Title
National Technology Policy and Computer Production in Asia-Pacific Countries

Authors
Kraemer, Kenneth L.
Dedrick, Jason

Publication Date
1995-12-01

NATIONAL TECHNOLOGY POLICY AND COMPUTER PRODUCTION IN ASIA-PACIFIC COUNTRIES

Kenneth L. Kraemer and Jason Dedrick

Center for Research on
Information Technology and Organizations
(CRITO)

Graduate School of Management
and
Department of Information and Computer Science

University of California, Irvine

NATIONAL TECHNOLOGY POLICY AND COMPUTER PRODUCTION IN ASIA-PACIFIC COUNTRIES*

Kenneth L. Kraemer and Jason Dedrick**

I. INTRODUCTION

The relationship of technology to economic development has gained increasing attention from scholars and policymakers in recent years (e.g. Evenson & Ranis, 1990; OECD, 1992). One area of discussion has focused on the role of government in regard to technology creation and diffusion. Some (Balassa, 1981; Little, 1982; Ranis, 1990) see government promotion of particular technologies as a corollary of industrial policies which attempt to "pick winners and losers," thus subverting the functioning of the marketplace. According to this view, market forces should determine where and how technology is produced and used, and government should limit its role to provision of public goods and mitigating market failures (although there is significant variation in the definition of what fits into these categories). Other analysts (Amsden, 1989; Wade, 1990; Ernst & O'Connor, 1992) point out that the private sector tends to chronically under invest in high-cost, high-risk technological innovations that have relatively long payback periods. Under such circumstances, it is argued that government must act to support technological development, either through its own research activities, or through subsidies to the private sector.

The former view has been explicitly embraced by the governments of the United States (prior to the Clinton era) and the United Kingdom, within the broader context of so-called "market-directed" economic systems. Such an approach is marked not by an absence of technology policies, but rather by the absence of a centralized, coordinated strategy. The latter view is more prevalent in Europe, Japan and the East Asian newly industrializing countries (NICs), whose "plan-directed" economic approaches are more amenable to government manipulation of market forces. This view has guided the development of a more coordinated approach to technology policy in those countries.

While this dichotomy of views has created considerable controversy in academic and policy circles, some voices are beginning to suggest that it is time to move beyond the ideological debate and attempt to understand how government policy can be applied to achieve economic objectives. This approach calls for a careful consideration of the effects of past and present policies to gain insight into what policy approaches are effective under what circumstances. There have been few studies of technology policies which compare a number of countries systematically in order to analyze policy outcomes.

This paper looks at government technology policies in the Asia-Pacific region in regard to information technologies, in order to compare the effectiveness of various policy approaches in promoting the production of computer hardware, software and services. The Asia-Pacific region has been the fastest growing economic region in the world for the last 30 years and is expected to continue to be so into the 21st century. In the past ten years, the region has seen rapid growth in the information technology (IT) sector, led by the development of a competitive and large IT industry in Japan, followed by rapid growth in Korea, Taiwan, and Singapore. Each of these countries has developed strong government policies for the promotion of the IT industry, believing that the state had to take the lead in planning the development of the industry and not be content allowing market forces to prevail. Even the market-oriented Australian government established an Information Industries Strategy in 1987.

However, other countries in the area, namely New Zealand, Hong Kong, and Australia pre-1987, have taken a generally free market approach toward IT. Each of these countries has become a major user of IT and a producer of IT in certain product niches. Developing countries such as Thailand, Malaysia, Indonesia and the Philippines are in the early stages of computerization and have recently begun to formulate national IT plans. Thailand has promoted hardware production since the early 1980s through tax and other incentives to the private sector.

A number of rationales are given for government intervention to promote IT production. IT is considered a high growth industry with potential for creating jobs and economic growth. Also important for the East Asian countries is the fact that IT production requires low energy and raw materials inputs. These factors are important considerations for countries attempting to adjust to rising wages and maintain economic growth despite the lack of natural resources. IT is also considered an economic and technological driver, as technologies developed for IT can be applied to other industries and a growing IT industry can drive growth in supporting industries such as components and manufacturing equipment. Finally, IT is considered to be of strategic importance for national defense, as illustrated by the role of military procurement in the early development of the U.S. computer industry.[1]

Although we are interested in IT broadly conceived (including computers, telecommunications, semiconductors and various information services), we focus on the computer sector—hardware, software, services—in the empirical analysis. We treat other sectors of the IT industry as complementary to the computer sector. They provide inputs (components, semiconductors), industrial capacity, skilled workers, and needed infrastructure (e.g. telecommunications). We choose the computer sector because of its strategic importance, because national IT policies target this sector for development, and because understanding the nature and effects of environment and policy requires such focus. We select eleven Asia-Pacific countries because they represent different levels of economic development, as seen in Figure 1, are at various stages of computer industry development, and take different policy approaches.

Figure 1. Countries by Level Of Economic Development

Developed	Newly Industrializing	Developing
Japan	South Korea	India
Australia	Taiwan	Malaysia
New Zealand	Hong Kong	Philippines
	Singapore	Thailand

Computer production was very low in all the countries except Japan in late 1970s. During the 1980s, Singapore, Taiwan, Korea and Thailand experienced tremendous growth in computer production, while Hong Kong lost its initial lead. What accounts for this tremendous growth? Each of the three NICs adopted national IT plans around 1980 which targeted the microcomputer industry for development. Each used different vehicles to implement this strategy, based on its local environment: Singapore teamed up with the multinational corporations (MNCs); Korea pushed its large conglomerates into computer production; and Taiwan orchestrated the efforts of its many small firms through government-run laboratories and institutes. In addition, each government provided a series of trade, tax and industry promotion incentives. Thailand did not implement a specific national IT plan, but did provide tax breaks and other incentives to electronic companies to spur hardware production. India employed the strongest government intervention in the computer industry, but focused on nationalist goals of technological independence and state ownership of production, an approach which resulted in limited success in computer production.

Hong Kong, with its laissez faire approach, grew slowly in computer production during the 1980s, and its industry remains limited to simple screwdriver type assembly operations. Australia and New Zealand maintained a market-directed strategy and had little success in computer production. In 1987, Australia offered some limited incentives to MNCs to encourage increased exports and R&D, but computer production had not taken off as of 1990. Malaysia and the Philippines are in the early stages of implementing IT plans, but are considered market-directed for this paper, which looks at IT production from 1984 to 1990.

As the foregoing discussion suggests, this paper provides evidence of the effects of technology policies on computer production, based on comparative analysis of the countries in the region. Section II of the paper presents the conceptual framework for the analysis. Section III presents the methods and data used in the analysis. Section IV compares government strategies and policy instruments and presents comparative data on computer production. Section V presents comparisons and conclusions based on the data and case studies discussed. Section

VI provides recommendations to policymakers as to what factors they should consider in dealing with computer policy.

II. CONCEPTUAL FRAMEWORK

Broadly, national strategies toward computer production can be characterized by what some analysts distinguish as plan-directed and market-directed economic strategies (see Weber, 1968; Johnson, 1982; Wade, 1990). Plan-directed strategies are based on the idea that the market is a tool for achieving economically and socially desirable objectives and that government has a role in directing the market toward such objectives. Market-directed strategies are based on the idea that the operation of the free market will lead to optimum resource allocation and result in the most desirable economic outcomes. Thus, the government's role is limited mainly to regulating the private sector to achieve social goals such as pollution control or equal opportunity, and to providing public goods such as education and infrastructure. While plan-directed strategies treat the market as a means to achieving government-determined ends, market-directed strategies treat the market as an end in itself—an alternative allocation mechanism to political/bureaucratic processes.

The market- versus plan-directed dichotomy represents two models of industrial and technology policy. In the plan-directed model, government policies are aimed primarily at economic and industrial development, with certain industries targeted for promotion. In the market-directed model, it is believed that market forces can better allocate resources than politicians or bureaucrats, and that the government should concentrate on ensuring the smooth operation of capital, labor and product markets. Government promotion of a particular industry is only justified on non-economic grounds, such as national security.

Under the plan-directed model, industrial policy is usually designed and implemented by an economic "pilot agency," such as Japan's Ministry of International Trade and Industry (MITI) or Singapore's Economic Development Board. Industry coordination is provided by this agency or by a sector-specific agency created for this purpose, such as Singapore's National Computer

Board. However it is organized, the plan-directed economies are marked by strong industry coordination.

