

PAYOFFS FROM INVESTMENT IN INFORMATION TECHNOLOGY: LESSONS FROM THE ASIA-PACIFIC REGION

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ABSTRACT

This paper examines the factors influencing investment in IT, and the payoffs from investment in IT use on productivity and economic growth, in eleven Asia-Pacific countries for the period 1983-1990. Using systematic and empirical analysis, it concludes that the primary factors influencing investment in IT are four: national wealth, structure of the economy, wage rates, and IT infrastructure.

Carrying the analysis further, it looks at the effects of IT investment on the economy and finds a significant positive correlation between investment in IT and growth in both GDP and productivity over the eight year period. Countries that invested more in IT achieved consistently higher levels of GDP and productivity. This finding is consistent with the notion of IT-led development. And it provides evidence which refutes the so-called "productivity paradox", or the notion that investment in IT has not paid off in productivity improvements.

These results have several implications for Asia-Pacific countries. They clearly indicate that investment in IT pays off for national productivity and economic growth. But, they also suggest that countries face critical tradeoffs between investment in IT production and investment in IT use.

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INTRODUCTION

There is a growing recognition among economic development specialists (e.g. Ranis, 1990) that investments in technology can play a critical role in stimulating economic growth and productivity. The rapid economic growth of the East Asian newly industrializing economies (NIEs) is at least partially attributable to their investment in technologies to upgrade the productivity and competitiveness of export-oriented industries. The economic stagnation of other developing countries has been blamed in part on government policies which restricted the importation of advanced technologies from abroad.

One of these technologies with the potential for stimulating economic growth and productivity is information technology (IT). Some researchers make a specific argument for the value of investment in IT as a stimulus for economic development. These arguments for IT-led development are based on the notion that investments in IT can accelerate economic growth by enhancing worker productivity and increasing the returns to investment in other capital goods.

IT is seen as a set of generic technologies, such as semiconductors and software, which are pervasive in their impacts on industrial and economic development. Unlike a new technology for steel or chemical production, IT can be applied in virtually every economic sector, from automobiles to insurance to aerospace. Its application can make

production more efficient, enhance existing products and make possible new products and services. IT can reduce the cost to business of obtaining and processing information on markets, suppliers and competition, improving organizational efficiency and responsiveness. In addition, the IT industry itself can be a source of economic growth and jobs. For these reasons, investment in IT is believed to enhance national productivity and competitiveness, spurring economic growth. The IT-led development hypothesis is illustrated by Mody and Dahlman (1992), who suggest that IT development may have led or anticipated economic growth in the East Asian NIEs.

Such a conclusion runs contrary to empirical research about the so-called "productivity paradox" (Roach, 1987 and 1988; Baily and Gordon, 1988; Loveman, 1988). That research shows that productivity gains in the aggregate economy from computer use have been limited, despite the rapid improvement in price-performance ratio of computers and heavy investment in IT. This argument is based on the fact that the United States has invested heavily in computers over the past three decades, yet productivity growth has slowed during that period. Investments in information technology have been large. Roach (1988) points out that IT often accounts for a quarter or more of a firm's capital stock, and Attewell (1990) reports that IT accounted for 48% of all new capital investment in 1988 and "the proportion is still climbing." Roach looked at the relationship between investments in IT and productivity from the early sixties through 1987. He found that IT investment in the service sector grew tremendously relative to IT investment in manufacturing, with 84% of the nation's multi-billion dollar IT investment going into services. However, manufacturing gained in productivity during this period while productivity in the service sector remained stagnant. As put by Roach (1988), "the level of white-collar productivity in 1987 was actually no higher than it was in the mid-1960s."

These previous studies of the economic impacts of IT have either been limited to a few developed countries (mainly the U.S. and Japan) or are largely based on case

studies and anecdotal information. In this paper, we pursue two questions empirically, using data from eleven Asia-Pacific countries with different levels of economic development and different policy approaches to investment in information technology. The countries are shown below by level of economic development (Figure 1).

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

CONCEPTUAL FRAMEWORK

For the purposes of the quantitative analysis in this paper, we focus on investment in IT use, as measured by investment in computer products and services. A companion paper (Kraemer and Dedrick, 1993) takes a quantitative approach to the factors determining levels of IT production. We define the IT sector to include computer hardware, software and services. We treat telecommunications, semiconductors and other electronics industries as part of the IT infrastructure, supporting and complementing the production and use of computer products and services.

