

[136] As Vogel puts it "If any single factor explains Japanese success, it is the group-directed quest for knowledge. In virtually every important organization the national government to individual private firms, from cities to villages, devoted leaders worry about the future of their organizations, and to these leaders, nothing is more important than the information and knowledge that the organizations might one day need. When Daniel Bell, Peter Drucher, and others hailed the coming of the post industrial society in which knowledge replaced capital as society's most important resource, this new conception became a great rage in Japan's leading circles. But these leading circles were merely articulating the latest formulation of what had already become conventional Japanese wisdom, the supreme importance of the pursuit of knowledge." Japan as No. 1, Harvard University Press, 1979.

[137] Aoki, Masahiko, *Information, Incentives and Bargaining in the Japanese Economy*, Cambridge University Press, 1988.

The NICs have used informatics to modernize public administration, reduce transactions costs between business and government, and improve the delivery of public services. Singapore's strategy is perhaps the most coherent and ambitious in this regard. It has included a phased program of civil service computerization. It also has involved identifying strategic applications to improve economic and social transactions, promote "one-stop" service, and establish information "utilities" for user communities such as health, education, law, and commerce. Japan's IT applications in the public emphasize developing databases for public administration. Korea, Taiwan and, to a lesser extent, Hong Kong also have promoted public-sector computerization, giving priority to reducing transaction costs to businesses, such as registration, tax administration, and customs clearance. These countries have invested in IT applications (networks, databases) in support of public R&D institutes, educational institutions, libraries, and information dissemination.

The ongoing knowledge revolution; is dividing the world into rich fast-moving economies that use information and poor slow-moving economies that do not. Information is leveraged by an infrastructure that, organizes and shares it. IT innovations enable individuals and countries to tap growing knowledge at filling costs. The IT revolution concerns not material or physical attributes such as energy or motion, but information and thinking. It allows researchers to collaborate globally, to process massive amounts of information, and to simulate complex systems. As an "informing" technology, IT is altering the world, to an extent not experienced since Gutenberg invented the printing press. These considerations inspired Japan to promote the "information society" and more recently the "advanced information infrastructure society" and the "intellectually creative society of the 21st century."[138] They also have inspired Singapore's vision of the "intelligent island."

Informatics is used to capture, organize and share local information, and to blend local and global knowledge in a dynamic learning process. Information becomes a strategic asset only when its is relevant and timely for users. Community knowledge exploited for development and grassroots learning. But local knowledge left in isolation is static. Japan and, to a lesser extent, the NICs have integrated modern and traditional systems of information and communication and sought access to the world's information without ignoring local information resources. They have viewed informatics as a force for globalizing their communities. But they also have recognized that a national information infrastructure must be connected to community networks, allowing broad participation. In Japan top-down approaches to NII are increasingly complemented by initiatives and experiments or carried out by local governments and non-

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[138] The term "informatization" was coined by the Japanese in the 1960's and has been used as a guiding slogan for local and national public and industrial policies for more than three decades. In the 1980s, concerned with excessive concentration of economic and human resources in Tokyo metropolitan area, many policy initiatives began to promote "informatization" in local areas.

government organizations. Increasingly, the information infrastructure is a multi-layered infrastructure, involving communities, regions, and nations.

National Strategic Management

The performance of Japan and the NICs in informatics suggests that strategy is as important at the national and industry levels as it is at the corporate level. The public and private sectors have developed a consensus on vision and goals, and taken advantage of market opportunities and technological changes. The NICs have used diverse strategies to build their IT industries, which in turn have been used to modernize other industries and infrastructures. But they used similar frameworks, processes, and institutions to formulate and implement strategies. These common characteristics we label "consensual strategic management."

Competition in an ongoing technological revolution calls for new concepts and principles beyond those offered by the traditional national comparative advantage.[139] The informatics industry can lead the growth and technological transformation of whole economies. It also is characterized by intense global competition, fast technological change, complementarities and links, and uncertainties. These characteristics require, exact timing for market entry, anticipation of core capabilities, continuous technology learning, and development of supporting institutions and infrastructures. As a technology and an infrastructure, IT also demands experimentation, new skills, and managerial practices, coordination, and support institutions. These considerations, in turn, call for new strategic behavior, policy instruments, and competencies.

Consensual strategic management, as practiced by Japan and Asian NICs has five aspects:

- developing shared vision,
- maintaining outward orientation,
- building core competencies (anticipating and sustaining investment in capabilities, guided by strategic intent)
- promoting strategic planning and learning at all levels, and
- focusing and coordinating public-private efforts.

[139] Mody, in "Alternative Strategies for Developing Information Industries", suggests some of the reasons why conventional trade theory is of limited help in addressing the complex considerations arising from the nature of the information industry, in Wellenius (1993).

1. Shared Vision

Japan, Korea, Taiwan, and Singapore developed national visions that anticipated informatics as an industry, technology, and social and economic infrastructure. Japan's MITI has developed successive strategies since the mid-1950s that set the direction of economic development and the contribution expected from individual sectors. The process of developing these visions and preparing the plans provided a public forum for identifying needs and priorities. It also enabled the private sector to consider its problems and aspirations in a broader perspective. Rather than drawing blueprints, MITI set policies and guided industry toward its vision, and sought the opinions of expert groups and businesses. As Japanese corporations have matured and of the economy has grown complex, the process of reaching consensus has become more demanding. But the effort has mobilized resources for and helped industry adjust to the energy shocks of the 1970s and to the informatics revolution.

MITI's recent Program for advanced information infrastructure is a case in point.[140] It articulates a view of the economy in which the principal means of generating economic value has shifted from manufacturing to intellect; diversification and enhanced productivity of intellectual activities are essential to further economic development, and to confronting emerging issues such as global environmental impact. The program outlines the directions in which an advanced information society should move. It builds on national discussions of the need for an advanced information society and describes short- and medium-term prospects for developing IT applications for government, industry, and households. It advocates deregulation in the information and communication sectors. It draws on the recent initiatives of the U.S. and Europe to outline national applications, testbeds, and policy priorities.

In the country cases, such national visions and strategic plans drew on the views of industrial associations, research institutes, and other bodies outside the government.

Shared visions create awareness of future possibilities and promote long-term development. They build credibility, predictability and commitment. They clarify government intentions in promoting priority industries and complementary infrastructures and capabilities. They help focus private sector efforts and foster long-term investments in technological capability and infrastructure development. These visions are translated into corporate behavior through incentives, training, cooperative research, directed credit, and support institutions.

Such visions are also influential at the corporate level. Japan's NEC articulated a corporate vision that anticipated the convergence of computing and communications technologies

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140 Ministry of International Trade and Industry, "Program for Advanced Information Infrastructure", May 1994, Japan. Earlier visions were intended to inspire a paradigm shift towards knowledge-intensive industrial structure.

and built core competencies to exploit it. Korea's Samsung, Hyundai, Goldstar, and Daewoo invested in design and production, overcoming entry and scale barriers and establishing the country's position as a major producer in the microelectronics. Singapore's Port Authority envisaged the role of IT in transforming its operations and accordingly developed a strategy, introduced small systems to gain experience and understand the potential of IT, then building some of the most advanced applications to make Singapore's port the most productive in the world.

"Seeing the future first" is likely to be critical to competitiveness as the NICs come closer technological frontiers.[141] As followers, NICs have relied on industrial nations to anticipate the evolution of industries and technologies, and on foreign contractors and multinationals meet customer needs. Japan led the way in having corporate management take a long-term view of their industry and of trends in technology, demographics, regulations, lifestyles, and natural resources. Such foresight is essential to create products and capabilities beyond those meeting customer needs already served. Management's focus on the future is supported by an array of tools: market research, competitor analysis, scenario planning and technology forecasting. The quest for industry foresight may explain the practice of Japan, and more recently of Korea and Taiwan, to establish "listening posts" to scan technology and monitor the demands of sophisticated customers and markets.

2. *Outward Orientation*

The desire to "catch up" and export, helped shape the external outlook of policymakers and business managers in Japan and the NICs. Their orientation has been most pronounced in dynamic industries like electronics. It was also reflected in the use of IT as a tool to link local producers to export markets, and to build advanced infrastructures to attract multinationals, enabling the NICs to become regional hubs for global industries and services. Their orientation helped link national and corporate visions to the practical realities of the marketplace, the demands of changing technologies, the contributions of collaborators, and the challenges of competitors.

The case studies the variety of instruments available to develop and support this external orientation. At the national level, this included the creation of technology watch and market intelligence capabilities through specialized R&D institutes and general trading companies. Focus on export markets helped achieve economies of scale and led to dynamic learning. Export incentives and institutions not only motivated firms to meet the exacting quality and responsiveness requirements of foreign markets, but also to develop information channels on international best practices and technology trends. The NICs also attracted international

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[141] For an insightful view of the crucial need for top management to develop a long-term view of their industry see "Seeing the Future First", by Hammel and Prahalad, *Fortune*, Sept. 5, 1994 (pp. 64-70).

corporations with the intent to access foreign markets and technologies and accelerate their own learning processes. Links with multinationals varied over time, in line with changing local capabilities and bargaining positions. The Korean conglomerates are now in a stronger bargaining position than most firms in other NICs and negotiate much better technology transfer deals. Government institutions informed local partners of new technology sources and possibilities and at times influenced the terms of transfer, particularly for SMEs. This was necessary, given information market failures and the bargaining power and information asymmetry in dealing with IT multinationals. Most important was government's investments in science and industrial parks (Taiwan, Singapore, Hong Kong), technical education and training, and technology support institutions. Singapore devised some of the most innovative mechanisms to promote IT exploitation through worldwide and long-term partnerships with multinationals.

Although Japan and the NICs have not copied each other's strategies and institutions, exchange of ideas and openness to external best practices have been important. Private-sector entrepreneurs were exposed to the technology and business strategies and best practices of their neighbors. Knowledge of Japan and access to Japanese institutions were particularly important for Korea and Taiwan. Korea created Japanese-like institutions including, *Chaebols* (after the *Zaibatsu*), general trading companies (the *Sogo Shosha*), the Economic Development Board (after MITI), and public research institutions. The IT revolution has enhanced the ability of these nations to learn from each other.

The external orientation of corporations has been manifested in various ways. The IT industry and its users challenged competitors to meet international best practices in IT production and use. Their study of the competition focused learning, and elevated performance. They developed rich networks and alliances within their family of companies, suppliers, and customers, and with joint research associations and national R&D institutions. These links helped to reduce costs, increase flexibility, set standards, and diffuse technology. The strength of these links are seen in the pervasiveness of industrial clusters, just-in-time procurement and cooperative mechanisms. Corporate networks enable the nimble orchestration of regional IT production and distribution, particularly in Thailand, Malaysia, Indonesia, and China. As they approach technology frontiers, these corporations are building strategic alliances or acquiring specialized high-technology companies overseas to complement their core competencies.

These firms are participants in a new paradigm of organizing business. The product unit is flatter and team-focused, allowing information to flow quickly among the ranks. Management's perception of the firm's boundaries has expanded, encouraging alliances and information flow between the firm and its suppliers and clients

3. Core Competencies and Strategic Intent

The case studies illustrate how late industrializers have exploited the emergence of a new techno-economic paradigm. IT requires new skills, and organizational patterns. The IT revolution is causing many dislocations and uncertainties among firms and industrial economies, creating opportunities for entrants to challenge market leaders. The Asian industrializers have sought to move into higher-value industries, adopting IT to production to meet the faster and higher standards of quality and reliability demanded by OECD markets, and "leap-frogging" technologies in modernizing (digitizing) their telecommunications infrastructure.