The market- vs. plan-directed distinction provides a good theoretical starting point for analyzing and comparing industrial and technology policies in different countries. However, in its simplest form, the distinction has two drawbacks. First, there is ideological baggage attached to these terms, especially in the U.S., where the concept of a planned economy was long associated with a Soviet-style political and economic system, and more recently has been denounced as an effort to "pick winners and losers," rather than letting the market function. Second, the distinction implies that countries fit cleanly into one group or the other, and that the two sets are mutually exclusive.

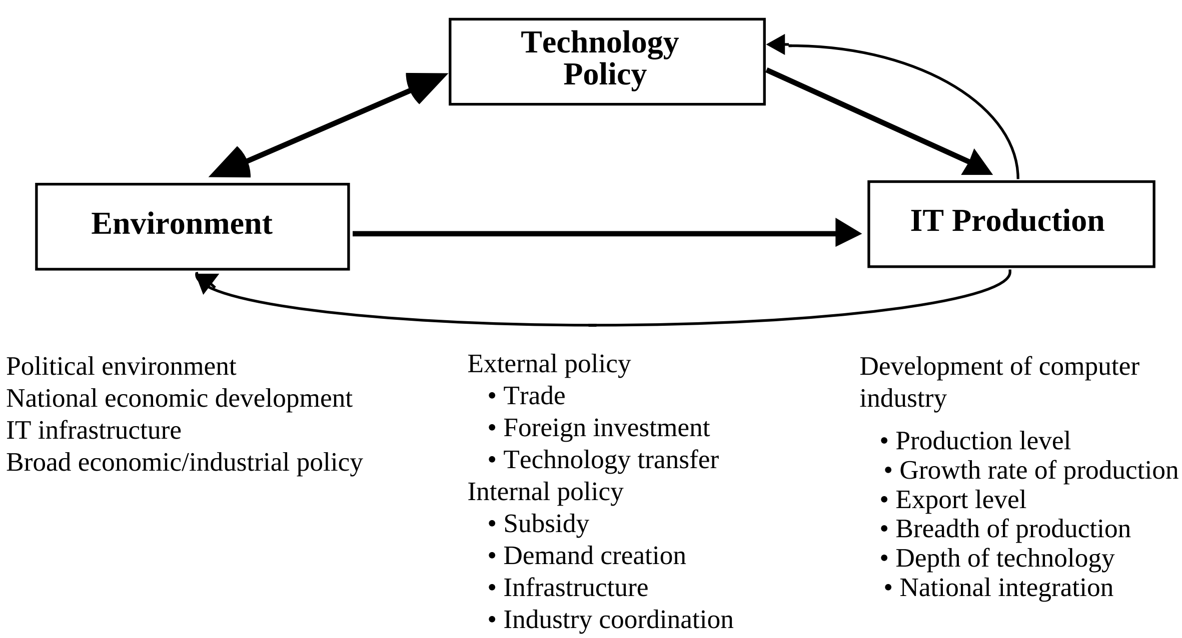
In response to these perceptions, this paper provides a more nuanced approach to defining technology policy. First, it asserts that the distinction between plan-directed and market-directed strategies is not absolute, but a matter of degree. All governments are engaged in policies which have an impact on the development of high-technology industries. Governments operate public education systems, provide support for research, influence exchange rates and interest rates, set tax and tariff rates, and regulate telecommunications and other public utilities. All of these policies affect the computer industry. More directly, government procurement accounts for a large share of most countries' computer markets, in some cases over 50%. The procurement procedures employed have a major effect on the industry. Thus, it cannot be argued that some governments have technology policies and others do not. The definition of market- versus plan-directed is based on the nature and extent of government intervention, rather than its presence or absence. In regard to government policies toward the computer industry, this paper defines countries' policies as predominantly market-directed or plan-directed on the basis of empirical data on the extent of government planning and intervention.

To understand the factors driving the development of computer production in Asia-Pacific nations, it is necessary to acknowledge that in addition to government policy, computer production is strongly affected by national economic and political environments. The framework for analysis employed in this paper (Figure 2) posits that computer production is shaped by environmental factors, such as the state of economic development and the presence of an adequate infrastructure, both directly and through the moderation of technology policies which promote (or inhibit) computer production. It also shows that the environment and infrastructure are affected by government policies in areas such as education, science and technology and direct investment in infrastructure. Based on this framework, three questions define the focus of this paper:

1. What is the nature of success in computer production?
2. What types of environmental endowments are related to success in computer production?
3. What types of government policies are related to success?

In analyzing these questions, we employ the framework for analysis illustrated in Figure 2.

Figure 2. Framework for Analysis



This paper does not deal directly with the issue of the use of computers in the economy and the effects that promotion of computer production might have on use. This is a critical issue, and is dealt with in a companion paper (Kraemer and Dedrick, 1993a). The current paper focuses on the effects of environment and policy on development of a computer industry.

Success in Computer Production

There are no agreed upon measures for success in computer production, but we use six measures to provide a basis for comparing success among the countries in this analysis. These include measures of industry output and exports, the breadth and depth of the industry, and the integration of the industry into the domestic economy. Three of these are quantitative and three are qualitative.

Quantitative Measures

- *Level of production* refers to the quantity of production in dollar volume. The *dollar volume of production* is a quantitative indicator of how large a player a particular country is in the computer industry in comparison to others.
- *Growth rate in production* refers to the growth rate of the computer industry from 1983 to 1990. This period is important, because three of the plan-directed countries (Korea, Taiwan, and Singapore) put National IT Plans into effect in the early 1980s, while Japan launched a series of new national R&D efforts for the IT sector (Sigma, Fifth Generation Project, TRON). Thailand also implemented investment incentives to promote computer (and electronics) production in the 1980s. The effects of such plans, if they exist, should show up in growth rates over that period, compared to the countries with no plans.
- *Export orientation* refers to the level of exports in dollar volume. The *dollar volume of exports* is an indicator of the relative size of the country's participation in the international computer market and its ability to compete internationally.

Qualitative Measures

- *Breadth of production* refers to the range of categories in which the country has significant production capacity. We count seven major categories: four for hardware and three for software/services. The hardware categories are: 1) mainframes, 2) minis, 3) micros, and

4) peripherals. The software and services categories are: 1) system software, 2) packaged applications, 3) custom applications. These can be further subdivided to provide a clearer picture of the comparative breadth of different countries. For instance, production of peripherals can be broken down into monitors, keyboards, mother boards, power supplies, etc.

- *Depth of technology* refers to the level of technological sophistication involved in computer production. We define three levels of sophistication for hardware and three for software. For hardware, they are: (1) assembly, (2) manufacturing, and (3) research and development. For software, they are: (1) coding and data processing, (2) systems integration, and (3) software design.
- *National integration* is the degree to which the computer industry is integrated into the domestic economy and local capability is created. This includes the level of participation by domestically-owned companies, and the amount of backward and forward linkages. Each of these is an indicator of the extent to which the national economy is receiving long-term benefits in the form of technology transfer, human resource upgrading, and links for local entrepreneurs to the international economy. If a country serves only as a platform for production by multinational corporations, the benefits of computer production may largely be lost if those corporations relocate their production activities to another location.

In order to compare the countries' success as computer producers, we score them from one to five in each of the three qualitative categories. We then give each country a total score for sophistication and local capability in computer production, based on these rankings. The countries are ranked according to these scores, as well as for the three quantitative measures. These rankings are combined to provide an overall rank for hardware and software production for use in conducting Spearman rank correlations against various environmental factors, as well as comparing the effectiveness of different policy approaches.

Environmental Endowments Related to Success

A country's ability to become a computer producer is believed to depend very much on its existing endowments for production. These include broad factors such as political stability and level of economic development. *Political and social stability* are important factors in determining the willingness of the private sector to invest in a country, especially in a high risk industry such as computer production which requires large investments in plant, equipment and technology. A nation's level of *economic development* determines the size of the local market for high technology and the quality of the infrastructure. In addition, a number of specific endowments are believed to be necessary to success in computer production. These constitute what we refer to as the *information infrastructure*. While these vary somewhat between hardware and software/services, as shown in Figure 3, the general requirements are similar.