We are interested in the answers to two questions about investment in IT use:

1. What environmental factors affect the level of IT investment in a country?
2. Does investment in IT lead to increased productivity and economic growth?

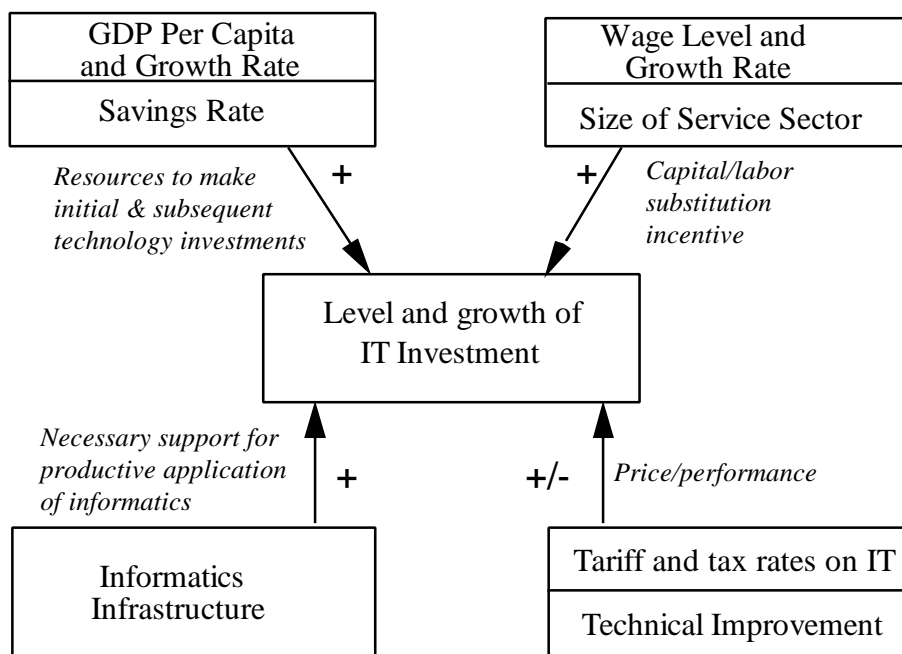
We examine these questions using quantitative analytical techniques to measure the relationship between environmental factors and investment in IT. The conceptual framework for considering the above questions has two components. The first is a model of factors determining a country's level of IT investment (Figure 2). The second is a

model of the effects of IT investment on national productivity and economic growth (Figure 3).

Economic Factors Influencing IT Investment

Investment in IT use can provide a return on investment in two ways: (1) IT improves labor productivity by substituting for labor or improving the productivity of workers; (2) IT improves capital productivity by complementing other investments. For example, plants and equipment can be made more productive through the application of computers to planning, production and inventory control.

Figure 2. Determinants of IT Investment



We hypothesize that returns on investment in IT at the national level are influenced by four key factors: *National wealth*, measured by GDP level and growth, as well as savings as a percentage of GDP; *wage rates and growth*; *structure of the*