The capacity to leap-frog however is often underestimated.[142] Pavitt (1984) documented this case for the electronics industry in the U.K., and Hobday (1992) did so for Singapore. Singapore relied on multinational subsidiaries' access to parents' resources for IT production capabilities, but the subsidiaries had engaged in incremental, painstaking, learning. Local firms then learned took advantage of imitation, OEM and hiring from multinationals.[143] They developed capabilities other than IT: pre-electronic technologies (precision engineering, manufacturing skills, and electro-mechanical interfacing), management, marketing and after-sales services. Firms did not leap-frog but progressed in response to market growth, the supply of engineers, and improved infrastructure. Singapore's route toward IT suggests cumulative learning rather than a leap from one paradigm (mechanical) to another (electronics).

Leap-frogging may be easier for IT as a generic technology and information infrastructure than as an industry. But even here developing complementary inputs and skills is necessary. Experience of the NICs and industrial countries suggest that benefitting from IT use depends on intangibles process reengineering, managerial quality and leadership, flexible and multi-skilled labor, and institutional learning and experimentation. In telecommunications infrastructure, the NICs have adopted digital, electronics-based systems faster than advanced countries have. Less committed to older technologies and suppliers, they leaped to advanced electronics. But successes like Korea's, basic telecommunications were rapidly upgraded, growth was imbalanced because of a shortage of application software capabilities.

Except Hong Kong, each of the countries discussed here set a strategy to master core technological capabilities and become competitive in the IT industry. They pursued diverse

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142 Soete (1985) first put forward the leap-frogging view. Perez and Soete (1988) argue that "windows of opportunity" arise at the early stages of diffusion of a new techno-economic paradigm.

143 OEM (original equipment manufacture) is specific form of sub-contracting whereby a foreign multinational or buyer provides the detailed technical specification to the latecomer firm which then manufactures the product. The multinational then markets the product under its own brand name using its own distribution channels. OEM usually involves long-term training and technology transfer to the latecomer. ODM (own design and manufacture), which signifies a new stage of innovation, occurs when the latecomer firm also designs the product, which is then purchased and distributed as in OEM. ODM arrangements are often complex and varied. Sometimes they occur in close cooperation with overseas purchasesers, as in the computer industry. During the 1980s OEM/ODM accounted for between 50% to 60% of Pacific Asian electronics output. OBM (own brand manufacture) is where the latecomer has acquired the technology and marketing capabilities to compete head on with industry leaders with internationally recognized brand names.

approaches and chose their own copetencies, but their strategic intent sustained their efforts and led to cumulative learning and higher value-added production. The need to anticipate the firm's or the country's comparative advantage has become important, to allow for lead time for learning, lumpy imvestments, the building of support infrastructures, and training or recruitment of a critical mass of engineers.

Strategic intent has guided a balance between focus on certain products and markets, to realize economies of scale and cumulative learning, and breadth of involvement, to exploit links and economies of scope, take advantage of technological complementarities, and hedge against uncertainties. It has allowed Japan and Korea to build a robust and diversified industry. In the early stages they developed scale and simple manufacturing and organizational skills. Product sequencing and timing for market entry also were crucial. They focused first on assembly of foreign consumer products and components, then produced components and simple consumer electronics of their own national firms, and finally made more sophisticated electronics components and products, including computers and telecommunications equipment.

Strategic intent is illustrated in the success of Japanese corporations such as Sony, Matsushita and JVC in a global marketplace for products such as videocassette recorders based on technologies originated in the U.S. or Europe.[144] The VCR, like most IT products, is a "system" product; its performance depends on diverse technologies in electronic circuitry, magnetic materials and electromechanics. These successful pioneers skillfully managed their capabilities, improving and then integrating technologies. Results followed a decade of learning by trying. They sold products, studied response, and tried again. Management provided consistent direction and sustained financial support over long development. They held a conviction that the VCR would follow color television. Technical teams set performance specifications for a compact, inexpensive VCR and developed the necessary technologies, using R&D to solve technical problems.

The VCR is not an exception. Experimentation and disciplined learning, guided by strategic intent, are common to other Japanese IT products. Korean and, more recently, Taiwanese firms are following similar patterns as they to move to higher value-added products. They had to cross-subsidize their businesses, redeploying profits to infant industries to ensure growth and technological dynamism.

These countries, except Hong Kong, have held to a strategic intent in developing technological capabilities and nurturing core competencies. Building technological capabilities in the IT industry has been an explicit objective. A long and demanding process was necessary to

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[144] For a detailed case study of the VCR industry see Rosenbloom and Cusumano, "Technological Pioneering and Competitive Advantage: the Birth of the VCR Industry", *California Management Review*, Vol. 29, No. 4., University of California, 1987.

attain the best practices of industrial countries. Competitiveness in fast-changing technologies and markets is even more demanding. Guided by a national strategic intent, governments used policy instruments such as trade, credit, foreign investment, specialized education, and technology support to complement firm- efforts to develop core competencies (see Roles of Government below).

Strategic intent and the sustained development of core competencies also explain some of the motivations and modalities of national policies and programs to diffuse IT as a generic technology. Japan recognized early on the importance of managerial awareness and technical capability to exploit IT to enhance the competitiveness of various industries. For large IT users, its policy instruments mainly were indirect, such as financial incentives for modernization. For SMEs, they involved novel interventions, such as support of technology diffusion groups and robot-leasing companies. National IT programs have shifted emphasis from production to diffusion, from centralized to distributed applications, and from to improved productivity to consumer responsiveness.

Singapore provides the clear example of a strategic intent to exploit IT as an infrastructure. The competencies involved are more than technological. They include understanding the information needs of various industries and services, coordinating public and private initiatives, using government computerization as a resource for IT users and managers, motivating multinationals to test advanced IT applications, and designing and disseminating lessons from demonstration projects.

4. Agile Planning, Multi-level Learning

National strategies to develop and diffuse IT have involved collaboration among several levels of government and between public and private agencies. Strategies were not government-driven, though it was a coach, catalyst, coordinator, and regulator. Formal systems planning, typically top-down, proved inadequate to IT's changing of applications, which have become less monolithic, more pervasive, and integral to organizational and business processes. National plans such as Singapore's included only, strategic or demonstration projects; it did not set priorities for public information systems investments at all levels. Typically investments in public information systems focused on cross-sectoral functions such as financial management or on public databases and networks that provided a platform for diverse applications such as TradeNet.

Below this level, systems investment priorities were set at the sector or agency levels, where business strategies are formulated. At lower levels, planning engaged stakeholders and potential users in pilots. Japan has supported community networks and local government systems applications. MITI's has helped build consensus on the broad thrusts of national programs and strategies to enable, rather than replace, local initiatives. Strategic investments in the evolving national information infrastructure have been complemented by grassroots learning, building a customer base, and stimulating the demand for applications to use and upgrade this infrastructure.

The NIC's experience suggests that national strategies need to address systemic constraints to the use and diffusion of IT. This involves organizational adjustments and coordinated actions by firms, industries, and government, with emphasis on management, skills, and restructuring. A multi-level examination would identify economy-wide information and communications needs and target large-scale applications for strategic and demonstration effects. It also would suggest funding mechanisms, policies, and services to support bottom-up initiatives and pilot projects, and meet the needs of smaller organizations with limited capabilities.

To adopt IT, enterprises must be for institutional learning. SMEs often have difficulty monitoring technological development and acquiring the skills to manage new technology. Most IT vendors do not tailor their systems for SME use. Technology diffusion programs have encouraged the use of consultants and the adoption of best practices -- changing organizational processes and promoting complementary investment. Technology support institutions enablers institutional learning within enterprises.

Among industries, electronic networks, databases and value-added services require standards -- for example, exchange of trading orders and invoices. Firms increasingly depend on networks for production and distribution. Government policies such as legal safeguards are needed to secure confidential information and electronic transactions.

Among governments, awareness of the opportunities to use IT to enhance coordination, productivity and responsiveness is often low. Coordinated decision making and training required to invest in common databases and networks. Information and technology policies promote government or sector-wide information sharing. At the national or cross-sectoral level, the design of large transaction systems, such as financial and tax administration, require public-private planning.

Hence, a national IT strategy should be articulated at several levels. A central body typically provides a forum for coordination between government and the private sector, and set policy for areas such as intellectual property rights, confidentiality of data, and standards for electronic transactions. It outlines government's role as an IT consumer and regulator. Committees invite advice and cooperation, from central implementing agencies. Private sector involvement ensures transparent policy design addressing of common interests. Strategies for selected sectors such as finance, education and SMEs are formulated jointly by sectoral ministries, trade associations, and NGOs. A dialogue is often needed among similar businesses such as banks, the garment industry or information services.

IT strategies evolve. They do not emerge full blown. Singapore's IT plans have required successive formulations, since 1980, each increasing the scope and collaboration among public and private agencies. Strategies were guided by visions from the top and local best practices. For larger countries such as Japan, these processes involved more time and cooperation from various decision-making levels.

Effective national IT planning processes -- agile, strategic, collaborative, multi-level, and learning-oriented -- parallel the IT practices of innovative corporations. Even in corporations, where lines of command are clearer, exploitation of IT to reengineer business processes and promote product innovation has required new modalities of strategic planning and management. Businesses had to make IT an integral factor to realize its potential. Management set exciting visions, leaving discretion for experimentation during implementation. Planning and experimentation at many levels and functions supported the sharing of experience and built on successes. Line management "owned" these processes. Complex new systems were tested and then introduced in stages to ensure learning and adaptation. Outsourcing and continuous contact with outside sources of information kept IT planning and management agile, helped exploit the best ideas in the marketplace, and yet ensured that new IT applications would fit the vision and needs of the organization. These processes provide direction, develop commitment to IT plans, encourage learning from suppliers and customers, and potential users benefit from the new systems.

5. Public-Private Collaboration

The East Asia cases exhibit the coherent efforts of public and private agencies to diffuse IT. Mutually reinforcing plans were made possible by national visions, external orientation, incentives for learning and collaboration, and a rich array of institutions promoting government-business cooperation. Coherence of actions has been key to competitive advantage, speeding up the learning process, demonstrating the feasibility of IT applications, building information networks and resources, and exploiting links and externalities. Government-business partnerships enabled anticipation and response to opportunities, technological changes and competitive challenges, and reduced the risks of failure of targeted public interventions.

Government-business partnership in Japan, Korea, Taiwan and Singapore set an example for late industrializers. Since the 1950s industrial competition has required increasing coordination, knowledge of world markets, focus of resources, timing, predictability, and commitment to core competencies.[145] Japan and the NICs created mechanisms to consider public-private action: councils, trade associations, rural cooperatives, public-private institutions, administrative "guidance," technology research associations, "relationship" banking, and supplier-assembler links. These institutional innovations have contributed to successful, competitive economies.

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[145] This is consistent with Porter's findings that the process of creating and sustaining national competitive advantage requires strong interactions and coordination among a large number of factors and support institutions (op. cit., 1990).