Figure 3. Infrastructure Requirements for Computer Production

Requirement	**Hardware**	**Software/Services**
Capital	Large amounts of long-term capital at competitive rates. "Patient" investors.	Venture capital. Investors who understand the unique nature of the software industry.
Human resources	Computer scientists and engineers, manufacturing managers and engineers, technicians, marketing and finance specialists.	Programmers, systems analysts, software engineers. English language competence very useful.
R&D	R&D institutions able to effectively apply imported technologies to local production and to develop technology locally.	Ability to adapt imported programs to local uses and languages.
Industrial capacity	A strong industrial base, especially in complementary industries such as consumer electronics, components and semiconductors.	--
Physical infrastructure	Adequate transportation, telecommunications and electricity systems	Telecommunications network with data transmission capabilities
Other	--	Access to necessary hardware and software development tools.

As pointed out in the conceptual framework, these factors are part of the national environment in each country, but are not determined by market forces or natural endowments alone. All are affected to a great deal by government policy in areas such as education, science and technology, and regulation of financial institutions. Even the presence of complementary electronics industries in many Asia-Pacific countries can be related to earlier and ongoing government policies to promote those industries. Thus, environment and policy are closely linked, not two separate sets of factors.

Government Policy and Success in Computer Production

There are several ways of characterizing government policies, as illustrated by King, et al. (1992), Arnold and Guy (1986), and OECD (1988). We have developed a scheme (Figure 4) adapted in part from analyses of the electronics industry by Dahlman (1990) and colleagues at the World Bank and by the US Department of Commerce (1990).[2]

Government policies which affect computer production fall into three categories. The first are broad *macroeconomic and industrial policies* such as monetary and fiscal policy. This paper will not look at those policies except in cases where they are more specific to the computer sector, as in the case of tariff rates on computer imports. This is not to underestimate the importance of such macro policies, but this paper focuses on technology policy related to computer production.

The second group—*external policies*—relate to the international environment. They include policies for trade, foreign investment and technology transfer. In each case, there are examples of incentives and restrictions which may be applied. For example, trade might be restricted by tariffs, quotas or non-tariff barriers, or it might be promoted by various export incentives. Foreign investment and technology transfer into the country can likewise be promoted or restricted by policies such as those outlined in Figure 4.

The third group—*internal policies*—are those which directly target the computer industry. These policies support domestic industry, create local demand, or develop infrastructure. Support to domestic industry can take the form of direct grants, tax incentives, low cost loans or direct government ownership of computer firms. Local demand can be created or increased through government procurement policies which favor local producers, incentives to users, or mobilization of bias to create a favorable attitude towards computer use. Infrastructure development includes provision of technical education, improved telecommunications services, and support for research and development.

Figure 4. Policy Instruments Defined

Category	Policy Instruments	Examples
External		
Trade	Export promotion	Export financing facilities, tax breaks on export income, overseas marketing assistance.
	Import restrictions	Formal: tariffs, quotas, licensing requirements. Informal: obstructive standards requirements, "buy local" requirements.
Foreign investment	Promotion	Tax holidays, free trade zones, employee training, subsidy of plant construction.
	Restrictions	Equity restrictions, limits on profit repatriation.
Technology transfer	Promotion	Requiring foreign firms to transfer technology or conduct R&D in the country, offsets requirements, assistance to local firms in obtaining and applying technology. Intellectual property protection for transferred technology.
Internal Domestic industry	Subsidies to industry	Payments to producers based on local production, industrial development grants, state-owned enterprises, government loans at below market rates with flexible repayment schedules.
Demand creation	Government procurement	"Buy local" requirements, pilot projects, procurement of new technologies, network development.
Infrastructure	Computer skills training	University education in computer science and related fields, vocational training for technicians.
	Telecommunications	Investment in networks, enhanced services, improved technology such as digital switching.
	R&D	Direct funding of R&D. Tax credits to firms for R&D expenditures. Creation of cooperative research consortia.
Industry Coordination		Presence of an agency or agencies which coordinate government policies relating to computer production.

Relationships Among Environment, Policy and Production

The analyses in this study are drawn from expected relationships between the foregoing three sets of variables. At the broadest level, we are examining the relative success of plan-directed and market-directed strategies.

At another level, we examine what environmental factors and government policies are related to success in computer production. With respect to environment factors, we expect that the greater the level of economic development and the greater the information infrastructure in a country, the greater the capabilities for computer production. The environmental factors represent initial endowments which enable and facilitate production. Once computer production is made a policy objective, both external and internal policies can affect successful development of a competitive industry. We expect that external policies promoting trade, foreign investment and technology transfer to a country will be positively related to success in computer production. And we expect that internal policies such as industry subsidy, demand creation, and infrastructure provision will also be positively related to computer production.

Moreover, we expect that both the nature and level of requirements for success in developing a hardware industry will be different from those required for the software industry. In addition, we expect that the requirements for developing local, indigenous computer production are different from those for developing production for export.

III. METHODS AND DATA

The method of analysis used to examine the expected relationships involves comparison of the environmental factors and government policies related to the success of each country in developing a computer industry. We measure success in computer production based on the six categories presented in the conceptual framework and rank the countries accordingly. We then examine the environmental factors and government policies associated with each grouping using rank order correlation and simple comparison tables in order to determine what factors are associated with success in computer production. The analysis has both static and dynamic elements. It is static in that it compares the computer production of all countries at the same point in time. However, it is dynamic in that it also looks at growth rates in production and changes in countries' policies over time.

The data for this analysis was collected from secondary data sources, country reports, and original data collection through fieldwork and interviews in each country. The secondary data sources used to construct the tables include the *Yearbook of World Electronics Data, Volumes I&II* (Elsevier, 1992) and various country level reports on the computer industry prepared by government agencies, consultants, and industry associations.

The fieldwork consisted of searching for published and unpublished documents, reports, papers, and statistics on computer production and use in each country plus interviews with about 30 selected individuals in each country from government (ministries of trade, industry, national computer boards, national laboratories, etc.), industry (hardware and software vendors, R&D institutes), industry associations (electronics, hardware and software/services), universities, research centers, and professional societies (computer societies). The interviews were used along with published literature to develop historical case studies on the production and use of computers in each country.

The conclusions in the paper are drawn from examining the data and the case studies, both independently and together. The data provide quantitative indicators and easy comparison while the case studies provide rich detail and depth of understanding which helps to draw and support the conclusions.

IV. CROSS-COUNTRY COMPARISONS

Computer Production

Table 1 presents comparative data on computer production and exports, broken down into hardware and software.

Table 1. Computer Production and Exports

	Japan	Korea	Taiwan	Sing.	HK	Australia	India	NZ	Malaysia	Phil.	Thailand
Hardware											
Production (US$mil.)	53207	3181	4944	6864	1823	755	697	15	411	97	1586
Avg. growth, 84-90	13.1	41.1	36.7	35.3	16.7	19.1	50.3	n.a.	56.1	47.6	138.1
Exports (US$mil.)	18772	2447	5504	8705	2706	370	200	54	602	71	1511
Software											
Production (US$mil.)	13800	14	282	223	133	768	431	155	n.a.	n.a.	n.a.
Exports (US$ mil.)	n.a.	13	28	86	12	96	268	60	n.a.	7.8	n.a.

Years: Hardware - 1990; Software - 1992 (Singapore, Taiwan, India), 1991 (Korea, Philippines), 1989 (Japan, Australia, New Zealand, Hong Kong)

Sources: Hardware: Yearbook of World Electronics Data, 1992, Volume 2
Software: JIPDEC, 1990 (Japan); Velarde, 1993 (Philippines); III, 1993 (Taiwan); EIAK, 1992 (Korea); NCB, 1993 (Singapore); Darshini, 1993 (India); Crocombe, Enright and Porter, 1991 (New Zealand); BIS Mackintosh Ltd., 1990 (Hong Kong)

As can be seen in Table 1, Japan's computer industry stands apart from the rest of the region in level of production and exports. Japan's total hardware production and exports are second only to the United States in the world. The next group following Japan in hardware production are Singapore, Taiwan, Korea, Hong Kong and Thailand. Far behind are Australia, India and Malaysia, while the Philippines and New Zealand have very little production. Growth rates in production are an important indicator of the effects of policy in the 1980s. Japan has the lowest growth rate, but this is to be expected given the already large size of the industry. For Japan to grow at the rates of the other countries, it would literally have had to take over the entire world's hardware production. However, Japan's performance in the 1984-1990 period is still impressive, considering it nearly tripled the size of an $18 billion industry in six years. Thailand showed the most impressive growth, with production increasing at 136% a year to nearly catch up to Hong Kong. Among the NICs, Taiwan, Singapore and Korea grew at 35-40% rates, while Hong Kong fell far behind at 17%. The Philippines and Malaysia showed high growth on a very low initial base.