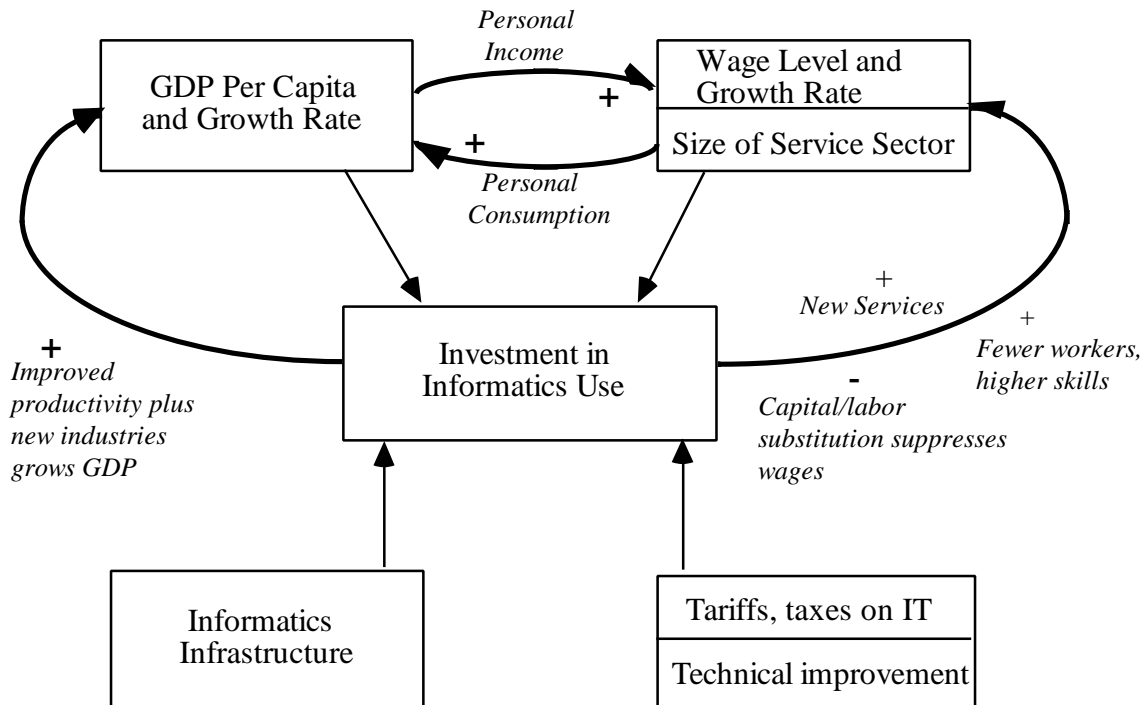
economy, especially the size of the service sector; *IT infrastructure*, including human resources, capital availability, telecommunications networks and a dependable power supply; and the price/performance ratio of IT products. Wealthier countries with growing economies and high savings rates should have more capital and more efficient capital markets to provide investment capital at a lower cost. A lower cost of capital means a higher return on investment. Wage rates are also expected to be correlated with return on IT investment, as organizations paying higher wages stand to gain a higher return from replacing labor or improving labor productivity. The size of the service sector as a percent of total output is expected to be related to the return on investment in IT, because productivity in the service sector is low and greater productivity gains are possible from the use of IT.

The presence of an adequate infrastructure is expected to be related to return on investment in IT because IT is a complex technology requiring supporting networks of electricity, telecommunications and skilled people. And finally, improvements in the price/performance ratio of IT products makes returns on IT investments more attractive because more computing power can be purchased for a given amount of investment. We hypothesize that each of these factors will be positively correlated with national levels of IT investment, since a higher potential return on investment should lead to higher levels of investment.

We also expect IT investment to have feedback effects on some of these variables in return. As illustrated in Figure 3, investment in IT is expected to improve productivity of existing industries and to create new industries related to use (e.g. distribution, maintenance, support), both of which lead to GDP growth. In turn, GDP growth is expected to push personal income and wages upward as the technology enhances the capabilities of some workers. It might also push wages downward in some industries as IT use deskills the jobs of some workers or eliminates them. IT use also might expand the size of the service sector in the economy by creating new services such as electronic

stock trading, automatic teller banking, electronic funds transfer, etc. Finally, though not explicitly considered in this analysis, IT use might improve the infrastructure. This might occur through the use of computers in education, or through upgrading of telecommunications networks with digital switching and cellular communications.

Figure 3. Productivity Effects of IT Investment



The following analysis measures quantitatively the relationships illustrated in Figures 2 and 3. Table 2 presents data for each country on environmental factors considered important in creating a favorable environment for IT investment. These include measures of national wealth, human resources, telecommunications infrastructure, R&D efforts, productivity, wage rates, size of the service sector, and capital availability.

METHODS AND DATA

In order to study the effects of different factors on IT investment, we first develop measures of investment which can be used to compare countries and to study individual countries over time. We use spending on computer hardware, software and services as a measure of IT investment, similar to the approaches of Flamm (1987), Gurbaxani and Mendelson (1990), and Brynjolfsson and Hitt (1993). To compare across countries, we use IT investment as a percent of GDP and as a percent of total capital investment, as well as growth rates for these figures, as common measures.

We then look at the effects of environmental factors on diffusion. To measure the effects of environment, we conduct correlation analyses using measures of the variables presented in Figure 2. These are correlated with IT investment as a percent of GDP and as a percent of total capital investment across the countries to find relationships at a given time. Where a statistically significant correlation is found, we conclude that a relationship exists between the two.