Maintaining public-private collaboration is neither easy nor without friction. MITI's engineering of a consensus on the information industry and on the sale of NTT involved ministries, politicians, research groups and business pressures. In Korea cooperative research sometimes was hindered by concerns over revealing business secrets and disputes over the dissemination of research. But, governments devised incentives and laws to overcome these barriers and reinforce cooperative R&D.

Public and private roles are being realigned to respond to global competition and technological change. Realignment has not meant withdrawal of the state or separation of public and private action but rather an evolving partnership. NIC governments continue to focus the financial and entrepreneurial resources of the private sector to realize national visions, learn new competencies and build advanced infrastructures.

Public-private programs also have helped IT users, particularly export-oriented industries and SMEs, to absorb technology. Cost-sharing schemes have delivered integrated assistance to SMEs, covering credit, marketing, advice, and access to technology and information. Recently, public-private action has focused on building knowledge, applications, protocols, and policies to accelerate the development of a national information infrastructures.

Roles of Government

Governments can promote the IT industry, diffusing technology and developing the information infrastructure. The instruments varied, , although there have been common patterns (*table 7.1*).

1. *Promoting the IT Industry*

The state has played several roles in the electronics industry: coach and coordinator for the private sector (Japan), creator of private conglomerates to battle abroad (Korea), incubator and supporter of SMEs (Taiwan), integrator and strategist (Singapore), and infrastructure provider (Hong Kong).[146] In Porter's framework, governments have engaged in four sets of actions to influence firms' ability to establish and sustain competitive advantage[147](*table 7.2*). First, they led improvement of factors of production: high quality technical education, responsive R&D and standards-setting institutions, advanced telecommunications and other physical infrastructures, and credit programs for selected IT

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[146] Dahlman. "Electronics Industry Strategy: The Role of Government". in Wellenius, et al (op. cit., 1993)

[147] Porter (op. cit., 1990).

industries. Second, they stimulated demand for domestic IT through export promotion, IT-user education, extension to SMEs, public procurement, and public sector computerization. Computerization programs set quality and technical standards and promoted domestic competition among IT service providers. Third, they promoted related industries by financing industrial and science parks, and pushed alliances with foreign firms. Fourth, they influenced corporate strategy and rivalry, sometimes directly by promoting mergers and favoring conglomerates (Korea), directing credit and incentives to promising industries, and participating in enterprises and joint ventures. Often they influenced corporate strategies indirectly by promoting management education, export contests, direct foreign investment, and domestic competition.

Table 7.1: Government Instruments for IT

	Japan	Korea	Taiwan	Singapore	Hong Kong
IT Industry	• Vision of knowledge-intensive industry • Electronics/software English education • Government-sponsored research consortia • R&D institutions • Government-sponsored technopolis • Credit for software developers • Credit for IT producers • Venture capital for startups and to acquire foreign technology firms • Information Technology Promotion Agency • Public procurement • Selective import protection • Standards	• Export promotion • Infant industry promotion/protection • National R&D projects • Cooperative research • Science park • R&D institutions (ETRI) • yax incentives for R&D • Preferential credit for conglomerates • DFI restriction; joint-venture promotion • Vocational training • Public procurement • Software protection • Standards	• Strategic industry promotion; information industry development plan • IT education and training • Public R&D funding and institutions (ITRI/ III) • Fiscal incentives for strategic industries • DFI promotion • Public enterprises • Software protection/patent law • Industrial science park (incubator) • Selective import controls and local content • Foreign-local joint-ventures	• National IT plans • "Intelligent island" • DFI promotion; recruiting IT multinationals; strategic alliances • R&D incentives and institutions (ITI) • Venture capital fund for IT businesses • Software quality assurance program • Software development assistance (cost-sharing of package development) • IT education and training • Public enterprises	• Laissez faire stance • Industrial parks • Technology center (incubator) • Vocational training • Grants to train engineers in ASIC design
Diffusion	• Public technology extension centers • Japan Small Business Corp. (cost-share IT training for SMEs) • Government-financed training for SMEs • Technology diffusion groups • Robot-leasing companies • Civil service training and computerization programs	• Korea Productivity Center: SME use of IT in manufacturing • Computer literacy and awareness • Preferential financing for domestic capital goods	• IT extension to woodworking, weaving, other industries • China Productivity Center • Public sector computerization (taxes, car registration, etc.) • Standardizing IT requirements for government and industry	• Civil service training and computerization program • Small Enterprise computerization program • Apparel industry computerization scheme • IT culture/ computer literacy programs	• Public sector IT strategic plan. • Electronic data interchange standards. • Hong Kong Productivity Council for SMEs
Infra-tructure	• NTT restructuring, privatization and regulation • High-speed testbeds • MITI's program for advanced Information infrastructure society • Public databases • New social infrastructure (national networks linking universities, local government, etc.) • Standards and protocols • Information society	• Nationwide specialized information networks (for administration, finance, education, health, defense) • Investment in telecom.: recent liberalization • ISDN, SAT and national high speed information networks • Access to foreign databases. • "Information society"	• Strategic national information systems (population, GIS, land use, medical, insurance, cargo) • Investment in telecommunications	• Medical, education & Law Networks • TradeNet • Enterprise Promotion Center-Net, (for SMEs) • Investment in telecommunications • State-of-the-art worldwide links	• Advanced infrastructures and VAS applications for trade and finance

Source: Using Porter's framework.

Table 7.2: Government Promotion of Competitiveness

Advanced factors of production	Domestic demand	Related industries	Corporate strategies, managerial practices, and domestic rivalry
• Specialized technical education and training institutions • Incentives for firm-based training • Regulating and investing in advanced communications, value-added networks and related infrastructures • Policy-based credit programs for SMEs, venture capital for technology startups • Public R&D institutions, cooperative R&D, and incentives for R&D • Metrology, standards, certification and testing infrastructure	• Coordinated and phased investment in national IT projects • Public information sharing policies, standards, and protocols • Demonstration projects • Government procurement practices • User associations and technology diffusion groups • IT user training • IT extension programs and cost sharing schemes for consultancy services • Incentives for investment in IT products and services • Trade policy • Intellectual property rights	• Promoting clusters through technology parks • Targeting and sequencing support industries • Promoting IT subcontracting and supplier networks • Promoting strategic alliances with IT multinationals	• Anti-trust or promoting merger and consolidation • Domestic competition policies • Export incentives and rivalry • Management education • Direct government participation through joint ventures and public enterprises • Promotion or control of direct foreign investment

Source: Using Porter's framework.

Governments also have exploited the synergies and dynamics among these four sets of actions. They have stimulated demands and standards that corresponded to the factors of production and technological capabilities they nurtured. They have promoted the clustering of technology-intensive industries and education and research institutions, to use the advanced factors. They have created the conditions for a domestic IT-components industry by targeting and sequencing the development of downstream industries in consumer electronics and computer assembly. They have collaborated with the private sector in sustaining competitive advantage and orchestrating actions for continuous upgrading.

Government roles have changed in response to technology, global competition, new opportunities, and its own capabilities. The state often used the same instruments in different ways. Korea, for example, promoted foreign investment to acquire basic technical skills and later, controlled it to permit local players to learn and achieve economies of scale. A key to understanding such apparent changes in role or use of policy instruments is to examine the initial conditions and strategic intent of the country to deepen technological capabilities.[148]

The Japanese government has constantly worked with the private sector to develop a national vision and eliminate bottlenecks to progress. Its interventions mainly have sought to strengthen private sector response. Public policies have been coordinated: selective trade and foreign direct investment protection, phased in with technological development; support for R&D through consortia and conditional loans; targeted technical education and training; and public procurement requiring progressively demanding performance. Trade barriers were used in the 1960s and 1970s to protect the development of computers, telecommunications and semiconductors; restrictions were used to bargain for access to foreign technology as well as to develop a market for domestic producers. While restrictions were relaxed in the late-1970s and 1980s, some were established for newer segments of the industry where domestic firms had not yet achieved competitiveness. Recently, protection policies have been replaced by promotion of strategic alliances and acquisition of foreign companies that possess key technologies. MITI helped Japanese companies bargain with multinationals such as IBM. It led R&D funding in computers, then relied on associations for targeted R&D missions, such as very large integrated circuit (VLSI) and the fifth generation computer project. Nippon Telegraph and Telephone , a government enterprise until 1985, led R&D for telecommunications equipment. MITI also influenced the structure of the domestic industry, in response to IBM's launch of the 370 system in the early 1970s, by consolidating six independent computer producers into three groups, even while enhancing R&D and competition among the consolidated companies.

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[148] For excellent accounts of the role of industrial policy in creating competitive advantage and for interpreting the NICs' experience in building technological capabilities, see Lall (1994), and World Bank Operations Evaluation Department (1993).

Tax and credit policies promoted the IT industry. Tax incentives targeted at IT producers and users were updated every two to five years. Credit was channeled through the Japan Electronics Computer Company, set up by MITI in 1961 to buy domestic computers and lease them in competition with IBM's leasing program. More recently, recognizing that Japan is behind the U.S. in software capabilities, MITI has developed special credit facilities and marketing and training programs for software developers.

Following the Japanese example, Korea achieved an impressive record in industrial diversification and deepening, within a shorter period than Japan. The government fostered conglomerates with the finances, technological depth and reach to compete internationally in demanding industries. The conglomerates were able to compete in the electronics because their financial resources, cross-subsidization, and internal labor markets enabled them to absorb market failures characteristic of new and demanding technologies. The government offered prolonged protection to selected segments of the electronics industry, then phased it out to force them to compete. Even during the protection phase, local producers were forced to export progressively greater output. The government subsidized technical education and firm-based training. It sponsored national technology projects to achieve specific technological capabilities (development of 1M and 4M DRAM), and invested in generic and specialized R&D institutions. It induced local firms to develop their own research. Until recently, the government was selective in allowing foreign direct investment. It used government procurement of computers and telecommunications equipment to raise value-added and performance standards for domestic producers. It focused and sequenced its interventions to spur entry into more demanding global markets.

Though a late industrializer, Taiwan built on the dynamism of its small and medium enterprises. Its strategy had elements of Korea's targeting and promotion of domestic IT industries: import protection, credit allocation, and selective F.D.I. But Taiwan's initial conditions were better than Korea's, thanks to the influx of capital and entrepreneurship from mainland China after the revolution. With these endowments, the Taiwanese government did not attempt to create conglomerates or to be as selective as Korea.[149] Rather, the government developed physical and institutional support, including R&D and the *Hsinchu* Science-based industrial park, to compensate for the disadvantages of small enterprises. The result is a diverse SME sector that emphasizes flexibility and export niches. The government also participated directly through public enterprises where economies of scale were critical, and through joint ventures with multinationals and spinoffs from the quasi-governmental Institute for the Information Industry. More recently, the government has acted as a venture capitalist to ensure access to successive generations of IT. While lacking Korea's technological depth, many Taiwanese firms were able to enter higher value-added activities by tapping government supports. Some, like Acer, are increasingly able to

[149] See Mody (1990) for the argument that Korea's promotion of conglomerates was, in part, an institutional adaptation to earlier scarcity of entrepreneurship.

invest in their own R&D and brand names and to team up with high-tech U.S. companies. In education, the government stressed engineering fields, especially electronics, and more recently software. It established in-service public training institutes for government employees and a comprehensive certification program for informatics specialists.