Japan also led the way in exports, at over $18 billion. Singapore followed at $8.7 billion, but this number is inflated by re-exports, as is Hong Kong's $2.7 billion figure (Elsevier, 1992, p. 13). Taiwan, Korea, Thailand and Malaysia follow Singapore. Malaysia tripled its exports in 1990 due to growth in assembly of components and peripherals for export. The other countries have very little export activity.

In software, the picture is much different. Japan again leads, but is followed by Australia, then Taiwan, India, Singapore, New Zealand, Hong Kong and Korea. India in particular has been successful in exporting software, as have Australia, Singapore and New Zealand. The others primarily develop software for domestic use.

Overview of computer industry by country

Japan produces a full range of products, from mainframes to minicomputers to microcomputers and peripherals. It has the technological capability to do advanced manufacturing and original design across the full breadth of products. In fact Japan is a leader in advanced technologies such as flat-panel displays, optoelectronics and a number of manufacturing processes (Kirkpatrick, 1991). In software, production volume is large, and Japanese companies have made extraordinary gains in productivity and reliability in the programming process, but they have yet to develop exportable applications for the international market except in computer games. In recent years, Japan's hardware industry has been hurt by the shift from mainframes to smaller systems, the appreciation of the yen, competition from the NICs, as well as a price war in Japan launched by Compaq in 1992. Companies are struggling to respond effectively to new market conditions. One response so far has been to move production, and even some R&D, offshore. In spite of its present difficulties, the Japanese computer industry has formidable strengths in technology and manufacturing and continues to challenge the United States for leadership in hardware production.

Taiwan has become a major producer of microcomputers and a number of components and peripherals. For instance, Taiwan has 70% of the global market for mice, 67% for mother boards, 40% for monitors, 35% for graphics cards, and 10% for microcomputers (III, 1992). Taiwan follows Singapore in total production, but much of Taiwan's production is by domestic companies, while Singapore is dominated by multinational corporations. There were 710 hardware and 350 software companies in Taiwan in 1990. Taiwan has focused on original equipment manufacture (OEM) contracts with foreign companies in the past, but companies such as Acer are succeeding in exporting their own brand name computers. Taiwan still depends on imports of technology and many key components, but its manufacturers are able to design and get standardized products (e.g. IBM clones) to market very quickly. Taiwan's software and services industry has grown rapidly, with output increasing from US$170 million in 1987 to US$282 million in 1990. Software exports have grown as well, but still only account for about 10% of sales.

Singapore leads the world in production of hard disk drives, exporting 14 million drives in 1991 (*Electronic Business Asia*, 1992, p. 38). Singapore also produced 1.7 million personal computers in 1990 and is home to a large number of companies producing components for the disk drive and PC industries. The industry is dominated by multinational corporations (MNCs), some of whom are moving R&D to Singapore and using Singapore as a design and testing site for new products, especially disk drives. Still, we rank Singapore behind Taiwan due to its Taiwan's greater depth and breadth of production, and the presence of a dynamic, locally-owned IT industry in Taiwan. Singapore's software industry reached an output of US$233 million with exports of US$86 million in 1991, ranking fifth in the region in production, but second in exports. Local companies play a more important role in the software industry than in hardware.

Korea's computer industry grew rapidly through most of the 1980s, but has staggered in recent years. The industry is dominated by a few giant *chaebol* (business groups), particularly Samsung, Goldstar, Daewoo and Hyundai, and a few smaller producers. They have been very successful in consumer electronics and memory chips, but have fallen behind Singapore and Taiwan in computer production. Korea's computer production is split evenly between personal computers and peripherals. The Korean government's TICOM project led to production of minicomputers by Korean companies based on imported technology, but so far sales are small and mostly limited to government agencies. Korean computer companies have been squeezed by price wars in the U.S. market and dependence on Japanese suppliers of components. Exports fell 50% in the first half of 1992 (*Electronics Business Asia*, 1992, p. 44) and slow economic growth has hurt domestic sales. Korea's software industry is still in its infant stages, primarily involved in adapting imported programs for the local market.

Hong Kong's total production and exports rank well behind the other NICs. It also trails those countries in breadth of production (PCs and some components) and in technological depth. Much of the production consists of goods made in China, then imported to Hong Kong for final test and packaging before being re-exported, often as 'Hong Kong produced.' (Elsevier 1992, p. 70). Hong Kong's IT companies conduct very little R&D and depend heavily on imported components. Hong Kong software companies are primarily involved in adaptation of imported programs for the local market and development of custom programs. There is great potential for those companies to tap the China market, but so far there has been little activity in this area.

Thailand has seen rapid growth in hardware production, from almost no production in 1984 to US$1586 million in 1990. This growth has moved Thailand well ahead of the other developing countries in the region, and in 1991, Thailand actually moved ahead of Hong Kong in IT hardware production (Elsevier, 1992, p. 14). Most of this production consists of assembly and export by foreign companies, mostly Japanese, Taiwanese and Korean.

Australia lags further back in hardware, with production a low percentage (0.3%) of GDP. IBM produces PCs and some components, and accounts for most of Australia's hardware exports. Australia is considerably more successful in software and services, trailing only Japan in the region in production and exports.

India's hardware industry has grown quite rapidly, from virtually nothing to US$700 million in a decade. However, production consists mostly of assembly of PCs and minicomputers for the highly protected domestic market. There is little component production, as past tariff policies made it most profitable to import components and assemble them for local sale. India's software industry, on the other hand, is quite dynamic. Taking advantage of a large pool of low-cost programmers and software engineers, Indian companies have exported programming services to US companies (body-shopping). Also, a number of foreign companies such as Citibank and Hewlett-Packard have moved some of their programming operations to India.

Malaysia experienced a surge in hardware production in 1990, after showing little growth through the 1980s. Malaysia's IT industry is concentrated in labor-intensive assembly operations by multinational corporations, with little participation by local companies and heavy reliance on imported components and technology. No information is available on Malaysia's software industry.

New Zealand has virtually no hardware production, but has a growing export-oriented software industry. New Zealand companies produce specialized software in areas such as agriculture, as well as business software under contract from foreign hardware companies such as Unisys.

The Philippines has a small hardware industry, although it is a significant producer of semiconductors. There is a growing information services sector based on subcontracting of data processing work for U.S. companies. Software exports totaled $7.8 million in 1991 (Velarde, 1993), but software and services exports combined for a total of $36 million (Devasahayam, 1992).

Based on case studies of the countries in the region, we score them from one to five for breadth of production, depth of technology and national integration in hardware production. The total is a measure of the sophistication of the industry and the extent to which national capabilities have been developed in hardware production. Similar ratings are difficult to make for software, since much less information is available about the nature of the software industries in each country.

Table 2. Country Rankings by Breadth, Depth and National Integration of Hardware Production

	Breadth	Depth	Integration	Total
Japan	5	5	5	15
Taiwan	3	3	3	9
Korea	3	2	4	9
Singapore	2	2	1	5
Hong Kong	1	1	1	3
Thailand	1	1	1	3
Malaysia	1	1	1	3
Australia	1	2	1	4
India	1	1	3	5
Philippines	1	1	1	3
New Zealand	1	1	1	3

Based on the statistical data in Table 1 and the rankings in Table 2, we rank the countries as follows for success in hardware production. Rankings in software are based on levels of production and exports in Table 1 only.

Table 3. Rankings of success in computer production

	Hardware		Software*
1.	Japan	1.	Japan
2.	Taiwan	2.	Australia
3.	Korea	3.	India
4.	Singapore	4.	New Zealand
5.	Thailand	5.	Singapore
6.	Hong Kong	6.	Taiwan
7.	Australia	7.	Hong Kong
8.	India	8.	Korea
9.	Malaysia	9.	Philippines
10.	Philippines		
11.	New Zealand		

*No data is available on software production in Thailand and Malaysia

We had expected, in line with conventional wisdom, that countries that are successful in the production of hardware would also be successful in the production of software. This expectation is grounded in the notion that capabilities, knowledge and skills are complementary and synergistic. We found, however, that the countries that are successful in developing a hardware industry are different from those that are successful in developing a software industry (Table 3).

Environmental Endowments and Success in Computer Production

A statistical comparison of the environmental endowments of the eleven countries in this study is presented in Table 4 (attached). We used rank order correlation analysis to determine the relationship of environmental factors to computer production. This produced some interesting findings. For example, our other research shows that a country's demand for computer products and services is closely related to level of economic development (Kraemer, Gurbaxani, King, 1992). However, computer production apparently is unrelated to the size of the local market, as a country can target production primarily for export rather than for the local market. This was illustrated in the preceding discussion of the computer industries in Korea, Taiwan, Singapore, Hong Kong and Thailand.