We next conduct correlation analyses of growth rates in IT investment against growth in GDP, productivity, and wages, in order to understand dynamic relationships among those variables. The correlation with wage rate growth provides a clue as to the extent to which IT investment is undertaken to replace labor as wages increase. The correlations with productivity growth and GDP growth are used to measure the effects of IT investment on productivity, as illustrated in Figure 3. Especially important is measuring the correlation of growth in IT investment as a percent of total capital investment against productivity growth. This measures the extent to which a shift in capital spending to a heavier emphasis on IT is related to increases in productivity, as the proponents of IT-led development suggest it should.

The data for this analysis were collected from secondary sources, from confidential industry sources and from our own case studies of each country. The secondary sources included IMF *International Finance Statistics*, the *World*

Competitiveness Report, the U.S. Department of Labor *Handbook of Labor Statistics*, the United Nations *Human Development Report*, the International Labor Office *Yearbook of Labor Statistics*, and the Pacific Economic Cooperation Conference *Science and Technology Profile* and *Pacific Economic Outlook*.

The confidential industry sources included two databases about IT flows, one covering the period 1983-1987 and the other covering 1987-1993. The databases included IT investment for each country by technology (hardware, software, services) and by industry (government, finance, distribution, manufacturing). Although the patterns of the data were remarkably similar between the two databases, the actual values were disjoint in some cases. Because the industry source for the data always revised data from earlier years in the later dataset, we took the later database to be more accurate. We therefore adjusted the earlier database to the later database by using the later data for the overlap year (1987), and then using growth rates from the earlier set to move backward to 1986, 1985, 1984 and 1983. The result is an integrated database covering ten years.

The case studies were conducted through field interviews and a literature review. Approximately 50 interviews were conducted in each country with representatives of industry associations, leading producers, government ministries of science and technology, trade, and economic planning, universities and research centers, and the computer industry press. Materials on the IT industry and on IT use were collected from national libraries, consultants and research centers. The interviews, materials and literature were then synthesized into case studies which all follow a similar outline (Gurbaxani, et al., 1991; Kraemer and Dedrick, 1992 and 1993; Dedrick and Kraemer, 1993a and 1993b; Kraemer, et al, 1992).

FINDINGS FROM QUANTITATIVE ANALYSES

Investment in IT Use

Table 1 shows total IT spending (hardware, software, services) as a percentage of GDP and of total capital investment for eleven Asia-Pacific countries as of 1990, and average annual growth rates in spending from 1983 to 1990.¹ We use spending as a percent of GDP as a comparative measure because it is related to the size of a country's economy. This is a better measure than IT spending per capita, since it is based on buying power rather than population. Table 1 illustrates two points clearly:

- Spending is related to national wealth. The developed countries are the heaviest users of IT, followed by the newly industrializing economies (NIEs) and then the developing countries.
- Growth in spending is fastest in the rapidly growing NIEs, as well as Thailand and Indonesia, which are playing catch-up with the developed countries.

Table 1. IT Investment in Asia-Pacific Countries

Country	IT Investment as % of GDP, 1990	IT Investment as % Total Investment, 1990	Average Growth in IT Investment, 1983-1990
Japan	2.18	7.52	n.a.
Australia/New Zealand	2.03	8.64	15.43
Singapore	1.84	5.05	18.06
Hong Kong	1.19	n.a.	15.22
South Korea	0.91	3.21	24.49
Taiwan	0.83	4.26	21.64
Malaysia	0.67	2.71	10.77
India	0.37	1.69	n.a.
Thailand	0.36	1.52	25.00
Philippines	0.25	1.44	12.21
Indonesia	0.23	1.14	18.09

Source: Confidential industry sources

n.a. = not available

Environment and Investment

Table 2 provides an overview of environmental variables for the countries. Each of these variables is a measure of one of the factors presented earlier in Figures 2 and 3.

¹ Australia and New Zealand data are combined in the original source, so the two are treated as one unit. Environmental data for Australia/New Zealand is obtained by using a weighted average of the two countries based on the relative size of their economies.

GDP per capita and savings rates are measures of national wealth. IT infrastructure is measured by adult literacy, secondary school enrollment, scientists and engineers per 10,000 population (human resources), telephones per 1,000 population (telecommunications), R&D spending as a percent of GDP (scientific capacity), and investment as a percent of GDP (capital availability). GDP per employee is a measure of productivity. Services as a percent of GDP is a measure of the size of the service sector. Average hourly wages in manufacturing and services are indicators of overall wage rates.