Hong Kong is different. It demonstrates the limitations for industrial deepening under a virtually laissez faire regime. The government only provided education and training, subsidized land to manufacturers, and information and support services to exporters. Its support was less intense and predominantly non-selective, and trade remained free. Hong Kong's growth in electronics was impressive, and in the late 1980s the industry was the second largest exporter, accounting for 22 percent. The pattern of industrialization reflected Hong Kong's tradition as a free trade center, a good infrastructure in trade and finance, the influx of Chinese entrepreneurs and technicians from Shanghai, as well as the non-selective and limited government intervention policies. Hong Kong has grown in trade and services because of its location and connections to the fast-growing mainland.

Foreign direct investment initially reduced Hong Kong's learning requirements but, lacking selective interventions to promote complex activities, industrial deepening by "natural" progression did not occur. The technology for fast-changing consumer electronics initially was unsophisticated, and Hong Kong companies spent only a small share of sales on R&D and aimed for short-term returns on their fast production for niche markets. The growing importance of application-specific electronics components and the relocation of electronics assembly of multinationals to low-wage China have led created unease among Hong Kong policymakers. In response, the government has become interested in educating electronics engineers and in diffusing IT to modernize and deepen industrial capabilities. The strategic issue now is to shift to a regional service center, based on advanced use of IT in services and infrastructure, without losing growth during the corresponding of "de-industrialization."

Singapore targeted consumer electronics, and more recently computers and software, for promotion and development. While Korea intervened directly to influence its conglomerates, Singapore's intervention mainly has been infrastructural. It declined to use trade protection but guided resources and lowered the cost of entry into difficult activities by investing in the requisite skills and infrastructure, such as its world-class port, airport and telecommunications. Having recognized the importance of IT and knowledge-based industries and services in the early 1980s, the government began promoting specialized technical education and attracting IT multinationals and inducing them to move to higher value-added activities. It created a national computerization committee and the National Computer Board to exploit the synergy between computers, software and telecommunications to improve national competitiveness.[150] It set up a few public enterprises to enter activities considered critical to the

[150] The Annual Report on Competitiveness for 1994 ranks Singapore second in the world in productivity.

country's comparative advantage, such as software operating systems and packages, and then it privatized them when they achieved adequate technological competence. Both functional and selective interventions helped guide F.D.I. toward deepening industrial activities.

Despite their diversity in endowments and approaches to improve them, these countries all extended their competitive advantage in electronics. All invested in training and infrastructure. But they differed in trade, industrial, capital market and technology policies. Hong Kong now has the least technological depth and industrial value-added. Japan and Korea developed complex technological capabilities and are now global players. All the NCCs devised interventions whose variety and subtlety cannot be captured by conventional labels such as state-planned, corporatist, interventionist or market-driven. As trade was liberalized and local capabilities increased, interventions became selective.

Export orientation has reduced the dangers of rent seeking that may arise from interventions. As the East Asia Miracle Study World Bank 1993 indicated, Japanese and Korean policymakers gave favors in return for export performance. This created non-market based "contests." They also used institutional mechanisms and incentives to enhance the learning capability and accountability of government agencies in designing and implementing interventions. Stringent standards of recruitment, education and training, and compensation helped improve interventions. Governments also used private expertise to guide interventions, by contracting out the delivery of extension-type assistance to SMEs, by including business leaders in national committees for industrial strategy formulation, and by developing national consultative mechanisms. For example, the director general of Korea's Ministry of Science and Technology is seconded from the private sector for three to four-year terms, and his salary is topped by private industry associations. Technical staff is seconded from industry to set targets for value-added telecommunications equipment manufacturers, and government procurement and is used to signal future quality and performance standards. In Korea and Hong Kong, industrialists participate in setting the incentive schemes and curriculum for technical training. In general, government agencies learned with the private sector, and thus became increasingly effective.

2. *IT Diffusion*

Attention to diffusing IT as a generic technology is more recent. In Japan the government has promoted IT use among SMEs and key industries. Compared with those in other industrial countries, Japan's programs were comprehensive and continuous. They involved partnerships of the central and local governments and business, which shared the costs of training, consultants, information services, R&D and demonstration projects.[151] The programs addressed

[151] See Hanna, et al., *Information Technology Diffusion: Experience of Industrial Countries and Lessons for Developing Countries*, World Bank Discussion Paper No. 281 (1995), for a review of lessons learned from the rich variety of programs developed to diffuse IT for private sector use.

market and capability failures in IT adoption and diffusion, particularly for SMEs.[152] Incentives and supports addressed the finance, marketing, information, managerial skills, learning costs, and risks required to adopt the new technology paradigm. They included technology extension institutions, testing labs and standards, technopolis schemes, MITI's technology diffusion groups, government-sponsored robot-leasing companies (to help SMEs avoid steep sunk costs and getting locked in to a generation of technology), and incentives for technology modernization.

Other NICs have used IT to promote productivity and flexibility. Extension programs focused on users such as garments (Singapore and Hong Kong) and woodworking (Taiwan) where technological and market changes eroded international competitiveness, and generic IT such as C.A.D. that promised greater productivity and responsiveness. The national productivity centers of Korea, Taiwan, and Hong Kong, following Japan's model, helped SMEs change business processes and adjust skills to generic IT applications. Singapore has perhaps gone farthest in diffusion, and become the most IT-intensive economy of the group. Led by its National Computer Board, the government has invested in IT to provide demonstration effects, set standards, make public-private transactions (through electronic interchange and value-added networks), and help SMEs access public information.

These governments increasingly recognize the potential of IT and the consequent improvements in business practices. Some, like Singapore and Hong Kong, view IT as an enabling technology for services, the fastest growing sector of their economies. Large firms can take advantage of advanced manufacturing technology on their own; in Japan and Korea IT diffusion businesses occurs mainly within conglomerates. Government programs therefore are increasingly focused on SMEs.

Little field research has captured the lessons of these diffusion programs; studies are needed.[153] It does appear, however, that programs succeed only government and business are genuine partners during design and implementation. Government coordinates and subsidizes. The private sector provides some funding, delivery channels, and knowledge of market failures, learning requirements, and user preferences.

3. Developing a National Information Infrastructure

Government develops the a national information infrastructure (NII). It set policies and standards, pools resources, guides demonstrations, invests in telecommunications

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152 For analysis of market and capability failures, as they relate to IT, see Hanna, et.al., 1994, op. cit.

153 For relevant lessons from the IT diffusion program of industrial countries, see Hanna, et. al. (1994, op. cit.).

infrastructure and regulates its services, builds public networks and databases, and protects intellectual property rights.

With the exception of Hong Kong, governments have led investment in the telecommunications infrastructure and begun to liberalize or privatize. In Japan MITI articulated knowledge-intensive economic development, and to reached consensus on the broad thrust of the NII. Recently, MITI and other key players are using the vision of the NII to press for further deregulation of information and communications. Meantime NTT, already partially privatized, has started to participate in developing the NII through strategic alliances with several U.S. companies: Silicon Graphics, to build interactive multimedia service to link consumers, businesses and government; Microsoft, to capitalize on its expertise in operating system software; and General Magic Alliance, to develop network operations and message handling standards.

There is a growing realization in Japan that building the physical "information superhighway" is not enough to realize the benefits from this new-type infrastructure. The challenge is to create relevant new services and applications that add value to potential users. So far, the battle among various actors such as NTT and the Ministry of Post and Telecommunications, has focused on deregulation and on the construction of a nationwide network of optical fiber to the home. But MITI's recent vision of this infrastructure, inspired by U.S. proposals of an NII, acknowledges the need to pilot and induce investment in applications for the public, industrial and household sectors. It envisages a catalytic role for government to promote on-line applications and databases in five areas: education, research, medical and welfare services, public administration and libraries.[154] It promises to address policies to protect intellectual property rights and facilitate the reuse of intellectual property, and to address Japan's key bottleneck of software engineering skills.

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[154] MITI's recent vision borrows extensively from current U.S. Government plans, even as the U.S. borrows from the experience of Japan in other spheres of Government business partnership: "The United States faces its own global readjustment. This will require moving beyond the notion that the only role that government can play is that of regulator. It calls, moreover, for an end to the rather unproductive debate about "industrial policy" and for a greater emphasis on identifying the joint interests of business and government and how they mutually support one another. Government has always had a role--which it cannot escape--in structuring economic relations and outcomes.

In the context of the National Information Infrastructure, the private sector clearly has the primary role for developing, deploying, and operating the NII. For the most part, industry will develop the technology, provide bandwidth, offer connectivity, and ensure the availability of services and products in the pursuit of profit. Government, however, cannot stand idly by. In its various roles as regulator, broker, educator, promoter, and institutional builder, the government must establish the rules of the game and the incentive structure that will help determine private sector choices.

The same is true for electronic commerce. In government's role as regulator, it will need to ensure that electronic markets are evenly deployed, open, and accessible on an equitable basis. Acting as a broker, the government can bring together potential, but disparate, network users, thereby helping to generate a critical mass. As a promoter, the government can take steps to overcome specific market failures. As an educator, the government can promote electronic commerce by fostering demand through the effective use of networking technologies. Finally, and most importantly, the government can create an institutional environment that strives to assure that electronic commerce is conducted in a manner consistent with the nation's overall social and economic objectives." Office of Technology Assistance (OTA), Testimony before House Committee on Science, Space and Technology, May 26, 1994.

Singapore leads the region in creating electronics data interchange (EDI) systems, and in demonstrating how the government can work with public and private sector users to set standards and protocols, to develop specialized networks such as TradeNet, to train users to articulate their needs, and to enable early adopters to share their experience. Singapore Telecom, a government-owned agency, has invested heavily in building one of the world's most sophisticated telecommunications infrastructure, and more recently, has begun a globalization effort and invested about one billion dollars in equity and management interests in about a dozen ventures in 12 countries, including the Philippines, Viet Nam, Australia, Britain, Norway and the U.S. The agency is seeking global as well as regional partners, to secure access to world-class technology and operating experience and to regional markets. Domestic experience with advanced services, combined with a vision of the "intelligent island", made Singapore telecom an attractive partner and a leading regional player. Korea, Taiwan and Singapore are pursuing a balanced strategy for an NII by developing public information resources, piloting advanced information services, and building the capabilities of users, in line with investments in the physical infrastructure.

Governments also played enabling roles in developing advanced infrastructures to support integrated logistics management and rapid response. Experience suggests that the development of such infrastructures need not involve large public sector investments, provided that the basic infrastructure is reasonably adequate to take advantage of IT enhancements. Governments are addressing the necessary policy conditions to facilitate development of these infrastructures, encouraging value-added service providers to enter this market, promoting competition among third party service providers, and developing institutions to set and promote standards. They cofinance or pilot IT applications that are risky or have high externalities. They also promote network-based applications aimed at industries and services comprised primarily of small enterprises (such as auto parts manufacturers in Taiwan and garment producers in Hong Kong). Government learning progressed over time: infrastructure was not provided once-and-for-all, but evolved in response to preferences revealed by early users and by the changing needs of the economy.