--Insert Table 4 here--

The environmental factors that are related to computer production are indicators of supply-push rather than demand-pull. Six environmental factors which show a positive correlation with success in hardware production: the number of scientists and engineers in the country; the number of scientists and engineers per 10,000 population; industrial employment as a percentage of total employment; R&D expenditures by companies; total R&D expenditures; savings as a percentage of GDP; and the overall level of non-IT electronics production (Table 5).

Table 5. Correlation of Environmental Factors to Computer Production[3]

	Hardware Success	Software Success
Human Resources		
# of scientists & engineers	.7500***	-
Scientists/eng. per 10,000 pop.	.7500***	.6190**
Complementary industry		
Industry as % of employment	.6667**	-
Non-IT electronics production	.9750***	-
Research and Development		
R&D expenditures	.6727**	-
R&D by companies	.7167**	-

** Significant at the .05 confidence level
*** Significant at the .01 confidence level

These correlations in Table 5 show three requirements for success in hardware production. The first is the presence of skilled human resources, represented by the number of scientists and engineers and their number per 10,000 population. This shows that cheap labor alone in not a basis for developing a computer industry. Hardware production requires people with the technical skills to manage sophisticated manufacturing operations, a requirement driven by the industry's strict demands for quality control, rapid changes in product lines and constant technological advances.

The second requirement is the presence of an industrial base, particularly a broader electronics industry. Complementary industries such as electronics, electronic components and electrical equipment can transfer skills, technology and capital to the computer hardware industry. This occurs through the movement of electronics firms into computer production and through the movement of workers between companies. Local electronics firms may also provide components to the computer industry, enabling the country to achieve a more integrated manufacturing capability.

The third correlation is with R&D investment. This does not necessarily mean that the successful countries invest just in R&D for computer production, given the fact that some of the leading producers (e.g. Singapore, Thailand and Hong Kong) are mainly export platforms for MNCs. However, R&D spending is evidence of investment in technological improvement within a country, and technological capability is an important factor in determining where production takes place.

The only environmental factor which showed a significant correlation with success in software production was scientists and engineers per 1000 population. Software production relies heavily on the labor of skilled technical people such as programmers, systems analysts and software engineers. The number of scientists and engineers is probably a surrogate measure, given that both depend on the presence of an advanced educational system capable of producing such technically trained people.

The other key environmental factor seems to be the use of English as the language of commerce. After Japan, the next four countries use English in business and technical education. This relationship is not surprising, as English is the international language of computer programming, and the largest software market is the United States and each of these countries has done well in exporting software. Japan's large market has created demand for Japanese-language software, but Japan has not been a successful exporter of software given the large size of its software industry.

The correlation of computer production to various environmental factors points out the importance of policies to develop infrastructure as well as policies which promote the computer industry specifically. Most of the factors noted above can be altered through government intervention. For example, tax incentives can be given for private sector R&D, funding can be provided for scientific and engineering education, and various policies can be used to increase savings rates. Such policies may take time to bear fruit, but have the added virtue of providing benefits to other sectors of the economy as well as the computer sector.

Government Policy and Success in Computer Production

Japan was the first Asia-Pacific country to target computer production as a national priority. Promotion of the computer industry began in the 1960s as a response to the tremendous success of the IBM 360 computer, which threatened to destroy Japan's nascent hardware industry. The Japanese government employed a broad array of strategies including protection of the domestic market, negotiating with IBM for technology transfer, creation of R&D consortia, and creation of a state-owned computer rental agency in order to enable Japanese computer makers to survive and compete with IBM in Japan and eventually internationally (see Anchordoguy, 1989, for a detailed account of Japan's computer policies).

The Japanese experience has clearly influenced the NICs' approach to computer policy (except Hong Kong). Our interviews with officials in government, industry and the computer-related professions also indicate that these countries look to Japan rather than to the U.S. as a model for industrial and technology policies. Japan had to overcome great disadvantages to catch up with the U.S. in hardware production. The three NICs, and to an extent Thailand, have sought to imitate Japan's success in developing a computer industry and look to Japan for guidance. While they still look to the U.S. for investment, key technologies, and market access, they also have developed strong ties with Japan. They monitor technical and policy developments in Japan; they imitate many of Japan's strategies and institutions; they look to

Japan for technology, financial assistance, training, and R&D partnerships; and they turn to Japan as their primary source of manufactured components.

Each of the NICs except Hong Kong is now attempting to follow Japan into the next stage of development, which involves production of higher technology products with greater local value added, and product design via local research and development efforts. This process of evolution has been partly a product of market forces such as increasing wages, but is also an expressly stated part of government computer policy.

Korea specifically targeted production of PCs and minicomputers. Korea has been more closed to imports which compete directly with its computer industry, and has put various restrictions on foreign investment, but most formal barriers have been removed or lowered since 1987. Korea has allowed imports of necessary components and capital equipment, and has negotiated with multinationals to gain access to technology in return for market access, much as Japan did earlier. Imports of PCs were prohibited from 1982 to 1987 and subsidies were given to domestic firms producing PCs. Meanwhile the government promoted minicomputer production through the TICOM project, in which minicomputer technology was licensed from the American company Tolerant to develop a Korean minicomputer. Each of Korea's four largest *chaebol*, or business groups, (Samsung, Goldstar, Daewoo and Hyundai) produced its own model of the TICOM machine. The government has given local producers preferential treatment in government hardware procurement and promoted R&D through its own investment and through incentives to the private sector.

Taiwan has worked with its numerous small and medium-sized enterprises to encourage their shift into computer production. The government has used semi-governmental agencies to develop technology which is then passed on to the private sector for commercialization. This approach takes advantage of the dynamism of the Taiwanese firms while helping them overcome the lack of resources to invest in R&D. The government has also developed purchasing consortia to act on behalf of small firms and get favorable prices on imported components.

Singapore's government has focused on creating a favorable environment for foreign investment through building infrastructure and providing a number of financial incentives to investors. This has proven remarkably successful, as Singapore has become the world's largest production site for hard disk drives and is a major producer of PCs and other components. The government has worked in partnership with MNCs to increase the level of R&D conducted in Singapore and to upgrade education in computer skills.

Thailand has also employed government policies to promote computer production and its production has grown rapidly. The Thai government's Board of Investment has provided tax and other incentives to firms setting up electronics production facilities, especially those producing for export markets. As of 1989, 72% of computer hardware firms had received promotion status from the BOI, providing them with subsidies for investment (Thailand Development Research Institute, 1989, Section 2, p.13). Thailand's policies to promote computer production have mostly come under the broader effort to promote electronics industries generally.

These policy approaches have taken advantage of the countries' respective strengths in infrastructure and industrial structure. In each case, there has been a partnership between the public and private sector, a focus on international competitiveness, and a strong role for one or two key government agencies acting as industry coordinators (Economic Development Board and National Computer Board in Singapore; Electronics Research and Service Organization and Institute for Information Industry in Taiwan; Ministry of Trade and Industry and Ministry of Communications in Korea; and the Board of Investment in Thailand).

India, on the other hand, took a very different approach to computer policy. In the 1970s, India pushed IBM for technology transfer in return for market access. However, IBM quit India altogether rather than participate in joint ventures or transfer leading technologies. India veered from the Japanese model by promoting a state-owned enterprise to produce mini- and microcomputers. Not only were foreign firms kept out of the market, but even Indian private firms were prohibited from making certain products until the late 1970s. India also maintained high tariffs on IT imports for much longer than Japan had, and did not push domestic producers to become internationally competitive as Japan had done. The emphasis on protectionism and promotion of public enterprises *at the expense of the private sector* in India was a critical divergence from the Japanese approach, and from the approaches taken by Korea, Taiwan and Singapore. India tried to achieve technological independence, rather than applying foreign technology to build a competitive computer industry.

Australia is generally open to imports and investment, but puts offsets requirements on government procurement of computers. The 1987 Information Industries Strategy targeted multinational corporations selling computer products in Australia. In order to gain access to public sector procurement, MNCs were required to meet targets for exports and R&D. Australia also provides a direct subsidy to computer firms equal to a percent of local value added production.