(Insert Table 2 here)

In order to determine the relationship between environmental factors and IT investment, we begin by conducting Spearman rank correlation analyses between each of the environmental variables and the level of IT spending as a percent of GDP and as a percent of total capital investment. These correlations are static, in that they compare countries at one point in time, in this case 1990. Table 3 shows the variables which were found to have a statistically significant correlation with IT spending.

Table 3. Correlation Between Level of IT Investment and Environmental Factors

Variable	Correlation Coefficients with IT investment as a percent of GDP	Correlation Coefficients with IT investment as a percent of total investment
<i>National Wealth</i>		
GDP per capita	.9273**	.8074**
Savings as % of GDP	.4630	.1206
<i>Human Resources</i>		
Secondary school enrollment	.8000**	.7700**
Scientists/Engineers per 1,000	.8833**	.7500*
<i>Telecommunications</i>		
Telephones per 1,000	.9455**	.9079**
<i>Structure of Economy</i>		
Services as % of GDP	.8364**	.8639**
<i>R&D Capacity</i>		
R&D as percent of GDP	.8984**	.6434
<i>Wages</i>		
Average wage in manufacturing	.8364**	.8987**
Avg. wage in services (bank teller)	.9286**	.6007

* Significance level = .05

** Significance level = .01

The correlations in Table 3 generally support the relationships hypothesized in Figures 2 and 3 between environmental factors and IT investment. In each case except savings rate, the environmental variable is strongly correlated with IT investment as a percent of GDP. Thus, IT investment is positively with a country's wealth, infrastructure, wage rates and capital investment levels. However, the lack of a significant correlation with savings rate suggests that capital availability is dependent more on overall national wealth than on the percent of GDP that is saved.

It should be noted that each of the other variables is also strongly correlated with GDP per capita, suggesting that level of wealth may be the key determinant of IT investment. It could be that the other variables are only correlated with IT spending because of their relationship to wealth. However, we also find all but two variables (service wages and investment as a percent of GDP) correlated with IT investment as a percent of total investment. This shows that in countries with a favorable environment for IT use (as defined in Figure 2), IT represents a larger share of total investment. This fact is not as easily accounted for by the simple argument that richer countries can afford the investment. This does not explain why they choose to invest more heavily in IT as opposed to other investments. A plausible explanation is that these countries can earn a higher return on investment in IT, due to favorable environmental factors, as Figure 2 posits.

It is also possible that the relationship is the other way around. That is, the reason for the correlation might be that the wealthier countries invested more heavily in IT in the past, and that their current wealth is at least in part a reflection of that investment, rather than the key determinant. Given the many factors driving economic growth, it is unlikely that the causality runs in this direction on a static level. That is, it is highly unlikely that Australia is richer than the Philippines because of its higher investment in IT. But, it is possible that there is a dynamic relationship between IT investment and growth in

productivity and GDP, as pointed to in Figure 3. The following section analyzes those variables to look for evidence of such a dynamic relationship.

Environmental Change and Growth in IT Investment

We next consider the dynamic relationships implied in Figure 3. Table 4 presents the correlation coefficients found by conducting Spearman rank correlation analyses between average growth rates in IT investment and growth rates in productivity, wage rates and GDP.

Table 4. Correlation of Growth in IT Use with Growth in GDP, Wages and Productivity

Variable	Correlation with Avg. Annual Growth in IT Investment (1983-90)	Correlation with Avg. Growth in IT Invest. as % of Total Invest.
Avg. annual GDP growth (1982-90)	.7463*	.6541*
Avg. annual wage rate growth (1985-90)	.1381	.3685
Avg. annual productivity growth (1982-90)	.8049**	.7127*

* Significance level = .05

** Significance level = .01

Table 4 reinforces the findings in Table 3 by showing that growth in IT spending is strongly correlated with GDP growth and productivity growth. This analysis, which is dynamic rather than static, supports the notion that IT spending is related to economic growth and productivity growth. More importantly, the second column shows that growth in IT investment as a percent of total investment is correlated with GDP and productivity growth. This is important because it shows that a shift towards IT in the overall investment mix is related to improved productivity.

The lack of correlation in Table 4 between wage growth and IT growth suggests that rising labor costs are not the major determinant of IT investment. The correlation between average wage rates and level of IT spending in Table 3 is more likely explained by the close relationship of wage rates to national wealth. This would mean that computers are employed primarily for reasons other than labor replacement.