Roles of the Private Sector

The dynamism and the complexity of competitive strategies of this industry make it necessary to rely on agile private sector players. Although governments played important roles as nurturers and strategists, success was based on private sector roles in to developing competitive IT industries and in diffusing IT among other user industries.

Apart from its direct role in production and use of IT, the private sector participated in five distinctive areas: (i) private sector association's input in industrial policies and diffusion programs; (ii) large corporations in technological deepening, and transfer to SMEs; (iii)

SMEs in flexible specialization; (iv) multinationals in services; (v) private sector in investment in information infrastructure.

(i) Private Association's Input in Policies and Programs

At the macro level, each of the NICs and Japan created institutions to improve communication with the private sector and to guide industrial policy. Formal deliberation councils included government officials, business and labor leaders, academics and journalists.[155] These were supplemented by a rich variety of informal mechanisms. These mechanisms improved coordination among firms and facilitated the flow of information between businesses and government. Information sharing made it difficult for firms to carry special favors from the government and for public officials to grant special concessions. Thus, these councils helped establish a commitment to the national development strategy, and reduced rent seeking in industrial policy. The deliberation councils in Japan, Korea, and Singapore also performed important monitoring functions, assessing performance at the industry level, and administering contests for export. Given the priority attached to the electronics industry, these national councils and private associations have been influential in shaping corporate strategies, and in allocating scarce public sector resources in support of these strategies.

Industrial associations have been important agents of industrial policy in japan, Korea, Taiwan. Their role took various forms. In Taiwan, for example, where the IT industry is largely composed of small firms, the Taiwan Computer Association (TCA) worked closely with the Electronic Research Scientific Organization (ERSO, a lab belonging to the Industrial Research Institute) to develop notebook computers.[156] The ERSO first projected that the global market for notebook computers would expand rapidly. The TCA then promoted a strategic alliance to develop a Taiwanese notebook. Some 30 firms joined the alliance, divided into groups to explore specific technical problems, with each group headed by an ERSO researcher. Nine months later, the cooperative research organization developed a prototype that was made available to the members of the alliance. Competition then resumed. Each local firm developed its own notebook, and in alliance with foreign firms, successfully exported it. This is a successful example of cooperative interaction between the government backed research institute, specialized sectorial industrial associations and individual firms to break into new products and markets, in line with industrial policy. The impact has been dramatic: this year (1994) Taiwan is expected to turn out some 2.5 million units, up by more than 80% from 1993, to become the second-largest producer after the U.S.[157]

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155 *The East Asia Miracle* (1993 op. cit.).

156 Chaponniere 1993.

157 *Far Eastern Economic Review*, Oct. 13, 1994, p.45.

Japan's peak business interest group, Keidanren, has been a leader in promoting collaboration for technological deepening. Research consortia, even while often funded in part by the state, are initiated by private firms. Private firms are the primary actors in all phases, from conceptualization to exploitation of results. For example, in the Key Technology Research Center, KTC, established by MITI and the Ministry of Posts and Telecommunications, promoted cooperative research by providing equity for R&D companies, conditional loans to private joint-venture research firms, and basic information sharing infrastructure. Participant firms retain all patent rights, which the research partners divide among themselves. The first four years of KTC, investments generated nearly 1000 patent applications. Technology is diffused and nurtured, while competition is maintained.

Governments have also induced the private sector, including multinationals, to play new roles. For example, the Singaporian Government created specialized IT training institutes as joint ventures with several multinationals. With the encouragement of governments, the large conglomerates in Japan and Korea created autonomous private research institutes. This has been complemented by a rich variety of collaborative private-sector driven R&D. Public and business leadership often collaborated to create a mass movement in support of IT diffusion, for large user groups generic applications. In Korea, Hong Kong and Singapore, industrialists are also actively involved in the design of technical education curricula and the training of engineers and technicians.

(ii) Role of Corporations in Technology Transfer and Deepening

Conglomerates in Japan and Korea have been key actors in IT production and diffusion. These enterprises pursued long term strategies of technological deepening and diversification, and used Their substantial financial and human resources to cross-subsidize and invest in promising segments of the electronics industry. Government policies helped reinforce their innovation and diversification strategies by reducing the risks and sharing the cost of R&D. More recently, the conglomerates have begun to develop globalization and regionalization strategies. Taiwan and Singapore are following suit, building bridges to mainland China and other regional IT producers, and developing strategic partnerships with leading IT multinationals.

Conglomerates have been also leading the IT diffusion process, within their own businesses and among their suppliers. Horizontal diffusion within these firms is facilitated through "multifunctionally specialized" career paths, in-house technical training institutes, and the use of engineers to achieve inter-business diffusion. Vertical diffusion through subcontracting is also vital, as conglomerates act to ensure that suppliers meet their quality and quick response requirements by using advanced information and communication systems. Advanced IT users among the conglomerates also acted as diffusion agents. For example, Fujitsu first developed its core competencies as a leading user of factory automation and flexible manufacturing systems, then established a Computer-Integrated-Manufacturing (CIM) consulting center to demonstrate flexible manufacturing technologies and systems integration.

New forms of international cooperation are playing an increasingly central role in IT diffusion in East Asia. A central requirement for efficient learning to use IT is to be tied into the best international information networks, through partnerships with leading IT users and producers. In the Korean case, strategic alliance has been formed between Samsung and Hewlett Packard for producing high-powered work stations, for example. Hitachi has teamed up with Goldstar in manufacturing DRAM chips. In Taiwan, ACER is working with Texas Instruments in manufacturing sophisticated memory chips. Singapore Telecom and software companies are engaged in building alliances with local companies in the Asian-Pacific region, exploiting a recently deregulated global environment. Large general trading companies, such as ITOCHU Corporation of Japan, are also building partnerships, with a focus on improving information processing and distribution capabilities throughout the region. NIKKEI, Japan's largest financial media organization, has one of the most comprehensive business and economic information networks in the world, with relationships and joint ventures with more than 40 major news and information services organizations around the world. It is in the process of positioning itself to exploit the multimedia revolution and the growing demand for information about the economies of the Asia Region. Japanese capital has already begun to provide the cement for a more integrated regional economy. The outward orientation of all other East Asian players suggest that the balance in the development of informatics has shifted from government stimulus to international firms.

(iii) Role of SMEs in Flexible Specialization

Small and medium enterprises have played a key role in IT production and diffusion through their agility and dynamism. As "followers", these countries had to learn fast and to be quick in bringing new products to markets, and SMEs provided such flexibility to the IT industries and downstream users. Several factors made a dynamic role for the SMEs possible. In Taiwan and Singapore, for example, success depended on the development of technical human resources, the quality of business management and entrepreneurship, the supporting technological infrastructure, and of course, the quality of macroeconomic management. As participants in a global industry, these SMEs have figured out precisely where they can prosper in the value chain of the global IT industry. They learned to be quick followers, knowing when to get in and when to get out of their fast changing niche markets. They claim the middle ground between the low-end labor-intensive economies like China, and the high-tech domains of the U.S. and Japan. With a shallower technological base, Hong Kong's electronics sector thrived on flexible adaptation to new market niches in the simple consumer products area. This is based in large part on its excellent integration into international supply and export networks. In Japan, the dynamism of SMEs is, in part, the result of the technology transferring role of the conglomerates. But, this is complemented by collective efforts and horizontal networks among SMEs such as the Technology Diffusion Groups. Such cooperative diffusion mechanisms are often induced or supported by the local and central governments.

(iv) Role of Multinationals in IT Diffusion in Services

Of special significance is the emerging role in IT diffusion by multinationals engaged in the services sector. Local producers in all industries are increasingly dependent for their competitiveness on efficient and responsive services. With the advance of telecommunications technology and the liberalization of services under GATT, mobility of production and trade in information services has increased and IT-based services have become important conduits for IT diffusion. FDI has become easier and increasingly countries are becoming foreign investors to preserve or advance their competitive position in a rapidly changed world. The NICs are taking advantage of those trends. FDI is providing access to the key "soft technologies" of product development, marketing and support services. Telecommunication services and the global networks of multinationals have become important gateways to international markets. Singapore and Hong Kong have been particularly adept at understanding this paradigm shift. This is integral to their vision of a role as regional hubs for regional-level satellite services and for the provision of knowledge-based services, including finance and trade.

(v) Private Investment in Advanced Infrastructure

The private sector is playing important roles in the development and support of advanced infrastructures (AI) in the East Asian region. Given the special nature of AI, the private sector is expected to play a more important role in AI than in traditional infrastructures. As AI is more user or demand oriented than traditional infrastructure, potential users must be aware of the potential benefits, have adequate incentives to use the new infrastructure, and face no regulatory barriers to exploit its potential. Governments assisted in organizing users, particularly SMEs, to pilot and take advantage of AI, and have developed (or cost-shared) risky applications on the information infrastructure. Increasingly, the private sector is encouraged to take a large part in all aspects of the supply side of AI. The breath and complexity of potential value-added services and applications needed simply exceed the capacity, flexibility and creative ability of most governments. The private sector is also active in creating an enabling environment for the effective provision and use of AI: training AI suppliers and users; financing R&D; keeping government informed of AI trends and of their implications for national competitiveness; forming and supporting industry associations; and promoting complementary managerial and organizational practices. *Table 7.3* summarizes the main roles of private providers and users of AI services, and the complementary roles of government.[158]

[158] Adapted from Reinfeld (1993, Op. cit.).

Table 7.3: Government and Private Roles in Creating Advanced Infrastructure

Responsibility	Government	Private Sector	
		Service providers	Service users
Physical Infrastructure			
Develop:	Study, fund, build	Possible (BOT)	For own facilities
Operate:	If necessary	If possible	For own facilities
Promote:	Active participation	If possible	For own facilities
Value-Added Services			
Develop:	Pilot studies, high-risk applications	Provision of VANs, integration, Consulting	Participation in pilots
Operate:	Generally not involved	Provision of VANs, system integration, consulting	Possible
Promote:	Assistance to small user firms	Market development	Possible
Support	Favorable regulatory framework	Training	Training
	Human resource development	Conduct R&D	Organizational changes
	Encourage R&D	Inform government on trends	User industry associations
	Coordinate with private sector	Coordinate with government	
	Establish competitive environment		

Source: Reinfeld (1993).

Is the East Asia Experience Replicable?

The answer is a qualified yes. It depends on which role or perspective is under consideration: IT as an industry, as generic technology, and/or as an enabling infrastructure. In this section, the issues concerning replicability are examined for each IT role, in turn.

(i) Replicability in Promoting the IT Industry

Most studies of the NICs have been conducted within the "market" vs. "state" debate, a debate that is missing the opportunity to shed light on the dynamics of technological learning at the sector and firm levels. Yet, latecomer companies have developed a variety of promising mechanisms to learn new technologies, and latecomer governments have developed instruments and processes to work with private sector organizations to enhance their technological learning and competitiveness. These lessons are more relevant to other developing countries than conventional Western models of industrialization, as developing countries are likely to adopt a "follower" strategy and face similar conditions to the NICs. Late industrializers are dislocated from key sources of innovation and the "user-pull" of demanding markets. They are forced to adopt new instruments and technology development strategies to overcome their difficulties. This study suggests that the place of government in stimulating technological advance is changing, and that the recent experience of governments in the NICs and Japan are more relevant to developing countries than earlier industrialization in the West. The proper role of the state for late industrializers, beyond education and basic infrastructure, cannot be viewed in isolation from the changing role of the state also in industrial countries. OECD countries continue to invest heavily in IT diffusion programs and in targeting IT user industries that face global competition, particularly from the NICs.[159] Moreover, OECD governments continue to escalate their intervention in trade and technology transfer to heighten the appropriability of the gains to innovation by their firms and to limit access to new technologies by foreign firms.[160] Newly industrializing countries may thus have to become more interventionist than in a benign environment, to "level the playing field" and to neutralize the negative consequences of OECD measures.