Hong Kong and *New Zealand* have followed generally laissez faire strategies toward computer production. The *Philippines* developed a National IT Plan, but has yet to implement its strategies. *Malaysia* has developed plans to promote IT use and software production, but is in the early stages of implementation. Up to this point, each of these countries can be seen as market-directed, although some trade barriers exist in Malaysia and the Philippines.

The degree to which various policy instruments are employed by the countries of the Asia-Pacific region is presented in Figure 6 (attached). The basis for this figure is a detailed case study of each country (Dedrick & Kraemer, 1993a and 1993b; Kraemer & Dedrick, 1993b and 1992; Gurbaxani, et al., 1991; Kraemer, Jarman & Dedrick, 1992; others in progress). Each check mark represents an important area of government policy activity. The activity must be on a scale large enough to have an economic effect.

--Insert Figure 6 here--

Figure 6 shows the degree to which government is involved in promoting computer production. While all countries have some check marks, some are active in almost all areas, while others' activities are very limited. Based on this body of evidence, we divide the countries into two categories according to their IT policies, as illustrated in Figure 7. The first group employs plan-directed strategies, while the other group takes a generally market-directed approach. The plan-directed group includes Japan, Korea, Taiwan, Singapore, Thailand and India, while the market-oriented group includes Hong Kong, Australia, New Zealand, Malaysia and the Philippines.

Figure 7 also presents the rankings for hardware and software success for the plan-directed and market-directed economies. This provides a picture of the relative effectiveness of the two approaches in developing a national computer industry.

Figure 7. Plan-directed vs. market-directed policies

	Hardware Rank	Software Rank
Plan-directed		
Japan	1	1
Korea	2	8
Taiwan	3	6
Singapore	4	4
Thailand	5	*
India	8	5
Market Directed		
Hong Kong	6	7
Australia	7	2
Malaysia	9	*
Philippines	10	9
New Zealand	11	3

Figure 7 clearly shows that countries which followed plan-directed policies were more successful in hardware production than those which followed market-directed policies. However, there does not appear to be any difference between these two approaches for successful software production. Market-directed policies appear to be just as successful as plan-directed policies. The most apparent reason for the differences between hardware and software production are the considerably greater infrastructure and investment requirements for hardware production. In most cases, these entry barriers to hardware production can only be overcome with government support (Flamm, 1990). The findings concerning software should be taken as preliminary at this point, however. The software industry is generally less developed than the hardware industry in the countries being discussed. Also, the plan-directed countries are just beginning to turn their attention to software, as illustrated by Taiwan's announcement of a US$6.9 billion IT program which will emphasize software production (20 of 42 new products targeted for development are software products) (Ng, 1992). The results of concerted efforts to promote software production will not be available for analysis for several years.

V. CONCLUSIONS

Market-Directed versus Plan-Directed Strategies

Taken as a whole, the findings about the relationship of environmental factors and government policy to computer production clearly indicate the viability of plan-directed strategies for hardware production. The most successful hardware producers each made strong coordinated efforts to intervene at all levels: through external trade and investment policies and domestic industry promotion.

Although a market-directed strategy appears to work as well as a plan-directed strategy for software, it might be too early to tell whether this is actually the case. The software industry is still in its infant stage in all of the countries in this study except Japan, and Japan has had an active plan-directed strategy as illustrated by the Japan Software Company, the Sigma Project, the Software Module Project, and the Software Production Technology Development Program (Anchordoguy, 1989). Internationally, the software industry is relatively young and free-wheeling, and the requirements for success are still not well understood. Indeed, some of Japan's software projects have been failures, and Japan remains far behind the United States in software. This situation may auger for less, rather than more, government intervention. But it is interesting to note that this has not stopped the plan-directed countries from developing government programs to stimulate software production.

Effects of Specific Policies

Success in computer production appears to be related to specific types of policies which target the computer sector. Based on comparing the countries in this study, we conclude the following about such policies:

- *Import restrictions* were used by Japan to give local producers a chance against IBM. Korea also used a ban on PC imports to give its industry a chance to develop. In each case, trade barriers were lowered after local companies had developed the capacity to compete with imports. This is a classic infant industry strategy, and seems to have been effective in these cases. India, on the other hand, maintained protection for a longer period, and its domestic industry failed to develop the capabilities to compete in international markets. However, since India has partially opened its domestic market to foreign competition, Indian firms have been able to compete effectively in the local market, indicating the viability of protectionism in creating a domestic industry. Still, employing trade barriers has a very high cost to the economy as a whole, as other economic sectors pay higher prices for computer products. Kraemer and Dedrick (1993a) find a strong correlation between growth in computer use and productivity growth in these same countries during the 1980s, so any policy which inhibits computer use has clear economic costs.

- *Export promotion* has been an important policy tool for export-oriented countries such as Korea, Taiwan, Singapore and Thailand. Export promotion is effective in encouraging firms to look outward to larger markets which allows economies of scale to be achieved. It also forces firms to pursue international competitiveness in price and quality and to employ the most advanced technologies available in their products and processes. The disadvantage of export promotion is that it can lead producers to ignore the domestic market, which may offer opportunities for close interaction with users in product development. This is considered especially important in software production (Schware, 1992).
- *Foreign investment incentives* have been an important tool in Taiwan, Singapore, Thailand. Hong Kong does not offer specific incentives, but its low tax, low regulation environment makes it an excellent location for foreign companies to do business. Each of these countries has become an important base for multinational computer companies. These companies can provide jobs, technology transfer and access to international markets. They can also offer opportunities to local firms as suppliers and subcontractors. Such incentives have a cost to government in lost tax revenues or subsidies paid out, and

may hurt local companies that do not receive incentives and have to compete with multinationals that do.

- *Restrictions on foreign investment* were used by Japan to limit IBM's access to the Japanese markets, and informal barriers still exist. India likewise has severely limited foreign investment. Such a strategy is likely to limit access to technology and foreign markets, although Japan was able to negotiate for technology transfer. In general such an approach would be counterproductive today.
- *Direct subsidies* to industry have been employed in several countries with mixed success. Korean industry received low cost loans and Thailand's producers received investment incentives, while Australia has paid a direct bounty amounting to a percent of domestic value-added. Korea demanded export performance in return for subsidies, while Australia's payments had no strings attached. Subsidies are most likely to be effective if they have performance requirements such as export or R&D targets.
- *State-owned enterprises* have been employed effectively as a means to provide supporting functions in several countries. For instance, Japan set up the Japan Electronic Computer Company (JECC) as a rental agency for computers in the 1960s and 1970s, allowing producers to get full payment for their product rather than having to wait for rental income. Korea set up DACOM as a data communications operation, Taiwan has used the Institute for Information Industries (III) and Electronics Research and Service Organization (ERSO) to conduct precompetitive R&D, and Singapore's National Computer Board has carried out government computerization. By contrast, India unsuccessfully promoted the state-owned corporation ECIL as a national champion in minicomputers. We would conclude that state enterprises can be effective in providing services that the private sector would not otherwise supply, but can not replace the private sector as producers of hardware and software.

- *Favoring local producers in government procurement* is useful in creating demand, but it increasingly comes at a cost of pressure from trading partners and complaints from user agencies if local technology is not world class.
- *Computer skills training* is very important in creating the necessary infrastructure for computer production (as well as use). Computer education was a major part of Singapore's National IT Plan, and has been a priority in Taiwan and Korea as well. India's large pool of computer professionals has been the key reason for its success in software production and exports. Other countries have not emphasized education as much and many face shortages of computer professionals.
- *Investment in telecommunications* is very important in promoting computer use (Kraemer and Dedrick, 1993a). It appears less important for production, as illustrated by the lack of a correlation between number of telephones and computer production. However, in the longer run, promoting computer use could indirectly benefit production by increasing domestic demand.
- *Support for research and development* appears very important in promoting hardware production. Table 5 shows strong correlations between hardware production and two measures of R&D (total R&D and R&D by companies). Also, the leading hardware producers (Japan, Korea, Taiwan and Singapore) have all promoted R&D heavily. Given the importance of company R&D, it is likely that incentives to industry such as R&D tax credits are very effective. Creation of consortia has been effective for Japan and Korea in the past, but competition among the companies involved is making this strategy increasingly difficult. Direct funding is most often used in basic research and precompetitive applied research, while commercial R&D appears best left to industry.
- *Industry coordination* has been important in Japan and Korea in the past in terms of avoiding "excessive competition" and coordinating government efforts. In both countries, such coordination is becoming much more difficult as large corporations resist government direction and numerous government agencies vie for a role in national

computer policy. Singapore's NCB has been effective in coordinating promotion of computer use, while the Economic Development Board coordinates efforts to attract investment and encourage MNCs to expand the scope of their activities in Singapore. This model of coordinating government policy efforts is most likely to succeed, but requires the presence of a body with the authority to direct the actions of other agencies.