DISCUSSION

Our findings show a strong correlation between growth in IT investment and productivity in national economies. This finding is consistent with the notion of IT-led development. It does not provide conclusive evidence of a causal relationship, given the relatively small proportion of IT in the overall investment picture, and the broad array of factors which affect economic growth. It is also true that if there is a causal relationship, the causation may run both ways between economic growth and IT investment, as the model presented in Figures 2 and 3 points out.

These findings provide evidence to refute the notion of the productivity paradox. Based on the quantitative analysis, as well as evidence from case studies of the countries being examined, we find reason to believe that IT investment, especially in conjunction with investments in supporting infrastructure, has a positive impact on productivity and economic growth.

Recent research by Brynjolfsson and Hitt (1993) supports our findings on the relationship of IT investment to increased productivity. The researchers studied data from 380 of the 500 largest U.S. companies from 1987 to 1991, representing over \$2 trillion in output (one-third of the U.S. GDP). They found a return on investment of 54.2% for computer investments, compared to 4.1% for all other investments. This study also challenges the "productivity paradox" by presenting strong evidence of productivity gains from IT investment. The data set used had the virtue of a large number of data points, and quite detailed information on both IT investment and company output.

Our findings and those of Brynjolfsson and Hitt actually complement and reinforce one another. We find a relationship using data at the national level across a diverse sample of countries. They find a relationship between IT investment and corporate productivity at the firm level across a diverse sample of companies within a single country. However, given that the companies in their sample represent one-third of

the U.S. GDP, they can also be considered representative of the relationship between IT investment and national productivity.

POLICY IMPLICATIONS

The findings above suggest that a policy of limiting investment in IT use in order to promote domestic IT production might not be in the interest of the overall economy even though it might benefit the IT industry in a country. This finding has important implications because national governments in many countries have developed, or are developing, policies to promote investment in the production and/or use of information technology, including investment by the government itself.

The rationale for such intervention is based on the perceived strategic value of IT, which stems from certain characteristics of the sector:

1. *Production of IT* is a high growth industry with opportunities for high value-added products and services. Therefore, the IT industries offer significant potential for stimulating domestic economic growth and jobs.
2. *Use of information technology* is considered central to competitive success in nearly all industries. Therefore, government policies which either promote or retard investment in the use of IT will have important economic effects.

These two characteristics of IT point to a critical policy issue: Should national governments promote the production or use of IT, or both? The development of national industries to produce IT has been an important goal of government policies in countries such as Japan, Korea, Taiwan and India. Other countries, such as Hong Kong and New Zealand, and Australia (at least before 1987) have taken a hands-off approach, preferring to let the market determine the levels of production and use.

The questions facing policymakers are whether there is more value in developing an IT industry or in applying IT to other sectors of the economy, and whether promotion

of one will be detrimental to the other. Flamm (1987) argues that use of IT offers greater economic benefits than IT production. Schwabe (1992) further argues that the presence of sophisticated users is vital to developing production of IT, both to provide a market and due to the importance of close interaction between producers and users. These points of view argue for policies favoring use, and if production is to be promoted, that it be done without trade barriers or other policy instruments which protect domestic producers but discourage investment in use by increasing the cost of IT products.

There are still questions as to what the tradeoffs are from policies which limit use to promote production. Japan clearly followed such a policy, especially in the 1960s and early 1970s, limiting access to its domestic market and requiring foreign companies to license their technology to Japanese companies in return for access to the Japanese market (Anchordoguy, 1989). Japan now has a large, technologically advanced computer industry, but one may ask what the costs were to the Japanese economy in terms of lost opportunities to apply IT in other sectors.

More importantly, policymakers must consider what the likelihood is of repeating Japan's success in developing a competitive computer industry, given the enormous capital and technology requirements of the industry. Recent trends in countries such as Korea, Brazil, India and Mexico have been to remove restrictions on imports, technology transfer and foreign investment in order to gain access to low cost IT products. Such a trend seems to be an acknowledgment that previous policies to promote production were too costly to user industries in those countries. Countries which have been successful in IT production, such as Singapore, Taiwan and Hong Kong, have succeeded largely through attracting multinational computer companies to invest in production facilities or subcontract with local firms. None of these countries has used protectionism as a tool for promoting IT production.

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