Risks of state intervention should be weighed against the dangers of not intervening.[161] Selectivity in intervention is often necessary in view of scarce public resources and the need to focus national resources for fast learning and maximum impact. The greater the degree of selectivity exercised, the greater the potential benefits. The cases of the fastest industrializers indicate that such interventions are feasible and successful. The case of Hong Kong

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159 Hanna, et. al. (1994, op. cit.).

160 Ernst and O'Connor (1989).

161 Lall (1993 and 1994, op. cit.).

suggest that *laissez faire* did not lead to technological deepening. Given the market failures inherent in the process of building technological capability, reliance on free market policies alone may lead to industrial stagnation or static competitive advantage. The fact that many developing countries have adopted incoherent industrial strategies and intervened poorly and with little selectivity does not mean that they should abandon all attempts at developing coherent strategies and realistic interventions. Rather, there is a need to understand those factors and processes that make for effective and strategic interventions, consistent with likely administrative capabilities and governance. Administrative capabilities can be improved over time. Interventions can also be designed to match or reduce reliance on public administration capabilities, drawing on the experience of the NICs and Japan as well as other OECD countries. Big policy mistakes can be avoided by limiting the duration of government support and setting performance-oriented criteria for promoted firms. A firm national commitment to export provides the discipline for both enterprises and policy makers. Involvement of private sector representatives in the targeting process can inform the process and make it transparent. The safest strategy may by to create the conditions for "winners" to emerge rather than pick them at a detailed level.

There is a strong case for improving state effectiveness to intervene in selective and agile ways, in as much as there is a case for improving state capabilities and governance to ensure effective and sustained structural adjustment. Recent research suggests that institutions shape what policies might be feasible and effective, and that governance capacity is essential to successful adjustment.[162] Yet the option of abandoning adjustment efforts cannot be seriously considered without taking into account the serious consequences. Similarly, it could be argued that changes in global competitiveness and leading industries are such that they now require the state to perform a new role, the capacity for which they have traditionally lacked. Adjustment programs have required the state to also play new roles, and to undo that which they have consistently "excelled" in doing, namely, over-regulating and rent seeking. Similarly, competing in the global and most dynamic industries require focused, selective and strategic promotion of new technological capabilities. A key is an effective state, not an absent one.

In assessing the risks of targeting and selective intervention a distinction should be made between "leader" and "follower" strategies. A leader strategy is based on innovation and a strong scientific research base. For a leader, like the U.S., targeting is difficult and risky because of the uncertainties inherent in judging the importance of new technological areas. The issue for developing countries, however, is about targeting according to follower strategies. For followers, such as the NICs, and Japan until recently, it was relatively easy to identify and target sectors that offered strong opportunities for productivity and growth, based on the experience of more advanced countries. They also have had a scope to benchmark themselves against the technological leaders, to identify gaps in performance or capabilities, and to plan how to bridge them. Thus follower strategies should be easier, provided the underlying competitive forces and technologies do not change radically. The key task is to select the right niches and sequencing, so

[162] See L. Frischtak, 1994, *Governance Capacity and Economic Reform in Developing Countries*, World Bank. Also see North (1990).

as to build capabilities, quickly, consistently and cumulatively. A second-tier of followers may be even more fortunate in having successful models of targeting and sequencing and thus be able to reduce uncertainties about the targeted technologies, the industrial learning requirements, and the learning process itself.

One controversial issue in promoting the IT industry is whether there is a valid case for selective infant industry protection and for gradual exposure to import competition. The country experiences examined here suggest a complex reality. Significant learning costs are involved in building technological capabilities in most segments of the IT industry. The promotion of such capability development has been a key part of the industrial development strategy of Japan and the NICs. Active government involvement has been necessary to ensure such development, and that involvement included selective import protection combined with export promotion. However, given the history of protection in developing countries, such measures must be carefully designed, sparingly granted, strictly monitored, and effectively accompanied by measures to force firms to progressively meet world standards of efficiency. The most effective means is to subject the industry to strong pressures to enter export markets, even while selectively protecting and phasing out import competition. For those developing countries who have already built up their technological capabilities under conditions of import protection, the lessons of the Asian NICs should be different. Their liberalization and policy reform measures should take account of the time and costs of upgrading factor markets, and of "unlearning" by industries that need to become efficient and shed the legacy of outdated skills and technologies. Even these countries may ultimately need to selectively intervene to build up capabilities in promising segments of the new IT industry.

To fulfill its new role, the state must practice "consensual strategic management". A public-private collaborative approach may have become a prerequisite for latecomers to compete in new and technologically demanding industries. For the foreseeable future, for any firm or country, the period of unchallenged competitive advantage will increasingly get shorter. Strategic intent and fast response have become increasingly necessary. Governments need to build national capabilities to monitor and respond to trends in global competition. Lacking such anticipatory and strategic capabilities, many governments in industrial and developing countries have often reacted to the necessary restructuring too little, too late. Without adequate capacity to respond strategically to new opportunities and adjustment difficulties, policy makers were often driven to protectionist measures for ailing industries, without moving to more value added and profitable industries. Such measures are counterproductive substitutes to strategic management.

Consensual strategic management can be learned. In Japan and the Asian NICs, the state learned to hone its intervention, to listen to the private sector, and to pragmatically correct its policies and programs in light of experience and changing circumstances. Outsider observers and aid agencies had consistently underestimated the capacity of the countries to learn and target new industries and build new technical capabilities. The key to such learning was to upgrade the skills and shape the rules and incentives governing the behavior of those in charge of policy and program implementation.

This learning is not limited to the state. Replicability is dependent even more on the leadership and managerial capabilities of the private sector. The level of technical competence of senior managers strongly influence their commitment to investing in technological and change-generating capabilities. Enterprise managers play important roles in promoting good communication and effective collaboration with external sources of technical information and knowledge: universities, suppliers, customers, and technology support institutions. Firm-based training also complements public education and facilitate life-long learning. Among the NICs, the firm remained the central agent in creating and managing technical change for sustained competitiveness. Managers invested heavily in their own education and firm-based training. They also learned to organize to influence government, to collaborate in R&D, and to build strategic alliances and common infrastructures. Any strategy for replicating the NIC's performance must invest in such private sector-based learning. Ultimately, the role of the government will depend not only on its own capabilities but also on business leadership capabilities.

Replicability of the specifics of the IT strategies of the NICs may be reexamined, due to changes in the global environment. For example, the strategy for entering the electronics industry through simple assembly for export, based on low-wage labor, may not be as viable now. The industry is much more developed and already relies on established suppliers for simple components, automation has reduced the share of labor total cost, and competitiveness is increasingly dependent on quality and delivery time. The shift towards "commoditization" of computers, however, may favor expanded sourcing of components and peripherals from other latecomer industrializers. Also, the increasing importance of software may favor countries with highly skilled but low-cost manpower.

Access to technology is a new emerging concern. Some evidence indicates that accessing the newest technology through licensing is getting harder. It is also now more difficult to "reverse engineer" in electronics technology. There is much greater emphasis, especially by the U.S., on intellectual property rights. One of the principal ways around such barriers is for developing country firms to enter into strategic alliances with IT multinationals. The first-tier NICs have invested more in their own technological capabilities, to become attractive partners for strategic alliance and to bargain more effectively for access to technology. For second-tier NICs such as Malaysia, Thailand, Mexico, and Indonesia, the strategy may have to rely on foreign direct investment and heavy investment in specialized technical manpower. For many developing countries, local IT production may continue to be out of reach for some time to come. For them, the priority should be on using IT to revitalize and transform traditional, less technologically demanding industries, and to modernize their basic infrastructures and services.

(ii) Replicability in Diffusing IT

For most developing countries, the pressing issue is how to promote IT diffusion. The experience of Asian NICs is even more relevant in this regard since most of the local IT users have been SMEs and traditional industries (such as garments). Advances in computing and telecommunications in the 1980s shifted the focus beyond IT production, towards exploiting this generic technology to increase productivity and competitiveness. The user-oriented strategy of Singapore is clearly a successful model and it suggests that the main returns from the IT revolution come from wide diffusion. Diffusion programs of the NICs have also emphasized low-cost extension of relatively mature applications such as PC-based CAD and MRP. They relied on a blend of public and private delivery of extension services. These features are most relevant to the design of IT diffusion programs in other developing countries.[163]

Diffusion programs to specific groups of users may be complemented by a national movement that would make productivity growth a national objective. This has been key to the successful diffusion of productivity enhancing technologies, as well the spread of managerial innovations such as JIT and continuous improvement, in Japan and the NICs. A proper policy and institutional framework must be in place which encourages firms to seek productivity-enhancing organizational and technical change as the primary means of competition. This is particularly important for capital-scarce countries where the primary concern is how to fully utilize existing assets. This requires that "best practices" in IT use and management be spread to as great number of firms and organizations as possible. Investments in computer-based applications and communication networks should be viewed in this context as complementary and reinforcing measures to the low-cost and vast productivity-enhancing potential of managerial innovation and organizational development.

(iii) Replicability in Creating the National Information Infrastructure

Perhaps the most relevant area for replicability for developing countries is the systematic investment in a national information infrastructure (NII). As an infrastructure, the NII is relevant to countries at all levels of economic development, and is increasingly essential to participation in global trade and industries.

The East Asian NICs have recognized the importance of investment in telecommunications and, more recently, in specialized networks. They devoted large shares of their overall investment to this infrastructure. In the process, they "leapfrogged" several generations of communications technologies, taking advantage of the dramatic change in these technologies since the 1980s. To effectively deploy limited resources, and starting with a minimal telecommunications base, a targeted approach was adopted.

Several elements of these strategies are replicable. First, successful implementation of a telecommunication modernization strategy requires national consensus on the strategic role of this infrastructure within the broader context of an NII. Second, government-business partnership is important to guide the broad directions for standards, regulations, and network-based applications. Third, specialized networks such as TradeNet require standardization and coordination among various agencies.

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163 For detailed guidelines in designing IT diffusion programs see Hanna, et. al. (1994, op. cit.).

The experience of Japan and the NICs also suggest lessons for what should be avoided or **not** replicated. First, new communications technologies have significantly lowered scale economies, making it fruitful to liberalize entry to investment in and operation of telecommunications services. Competition does need to be regulated, however, and the experience of Japan and the NICs suggests that regulation, monitoring and disciplining anti-competitive behavior is a difficult but essential task. Second, balance should be maintained between investing in the basic infrastructure and building relevant applications and capabilities to take advantage of the vast potential of such an infrastructure. In Japan and Korea, limited attention to applications and general shortage in software capabilities until recently, have resulted in imbalanced growth and limited data communications services. Third, although Japan and Korea have tied their telecommunications investments to developing their own local production capabilities in optical communication and digital switching, this would be the wrong strategy for most developing countries. The R&D costs involved, the human capabilities required, and the pace of technological change have been such that for the foreseeable future most developing countries will find it more opportune to leapfrog to these technologies and buy these products in the international markets.