Relative Importance of Environmental and Policy Variables

The empirical data and case analyses support the conclusion that both environmental and policy factors are vital determinants of success in computer production. This suggests that computer policy must take into account a country's existing level of environmental endowments to be successful. Policies which worked in one place will not necessarily work in another. For instance, the presence of strong electronics industries enabled Korea and Taiwan to develop an indigenous hardware industry which could compete in international markets. The lack of such an industry was an obstacle to India, whose hardware producers have succeeded in the protected domestic market, but not in international markets. Even if Indian policymakers had pushed those companies to export in return for protection, as the Korean government did, it is unclear whether the Indian producers had the manufacturing capabilities to compete internationally.

Computer policy is most likely to be successful if it takes advantage of a country's strengths, while moving to shore up weak areas. Singapore took advantage of its strategic location, its favorable investment climate (a product of earlier policies), and its experience in manufacturing to attract multinational computer companies. At the same time, it took steps to train thousands of computer professionals, improve its telecommunications infrastructure, and promote computerization of the public and private sectors. This combination of policies helped Singapore become the number two computer producer in the Asia-Pacific region.

Over the medium to long run, most environmental endowments are subject to influence by government policy. This is especially true for high-technology industries, which do not require natural resources, but depend instead on human resources, capital, physical infrastructure, and manufacturing capability, all of which can be enhanced by policy initiatives.

VI. IMPLICATIONS FOR POLICYMAKERS

The findings and conclusions detailed above suggest a number of implications for policymakers. The following implications stand out as particularly important to developing successful policies for computer production:

Development of human resources is critical to development of a computer industry.

The strong correlations in Table 5 between the number of scientists and engineers and hardware production show the importance of developing scientific and technical skills. This requires support for university education in computer science, electronics engineering and other professional skills such as manufacturing management, statistical quality control, and process engineering. Vocational training in electronics technologies is also important.

A successful policy must be international in focus.

There are two major aspects of an international focus that derive from the research. The first is coming to terms with the importance of multinational corporations (MNCs). MNCs dominate the industry and control most of the vital technology. New technologies are increasingly being developed by strategic alliances of MNCs and the role of MNCs in the diffusion of technology and production is critical. Government policy must take into account the strategic concerns of MNCs to be effective. Dependence on MNCs requires a strong government role if the host country is to benefit technologically. MNCs are often very hesitant to transfer technology, so government must provide incentives and support local R&D, as Japan, Korea and Taiwan have done. Government can also negotiate to obtain better terms for technology transfer, to persuade MNCs to increase production and R&D in the host country, and to form strategic alliances with domestic firms. Access to government procurement contracts, tax incentives, training programs and other incentives have been used by a number of countries as bargaining chips with multinationals.

The second aspect of an international focus is realizing the practical limits of an export-only strategy. Export-led growth is becoming more problematic due to increased protectionism and competition in industrialized countries. Yet, linkages to the international economy are more vital than ever for access to growth markets. Gaining such access may require more emphasis on strategic alliances and direct investment in major markets rather than merely exporting products. This approach can circumvent trade barriers, enable companies to develop closer relationships with customers, and keep abreast of technology developments. Such an approach is expensive and is probably not viable for small companies, but larger companies such as Korea's Samsung and Taiwan's Acer are investing abroad and developing strategic alliances with U.S. and other foreign companies.

Encouraging domestic use is not required for initial success in developing hardware production, but may be necessary at later stages.

The large hardware producers such as Singapore, South Korea and Taiwan do not have large domestic markets, but they have succeeded as exporters. However, at some point countries need to develop domestic markets as well, as these countries are now doing. This is partly in order to deal with downturns in the world economy and protectionism abroad. However, it is also important to develop domestic markets in order to have the close interaction with sophisticated users that facilitates developing and upgrading products to meet the needs of the market. Korea, Taiwan and Singapore appear sensitive to this implication as they are promoting computer use along with production. Japan, through its economic stimulus package and longer term technology programs, is encouraging governments and educational institutions as all levels to become computer users and network users as a means of developing its domestic computer market.

Computer policy should target the software and services sector as an important element.

The fastest growing segment of the computer industry is services, which grew worldwide at a 31.5% annual rate from 1986 to 1991. Software grew at a 13.5% rate, while hardware only grew at 3.2% a year (McKinsey & Company, 1992). Furthermore, trends in the international computer industry make continued success in hardware problematic even for the countries which have succeeded in the past. Barriers to entry for newcomers are very high, given the industry's capital and technological requirements. On the other hand, barriers to entry for software and services production are much lower. Software and services production does not entail large startup costs, and necessary tools (hardware and development tools) are easily accessible in international markets. Also, software and services production is labor intensive, creating an advantage for countries with low cost programmers and other computer professionals. Finally, software and services markets are less homogeneous than hardware markets, and domestic markets offer opportunities for local producers with close ties to customers. Production for export is more difficult, given the high costs of establishing marketing and distribution networks, but software producers in Australia, India, and New Zealand have had success in establishing links with multinationals to produce software for international markets. Taiwan is developing Chinese language software for export to China and Chinese speaking users in other countries.

Several countries are now directing government policy toward software production. Taiwan has targeted software projects for substantial government investment. The recent emphasis on creating computer networks in Korea and Taiwan is also likely to offer opportunities for local firms in software and services. India's CMC (a state-owned corporation) has already gained valuable experience in software development and systems integration working on large government network projects. Such projects can offer local firms the opportunity to work with state of the art hardware, and cooperate with multinational corporations providing that hardware.

Policies to promote domestic hardware production through market protection may hamper the development of the software and services sectors.

It has been common practice for countries seeking to develop a local hardware industry to erect import barriers to protect domestic producers. While this strategy might assist domestic producers, it also has high costs to other computer industry segments and the economy as a whole. For example, India's trade barriers limited the diffusion of computers in the economy, reducing the domestic demand for software and services. This limited the potential market for Indian software and services companies. Also, the restrictions on imports of particular classes of hardware denied India's software companies access to hardware platforms needed for software development. Indeed it was pressure from the software industry that led to a liberalization of hardware imports in the early 1990s. While governments might want to promote hardware production, use of trade barriers is likely to be counterproductive to the development of software and services industries.

Policies must be coordinated around strategic goals by a strong coordinating body which can compel action on the part of other agencies and the private sector.

Technology policies are most effective when coordinated to achieve a clear set of objectives. Since computer and information technology cuts across a number of natural policy domains, from industrial policy to trade, to telecommunications, to education, it is important to have a lead agency with the authority and capacity to coordinate policy efforts. This presents a serious problems in most countries, as departments and ministries are loathe to give up autonomy, and each relevant agency wants a piece of the action in a dynamic area such as IT. In the past, Japan's MITI and Korea's Ministry of Trade and Industry were able to take the lead on computer policy, albeit with competition from other agencies. However, the convergence of computer and telecommunications technologies has created competition for turf in areas such as information superhighways and value-added networks which has yet to be resolved in those countries.

Singapore has one agency, the National Computer Board, with the authority to coordinate policy. Likewise, India's Electronics Department has a strong coordinating role in computer policy. Taiwan has divided responsibility for computer policy among two institutions, with the Electronics Research and Service Organization (ERSO) in charge of hardware and Institute for Information Industry (III) responsible for software and training. Japan's Science and Technology Agency and Korea's National Computerization Agency have the mandate for policy coordination, but not the authority to do so, and elected officials are too busy with political reforms to focus much on technology policies. Thailand's Board of Investment is in charge of promoting production, while the Ministry of Science, Technology and Energy coordinates science and technology policy. Australia has no lead agency for computer policy. Different agencies act quite independently on R&D, export promotion, education, government procurement and other areas. The Philippine and Malaysian situation with respect to industry coordination is similar to that of Australia. Both have created national government bodies, but they lack authority. Hong Kong and New Zealand historically have made no effort to coordinate policy, although both are now considering coordination mechanisms.