NIC's governments have relied on the capabilities of the private sector for developing their public information systems. Governments, however, developed their own in-house capabilities to become effective investors and demanding users of IT. They learned how to analyze their own information requirements, how to contract out systems development and support services, how to prepare terms of reference and call for tenders, how to manage the subcontractor and accept or refuse the results, and overall, how to source and use the business sector to build the public information infrastructure. In this process, governments also promoted domestic competition and appropriate standards, and thus helped create a domestic market for their IT industry, particularly for application software, systems integration, and computer support services.

Improving information systems for public sector management holds major promises and opportunities for other developing countries. Availability of information on productivity, service standards and performance indicators can exert powerful pressure on public agencies, controlling corruption and promoting accountability. But the potential benefits will seldom be realized unless investments in public information and communication systems are part of a coherent program to reorient government and improve the productivity and accountability of the public sector. Building the information infrastructure within the public sector should be viewed as a learning process that focuses on changing the organizational incentives and structures as well as the information base and skills.

(iv) Replicability and Aid Agencies

It is tempting for aid agencies to discount the relevance and replicability of Japan's and the NIC's IT strategies for other developing countries. It could be argued that the essential ingredients for success of East Asian industrializers are the quality of leadership, public-private collaboration, and "unique" socio-political and institutional conditions. These arguments are similar to those raised in the U.S. in the early 1980s regarding the transferability of "lean production" and other management methods of the Japanese to the U.S. auto industry. Recent experience in the auto industry has demonstrated the feasibility of such transfer, and the consequent dramatic increase in productivity and competitiveness. Aid agencies need to desist the deeply rooted bias that only "Western" models of industrialization are "universal" and worth emulating.[164] This, of course, does not imply a blind and mechanistic replication of the new East Asian models. It only suggests that the menu of country experiences in now enriched and includes a possible positive role for government in developing technological capabilities.

Aid agencies, may be inclined to ignore market failures, a common and intrinsic feature of underdevelopment, for fear of supporting government interventions that might fail. A more balanced approach would "recognize both the limits and strengths of markets, as well as the strengths and limits of government interventions aimed at correcting market failures."[165]

Japan, and subsequently the first-tier Asian NICs, are already acting as powerful models for neighboring countries, and beyond.[166] Their demonstration effect for other developing countries cannot be underestimated. They represent the first successful industrializers among "non-Western" societies and institutions. Their experience has attracted the attention and emulation of second-tier industrializing countries. Replicability, therefore, is being tested on the ground, ahead of the theoretical debate and of current practices of aid agencies.[167]

Tailoring IT Strategies to Countries

National strategies for IT should be tailored to levels of development and technological capability, size and structure of the IT market, managerial competency, telecommunications infrastructure, financial and technology support capabilities, and the relationship between government and business. A more custom-tailored approach to IT policy prescription is required to take account of government capability in selective intervention and of

164 This deep rooted bias in development literature and practice is best depicted in Michael Adas' *Machine as the Measure of Men,* Cornell University Press, Ithaca, New York, 1989.

165 Stiglitz, "Markets, Market Failures, and Development", in the *American Economic Review*, May 1989, pp. 197-203.

166 A new wave of research in OECD countries is seeking to learn from these models for the already industrialized economies.

167 The East Asia Miracle Study, of the World Bank, was initiated in 1993, in part in response to Japan's request and funding; the "look East" policy of Malaysia, in contrast, started in mid 1980s.

the learning phase of local IT producers and users. That does not deny replicability, but warns against a simple formula for all contexts.

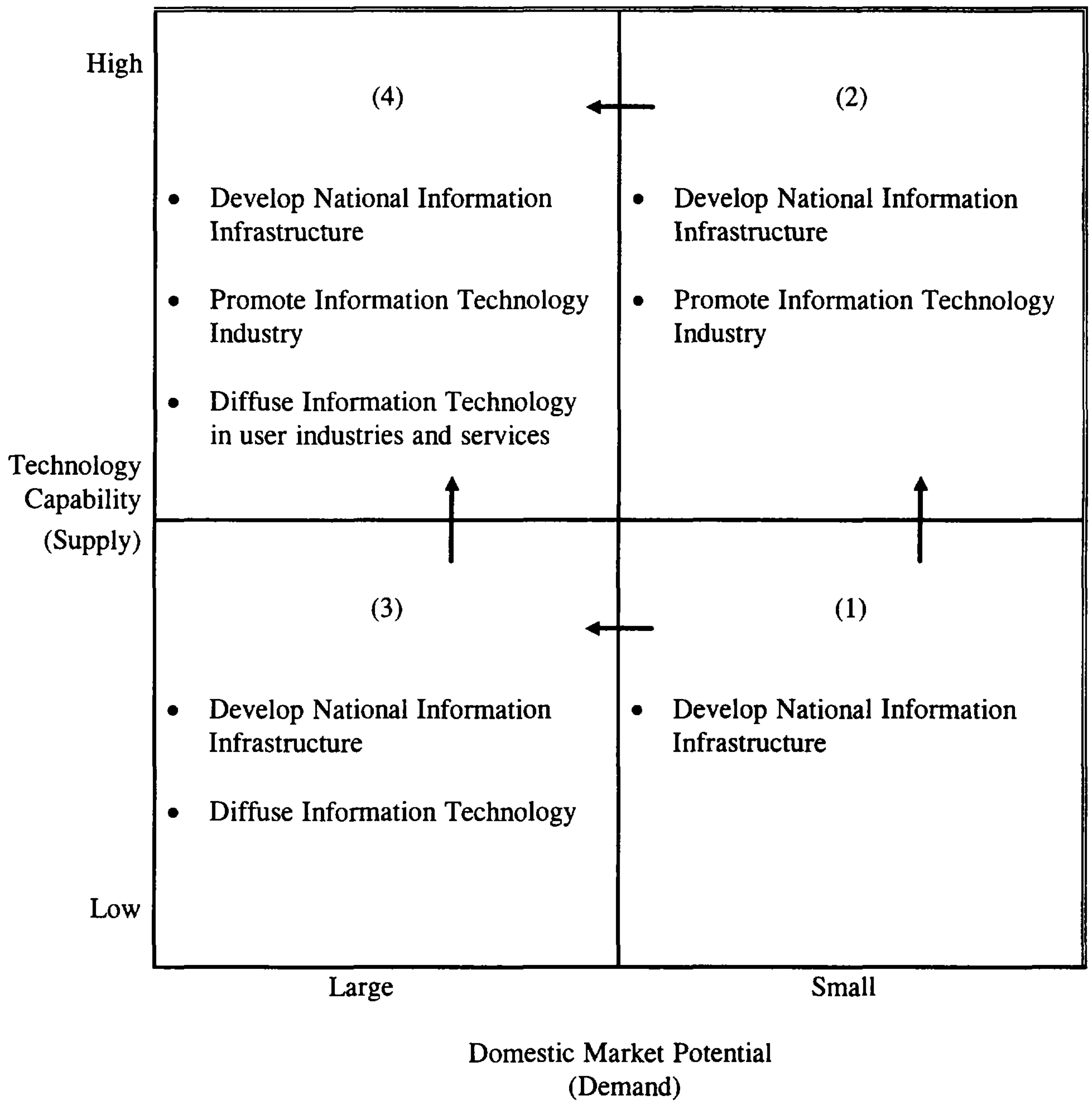
A simple scheme to think about tailoring IT strategies is proposed here (*figure 7.1*). The priority for promoting IT as industry, technology and infrastructure would vary primarily according to technological capability and domestic market potential of an economy. Accordingly, developing countries with relatively advanced technological capabilities and large domestic markets (such as Russia, India, Brazil, China, and Korea), may promote promising segments of the IT industry, develop policies and programs to diffuse IT in key user industries and services, and invest in strategic components of the national information infrastructure (NII). These countries can further exploit the synergy among these capabilities, for example, by developing those technological capabilities here of the IT industry (such as software) which are crucial for IT export as well as IT diffusion and NII development.

For countries with less advanced technological capabilities but a potentially large domestic base of user industries (such as Pakistan, Indonesia, Bangladesh, Viet Nam, and Nigeria), the primary focus would be on low-cost IT diffusion in promising user sectors and on selective investment in the NII. The development of NII may be used both to support IT diffusion and modernize basic public services. Economies with advanced technological capabilities and small domestic markets may adopt IT strategies that would target global market niches of IT for export and, at the same time, build a comprehensive NII. Singapore and Taiwan are models of such a strategy. Finally, small size economies with low technological capabilities cannot afford to be left out of the global information network and may focus their IT strategy on building a NII that would support the modernization of basic infrastructure and the export of services. This group may include Sri Lanka, Mauritius and many African and Caribbean countries.

A national IT strategy should deal with the problems and opportunities of a specific economy at a specific point in time. The experiences of Japan and Asian NICs suggest a much richer menu of strategic choices. Even when adopting similar perspectives, countries may pursue different instruments and coverage. For example, while small but technologically advanced countries may afford to build a world-class information infrastructure in support of the whole economy, large but low-income and less industrialized countries may have to focus their NII efforts on few national projects, to provide a basic technological platform and demonstration effects and to induce private and international investment capital.

The typology of countries and the assigned priorities to IT roles should be seen in dynamic terms. As countries learn to become advanced IT users and build a demanding domestic market, they may move towards selective development of the local IT industry. Small, less developed economies may build on the development of an advanced NII to export information-based services, to attract multinationals who are intensive users of the NII, and to diffuse information technology among their user industries and services. Countries with limited technological capabilities may design their investment plans in the NII, and their programs to promote IT use very selectively to ensure the development of common standards and competitive domestic markets, and to create opportunities for capability development among local IT producers.

Figure 7.1: TAILORING STRATEGIES TO COUNTRIES



Role of Aid Agencies

Should aid agencies promote IT use and diffusion? Can they play a role in creating a new type of infrastructure, the NII? Is there a role for aid agencies to play in promoting technological deepening and competitiveness of the IT industry, so that developing countries may participate in the largest and fastest growing industry in the world? What are the implications of the ongoing IT revolution for human resources development, employment, competitiveness, national development strategy, and international cooperation?

It is proposed that aid agencies develop a new focus on informatics. This focus would help developing countries adjust to the emerging, fast-moving information-driven global economy. Aid agencies may help developing countries to: (i) build a national information infrastructure; (ii) diffuse IT for private sector development; (iii) promote promising segments of the IT industry; (iv) develop human capital for the information-based economy; (v) facilitate development of a global information infrastructure (GII); and (vi) build national capacity for strategic management of IT.

(i) Build a National Information Infrastructure

Aid agencies may consider assisting countries to establish specialized "infrastructure development funds" for this new type of infrastructure: the NII. Such funds are being established for traditional infrastructures such as power and transport, to mobilize private capital and meet the large investments required, and to improve the management of infrastructure services. These funds leverage government resources and official development assistance by attracting cofinancing from the private sector. They also create credit histories for borrowers. In time, these borrowers can secure direct access to capital markets. Both the advanced elements of an NII and the telecommunication backbone would be attractive for both private and government-sponsored funds. Lessons learned from establishing and operating such funds for traditional infrastructure should be transferable to the NII.[168]

Aid agencies may also reorient their assistance to the telecommunications sector to promote the development of a responsive NII. The new emphasis would be to assist countries to formulate sector strategies and policies designed to promote new entry, competition, private participation, and user choice. Yet, this infrastructure and the services offered should be made also responsive to the needs of the social sectors, rural population and disadvantaged groups.

To fully exploit the potential of the NII and build user capabilities to develop applications based on this infrastructure, aid agencies may also explore the development of innovation funds and common databases for the public and private sectors. Applications such as electronic commerce or electronic libraries will require collaboration among public and private agencies to set standards, develop software, share development costs, pilot services, and ensure

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[168] World Bank, *World Development Report 1994*, Oxford University Press, New York, 1994.

user participation in design and management of the new services. Early applications and demonstration projects will vary, in line with national or local priorities. Aid agencies may help government, private, and non-profit organizations to use the NII to tap both global and local knowledge, and to organize information resources for priority user groups such as entrepreneurs and researchers. A bottom-up approach to build communities of users and demonstration effects would ensure a balanced investment between the information "highway", and the "feeder roads", and value added services to access and exploit the basic infrastructure. To enable information sharing and the development of information markets, aid agencies should also assist in the formulation of policies for public information sharing, data protection, privacy, computer security, intellectual property rights, and other legal and regulatory issues.

Governments are major collectors, users and providers of information in all economies. Information is typically a "public good". Public sector practices in collecting and disseminating information are critical to the coverage, quality, timeliness and relevance of such information. In most developing countries, information resources management in the public sector is poor, assigned low priority, and isolated from the ongoing IT revolution. Not surprisingly, whole economies and societies suffer from information scarcity, particularly small businesses and the poor. Aid agencies should give priority to improving the government's information resources management, including its practices in sharing these resources within and outside the public sector.

Aid agencies may also harness the power of IT for reorienting governments and modernizing the management and delivery of public services. Singapore illustrates the promise of using IT for one stop, non-stop public services. The NII may become a new channel for learning, extension, monitoring, and the delivery of basic services to vast populations. It may facilitate transactions between the public and private sectors through computerized payment systems, land and company registries, tax and customs automation, etc.. Apart from reducing transactions costs, these applications could build valuable databases, covering geographic, demographic, economic and trade information, for use by government, business and community organizations. Selective and phased investments in such large-scale applications can be planned as building blocks of a national information infrastructure. The NII could become a key tool for aid agencies concerned with reorienting governments, developing a competitive private sector, improving access to learning, and promoting participation and national consensus.

(ii) Diffuse IT for Private Sector Development

Aid agencies could play a role in developing institutions and programs to diffuse promising IT applications to SMEs, a role quite similar to their assistance to develop agricultural extension systems and spread the green revolution among small farmers. These enterprises have special needs that are often neglected, and have more direct impact on employment and poverty alleviation. Common applications using CAD and MRP, among others, are transforming product design, inventory management, production planning, machine utilization, subcontracting and procurement. These generic tools are spreading among all industrial countries and the Asian

NICs, and have become key to productivity, quality, flexibility and subcontracting in many industries. They may have become essential to the competitiveness and survival of SMEs. Therefore, almost all OECD countries and the Asian NICs have devised programs to spread the benefits of IT to their SMEs.

Two broad approaches may be used, in complementary ways. One is to develop programs that provide consultancy assistance for IT-based product and process innovation. This approach enhances the firms' internal capabilities to adopt and manage the new tools. Many lessons have been learned about improving the effectiveness of such "hands on" assistance programs.[169] Sharing the costs of such services with users, and promoting private sector participation in the delivery should enhance program responsiveness. They should aim at enhancing the strategic capabilities and management practices of user enterprises. As specialized consultancy resources are scarce in developing countries, IT consultancy development and training may be necessary. NGOs may be also mobilized for diffusion programs. Continuous evaluation and adaptation of these programs are a key to effectiveness.

The second approach involves "hands off" measures, such as establishing institutional, physical and knowledge infrastructures for SMEs. This involves reorienting existing or organizing new institutions, since industrial extension and private consulting services are often least responsive to SME needs. Knowledge infrastructure may include specialized databases and networks to facilitate SME access to technical and market information, and cooperation among SMEs and the larger enterprises. They may also include links between SMEs and universities, research institutes, testing and demonstration facilities and other knowledge transfer agencies. Aid agencies may help developing countries draw on international "best practices" in designing and managing such diffusion programs and infrastructures.

(iii) Promote the IT Industry

Aid agencies could play important roles in supporting developing counties to overcome entry barriers into promising segments of the global IT industry, and to restructure their private and public enterprises to become internationally competitive. The case studies indicate the importance of developing focused, coherent and realistic strategies, based on competitive assessment and clear understanding of the dynamics and technological learning required for various segments of the IT industry. Such strategic analysis is needed at the firm and country levels.[170] Aid agencies could facilitate worldwide sourcing of best practices and know-how to develop such strategies. They could also use the process of strategy formulation to build government-business partnerships and form strategic alliances between local and foreign firms.

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169 Hanna, et. al. (1994, op. cit.).

170 See, for example, Hanna (1994), *Exploiting Information Technology for Development: A Case Study of India*, World Bank Discussion Paper 246, Washington, D.C.

Technical assistance and advisory services may become more important than financial transfer in this area of development assistance.

Certain segments of the IT industry present unusual opportunities and challenges for developing countries. One of the most promising segments, for many developing countries in particular, is the software services. This is one of the fastest growing global industries, with relatively low entry barriers, and high value-added and labor-intensity. As a young and dynamic industry, born during the 1980s, it is private-sector owned and led. Software development is also a core capability needed for diffusing and adapting IT to local needs. Yet the dynamic growth of this segment is constrained by the lack of supportive policies and infrastructures for the predominantly small size enterprises involved. For example, financial institutions are not prepared to deal with the intangible assets, and unfamiliar markets and risks of software firms. Innovative programs are needed to improve access to appropriate finance, specialized marketing assistance, quality improvement consultancy services, and information on overseas markets. Specialized programs may also mobilize (through cost-sharing with users) local and international consultancy services to facilitate subcontracting and strategic alliances between local software companies, and foreign users and suppliers. Such programs may be complemented by policies to improve software protection, and to promote domestic competition and appropriate standards for public procurement of systems development and software services.

(iv) Develop Human Capital for Information-based Economy

Aid agencies must come to grips with the profound implications of information technology for the new global division of labor and the new skills required for managing and competing in the information age. Targeted programs are needed to educate public and private managers, to lead the process of changing the skill mix, building a flexible workforce and developing specialized IT staff and information resource managers. Singapore's experience in creating specialized IT training institutions, in joint ventures with leading IT multinationals, is a promising model. Educational programs should also integrate computer literacy and applications into management, engineering, science and other disciplines. Productivity of knowledge workers and access to global knowledge depend on skills in managing IT and information resources, and these capabilities are likely to increasingly shape national competitiveness.

(v) Facilitate Development of a Global Information Infrastructure

For the majority of developing countries, which have barely begun to industrialize, the key issue is how they can avert the prospect of isolation from the communication-driven globalization process. For many, foreign direct investment is unlikely to be a major source of access to the new technology. Many lack the basic infrastructural and human resource prerequisites to make effective use of the new technologies. For these countries, the most relevant policy concern is how to create an international economic environment that, in the least, avoids their marginalization.

The vision of a global information infrastructure (GII) to link the various NIIs of developing countries to a global one should provide a driving force for international cooperation.[171] Aid agencies may play a catalytic role by creating public-private fora to address the issues arising from implementing such a vision: promoting universal access to basic services on the GII, setting technical standards, building user capabilities, mobilizing private sector investment, demonstrating innovative uses in developing countries, and financing priority applications for human resources development and natural resources management.

(vi) Develop National Capacity for Strategic Management of IT

Aid agencies should assist governments in formulating strategies and policies to diffuse IT in support of overall national development strategies. They may advice governments about the strategic implications of information technology for key sectors like trade, manufacturing, logistics (advanced infrastructures) and education. The long-term objective should be to build local capabilities for scanning the global environment and developing "home grown" strategic responses to the ongoing technological revolution.

Assistance to develop local capabilities for strategic management of IT should aim to create partnerships between the public and private sectors to set policies, determine priorities, and focus resources on the strategic directions for IT development and diffusion. This assistance is best carried out through a collaborative process to develop a national IT strategy, that is, through learning by doing. Such a strategy would aim at:

(a) Creating an Enabling Environment for IT Diffusion: This would induce potential IT users to invest in their information and communication capabilities and modernize their transactions systems. As many countries tended to develop a framework biased in favor of protecting the domestic IT industry and restricting competition, this reorientation may require policy reforms in favor of low-cost access to information and technology acquisition -- lowering import duties on hardware and software and promoting domestic competition.

(b) Developing Capabilities and Institutions: Market failures in information, skills and capital, among others, are common in developing countries, particularly for new technology adoption and for small and medium enterprises. Incentives cannot do all the work. Capabilities and institutions determine the supply response to incentives. A national IT strategy would address supply-related constraints such as inadequate managerial and technical skills to invest in and use IT; to design and deliver information and software services; and to develop links with international sources of IT products and know how.

Government can play crucial roles in building responsive institutions to deliver information and support services, and to facilitate capability formation where market forces are deficient. Concerted efforts are typically needed to raise awareness of public and private

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[171] For pioneering such a vision see Gore (1994).

executives regarding the demanding process of managing IT-enabled organizational change. A national strategy develops the incentives and institutions to supply the necessary informatics manpower and research capabilities. Creating central oversight and expertise within the public sector may be also critical to setting critical standards, sharing core information, and coordinating major investments in the national information infrastructure.

(c) **Setting Directions and Priorities:** Setting clear goals for public investment in IT requires systematic identification of the gaps in a nation's information infrastructure. This process should be guided by a vision of what improvements in information and communication would be required to address the fundamental development problems of an economy.

Government computerization projects, such as those for public financial management or customs and tax administration, are complex and resource-intensive. Benefits from such national projects will be fully realized only when phased to match the absorptive capacity and skills of providers and users. Setting priorities could reduce the pitfalls of donor-driven investments. The process should avoid excessive centralization, promote experimentation, and support bottom-up initiatives. An informatics strategy may therefore aim at developing the necessary funding channels, learning mechanisms and support institutions to enable small central agencies, local governments and SMEs, to exploit IT in line with their own business strategies and best practices. The larger public agencies could build their in-house capabilities to manage their information resources, identify their information and communications requirements, and outsource systems development and user support to the private sector.

(d) **Facilitating Public-Private Collaboration and Coordination.** A national IT strategy should ensure that information infrastructure services with "public good" characteristics are sufficiently produced through public-private cooperation. Coordination is also needed to invest in common databases. Government should induce the private sector to invest in or share the costs of such networks and "public goods."

An IT strategy would also coordinate investments in IT projects with substantial externalities. Where demonstration effects are important, concentration of resources would show how different elements of IT (infrastructure, standards, training) could be selectively brought together for high-priority projects. This would induce the private sector to invest and collaborate, and at the same time make successful implementation more likely. A national strategy that is well-understood among businesses, policy makers and society at large could create the constituency for IT policy reform.

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