Finally, it is important to remember that the major economic and social benefits arise from the application of computers by other economic sectors and the public sector, rather than from production of computers. Therefore, policies which promote computer production at the expense of use may do more harm than good, even if they are successful in increasing production. This paper does not attempt to deal with the relative costs and benefits of computer application versus the development of a domestic computer industry. However, policymakers must keep these considerations in mind and not simply focus on the production side of the equation. Some less developed countries might benefit most from a focused strategy of promoting computing diffusion in the broader economy. Others might benefit most from a strategy focused on software or services production. The more technologically advanced countries might weigh the benefits of production and use and develop strategies to promote production in ways that do not inhibit use.

References

Amsden, A. (1989). *Asia's Next Giant*. New York: Oxford University Press.
Anchordoguy, M. (1989). *Computers Inc., Japan's Challenge to IBM*. Cambridge, MA: Harvard University Press.
Arnold E. and K. Guy (1986). *Parallel convergence: National strategies in information technology*. London: Frances Pinter.
Australian Information Industry Association (1990). "Member survey." Canberra: AIIA.
Balassa, B. (1981). "The process of industrial development and alternative development strategies." In *The newly industrializing countries in the world economy*. New York: Pergamon.
BIS Mackintosh Ltd. (1990). "Report on Hong Kong IT environment and manpower needs."
Crocombe, G.T., M.J. Enright and M. Porter (1991). *Upgrading New Zealand's Competitive Advantage*. Auckland: Oxford University Press.
Dahlman, C.J. (1990). "Electronics development strategy: The role of government." Industry Series Paper No. 37. The World Bank Industry and Energy Department.
Darshini, P. (1993). "IT industry booming in India." *IT Asia*, 7(9), September, p.6.
Dedrick, J. and K. L. Kraemer (1993a). "Caught in the middle: Information technology policy in Australia." *The Information Society*, November/December.
Dedrick, J. and K.L. Kraemer (1993b). "The Quest for Self-Reliance: Information Technology Policy in India." *Asian Survey* , Vol. XXXIII, No. 5, May, pp. 463-492.
Devasahayam, A. (1992). "Philippines software industry growing." *Asia Computer Weekly*, 13(17), May 11-17.
EIAK (Electronic Industries Association of Korea) (1993). *Statistics of Electronic and Electrical Industries*. Seoul: EIAK.
Electronic Business Asia (1992). "A changing scorecard on who makes what." November, pp. 38-39.
Elsevier (1990). *Yearbook of World Electronics Data*. Oxford: Elsevier Advanced Technology
Ernst, D. and O'Connor, D. (1992). *Competing in the electronics industry: The experience of newly industrialising economies*. Paris: OECD.
Evenson, R.E. and G. Ranis, eds. (1990). *Science and technology: Lessons for development policy*. Boulder, CO: Westview Press.
Flamm, K. (1990). "Globalisation in the computer industry." Background paper for OECD experts meeting, Paris:OECD, 1990.
Fransman, M. (1990). *The market and beyond.* Cambridge, UK: Cambridge University Press.
Gurbaxani, V, K. L. Kraemer, J. L. King, S. Jarman, J. Dedrick, K.S. Raman, and C.S. Yap (1991). "Government as driving force toward the information society: National computer policy in Singapore." *Information Society*, Volume 7, pp. 155-185.
III (Institute for Information Industry) (1992). *Information Industry Yearbook, Taiwan, ROC*. Taipei: III.
IMD International (1990). *World Competitiveness Report*. Geneva: IMD International.
IMF (International Monetary Fund). *International Financial Statistics*, various issues, Washington, D.C.
JIPDEC (Japan Information Processing Development Center) (1990). *Informatization white paper*. Tokyo: JIPDEC.
Johnson, C. (1982). *MITI and the Japanese miracle*. Stanford: Stanford University Press.

King, J.L., V. Gurbaxani, K.L. Kraemer, F.W. McFarlan, K.S. Raman and C.S. Yap (1992). "Institutions and the international diffusion of information technology." *Information Systems Research* 2(2) 97-110.

Kirkpatrick, D. (1992). "Who's winning the computer race." *Technology Edge*, May (originally in *Fortune*, June 17, 1991).

Kraemer, K.L. and J. Dedrick (1993a). "Payoffs from investment in information technology: lessons from the Asia-Pacific region." University of California, Irvine, Center for Research on Information Technology and Organizations.

Kraemer, K. L. and J. Dedrick(1993b). "Turning loose the invisible hand: Information technology policy in New Zealand," *The Information Society*, November/December.

Kraemer, K.L. and J. Dedrick (1992). "Industry coordination as a problem in national information technology policy: the case of the Philippines." University of California, Irvine, Center for Research on Information Technology and Organizations.

Kraemer, K.L., V. Gurbaxani, and J.L. King (1992). "Economic development, government policy and the diffusion of computing in Asia-Pacific countries." *Public Administration Review*, March/April, Vol. 52, No.2.

Kraemer, K. L., S. Jarman, and J. Dedrick (1992). "Laissez innover and the road to the information society: The case of Hong Kong." Irvine, CA: Center for Research on Information Technology and Organizations.

Little, I. (1982). *Economic Development: Theory, Policy and International Relations*. New York: Basic Books.

McKinsey & Company (1992). *The 1992 report on the computer industry*.

National Computer Board (1990). "IT industry grew 39 percent in 1989." *IT Focus*, March.

Nelson, R.R. (1992). "National innovation systems: A retrospective on a study." *Industrial and Corporate Change*, 1(2), 347-374.

Ng, V. (1992). "Taiwan approves $6.9b IT plan." *IT Asia*, 7:7, July, p.1.

Organization for Economic Cooperation and Development (1988). *New technologies in the 1990s: A Socio-economic Strategy*. Paris: OECD.

Organization for Economic Cooperation and Development (1992). *Technology and the economy: The key relationships*. Paris: OECD.

PECC (Pacific Economic Cooperation Conference) (1991). *Pacific Science and Technology Profile*. Palo Alto, CA: PECC.

Phang, Jennifer (1991). "HK council to help key industries," *Asia Computer Weekly*, Vol. 12 No. 39, Nov. 18-24, p.1.

Ranis, G. (1990). "Science and Technology Policy: Lessons from Japan and the East Asian NICs," in Evenson, R.E. and G. Ranis, eds. (1990). *Science and technology: Lessons for development policy*. Boulder, CO: Westview Press.

Schware, R. (1992). "Software industry entry strategies for developing countries: A 'walking on two legs' proposition." *World Development* 20(2): 143-164.

Statistical Yearbook of the Republic of China (1991). Taipei: Directorate-General of Budget, Accounting and Statistics.

Thailand Development Research Institute (1989). *The development of Thailand's technological capability in industry, Volume 5: Capability development for electronics and information technology-based industries*. Bangkok: Thailand Development Research Institute.

United Nations Development Programme (1990). *Human Development Report 1990*. Oxford: Oxford University Press.

U.S. Department of Commerce (1990). *The competitive status of the U.S. electronics sector, from materials to systems*. Washington, DC: Department of Commerce.

Velarde, C.S. (1993). "Philippine software industry on a high." *Asia Computer Weekly*, 14(18), May 17-23, p. 11.

Wade, R.(1990). *Governing the market*.. Princeton: Princeton University Press.

Weber, M. (1968). *Economy and society*. Ed. by G. Roth and C. Wittich. New York: Bedminster Press.

World Bank (1988). *Social Indicators of Development*. Washington, D.C.: World Bank.

* This research has been supported by grants from the Pacific Rim Research Program of the University of California, the National Science Foundation and National University of Singapore. The authors would like to thank the following for their comments and suggestions on earlier drafts: Robert Schware, Chrisanthi Avgerou, Erich Bloch, Antonio Botelho, Thomas F. Gannon, Frank Land, John McPhee and Mayuri Odedra.

** Communications should be directed to the authors at: Center for Research on Information Technology and Organizations (CRITO), Suite 320, Berkeley Place, University of California Irvine, Irvine, CA 92717-4650

[1] Dahlman (1990) points out that similar arguments are made for government involvement in the electronics industry.

[2] We chose the Dahlman and Department of Commerce schemes because they most closely parallel what we have found in our investigations and because they enable us to relate findings about the broader electronics industry to the IT industry.

[3] We ran correlations of each environmental factor listed in Table 4 against country rankings for hardware and software production levels, hardware and software success, and hardware and software exports. The correlations were virtually the same for hardware production level, hardware success and hardware exports. The only difference was the correlation with number of scientists and engineers was not statistically significant for exports and there was a statistically significant correlation between savings rate and hardware exports. For software, no statistically significant correlations were found for either production or export levels.