Title

Payoffs from Investment in Information Technology: Lessons from the Asia-Pacific Region

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PAYOFFS FROM INVESTMENT IN INFORMATION TECHNOLOGY: LESSONS FROM THE ASIA-PACIFIC REGION[1]

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ABSTRACT

This paper examines the factors influencing investment in information technology (IT), and the payoffs from investment in IT use on productivity and economic growth in twelve Asia-Pacific countries for the period 1984-1990. It finds a significant positive correlation between growth in IT investment and growth in both GDP and productivity over the seven year period. Countries with higher growth rates in IT investment achieved consistently higher growth rates of GDP and productivity. This finding is consistent with the notion of IT-led development. It challenges the so-called "productivity paradox", or the notion that investment in IT has not paid off in productivity improvements.

INTRODUCTION

There is a growing recognition among economic development specialists 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 (Amsden, 1989; Ranis, 1990). The economic stagnation of other developing countries has been blamed in part on government policies which restricted the importation of advanced technologies from abroad (Dahlman and Frischtak, 1990; Lall, 1985).

One technology 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 (APO 1990; Mody and Dahlman, 1992; OECD, 1988, 1993; Rahim and Pennings, 1987).

IT is seen as a set of generic technologies, such as semiconductors, computer systems 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 create new products and services. IT can reduce the cost to business of obtaining and processing information on markets, suppliers and competition, thus 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. Several studies (Mody and Dahlman, 1992; Rahim and Pennings, 1987) 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 "productivity paradox" (Baily, 1986; Baily and Gordon, 1988; Loveman, 1988; Roach, 1987 and 1988). That research shows that productivity gains in the aggregate economy from IT 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 invested heavily in IT during the 1970s and 1980s, yet productivity growth slowed during that period compared to the earlier post-war years (Baily, 1986).

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 private investment in equipment in 1988 and "the proportion is still climbing." Roach looked at the relationship between investments in IT and productivity at the national level for manufacturing and services 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, productivity in manufacturing increased 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." At the firm level, Loveman's (1988) study of sixty manufacturing units measured changes in output related to levels of investment in IT and other inputs and found the productivity gains from IT to be insignificant.

The productivity paradox does not deny the possibility of productivity improvements from the use of IT. On the contrary, those authors who have written most about the paradox tend to stress the enormous potential gains. But they also point out that the efficient implementation of IT is often hampered by many social and organizational barriers. They and other researchers (Attewell, 1990; Brynjolfsson, 1993) have offered a variety of explanations for why the expected payoffs might not show up. The explanations fall into four broad groups:

1. Measurement errors: Productivity measures, which are based on the level of output for a given level of input, fail to account for gains such as better product quality and variety or the availability of new services. Rapid declines in the price of computing power also make measures of IT stock difficult . Also, part of the value of IT is that it allows business to be more flexible and do new things, rather than just reducing costs or increasing output (Applegate et al., 1988).

2. Time lag for diffusion: New technologies require time for diffusion and organizational adaptation before potential benefits are realized. David (1989) shows that major gains in productivity from the application of the electric dynamo were not seen until 40 years after the technology was introduced. These gains were not realized until widespread electrification of factories took place and until factories replaced existing belt-driven machines with individually powered electrical machines. David suggests the same process is taking place with IT. Computers have been around for about 40 years and integrated circuits only twenty. Major productivity gains at the national level might be realized only as diffusion of personal computers reaches a critical mass.[2] Therefore, there is likely to be a considerable lag between the time of investment and the time that benefits show up in productivity gains while organizations introduce IT, learn how to use it, and adapt it to their needs.

3. Management of IT: New technologies require organizational changes in order to achieve potential benefits. David's study (1989) shows that it was not diffusion alone that produced the productivity gains from the electric dynamo. It was the combination of widespread diffusion of the technology and radical changes in production processes that finally led to a productivity boom. Thus, he suggests that major productivity gains from IT at the national level might not show up until business processes are redesigned to take advantage of the capabilities offered by the technology. In addition, IT might

not be productive even at the firm level due to outdated incentive systems which do not reward mangers and workers for improved productivity (McKersie and Walton, 1988). Therefore, there is likely to be a lag between the time of investment and the time that benefits show up in productivity gains while organizations redesign their business processes and make necessary changes in management practices and incentives in order to "capture" the potential productivity gains (Brynjolfsson, Malone and Gurbaxani, 1988).

4. Redistribution: IT might just redistribute the pie, not increase it, benefiting individual firms, but not the economy as a whole. This means that firms invest in IT to gain competitive advantage or to meet competitive standards, but that IT investment does not increase overall output.

The first three explanations suggest that we need better data, a longer time frame and better technology management to identify productivity gains from IT investment. The fourth suggests that IT investments will not increase output, but only redistribute it. However, in a global economy, nations could benefit from IT investment just by making their firms more competitive against foreign firms. This would suggest a global zero-sum game, but the potential for redistribution among nations.

Each of these explanations offer important insight into the productivity paradox, but are not very reassuring to business managers or public officials concerned about the return on their large investments in IT. Newer studies attempt to deal with measurement errors and time lags by using larger samples over longer time frames. Such research has been finding evidence of significant payoffs from IT investment at the firm level (Brynjolfsson and Hitt, 1993; Lichtenberg, 1993).

At the national level, previous studies of the economic impacts of IT have been limited primarily to U.S. data comparing one time period to another (the claims of productivity stagnation are based on comparisons with earlier years when productivity gains were greater). This paper pursues the question of returns from IT investment at the national level using data from 1984 to 1990 for twelve Asia-Pacific countries at different levels of economic development (Figure 1). This approach allows us to measure relationships between IT investment and output by comparing data across countries over time, rather than relying on comparisons of data on only one country at different time periods.

[Insert Figure 1 about here]

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, 1994a) 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 investment in IT use within a country?
2. Does investment in IT use 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 and the effects of IT investment on national productivity and economic growth.

Economic Factors Influencing IT Investment

We hypothesize that levels of investment in IT use at the national level are influenced by four key factors as seen in Figure 2: 1.) *National wealth*, measured by GDP level and growth, as well as savings as a percentage of GDP; 2.)*wage level and growth rate*, 3.) *IT infrastructure,* including human resources, capital availability, telecommunications networks and a dependable power supply; and 4.) *price/performance* of IT products, including the price/performance ratio of the products, as well as taxes and tariffs. 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 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. Gurbaxani (1992) has estimated that for every 1% drop in price in IT products, there is a 1.5% increase in demand. Tariffs, taxes, and factors which affect the price of IT products will affect the price/performance ratio of IT in a given country.

[Insert Figure 2 about here]

Economic Returns from IT Investment

While we expect the level of investment in IT use to be influenced by economic factors, we expect such investment to increase national *productivity* and *economic growth* in return (Figure 3). Investment in IT use can improve productivity in two ways:

1. *IT improves labor productivity directly* by substituting for labor or improving the productivity of workers. The gains in labor productivity can be seen most easily when computers are installed to perform routine data processing functions and replace workers carrying out those functions. Less visible are the gains in productivity achieved

by providing workers with timely information and tools for planning and carrying out their work.

2. *IT improves capital productivity* by complementing other investments. Plants and equipment can be made more productive through the use of computerized control systems which allow automation of processes and greater flexibility in production. The entire production system can be made more productive through the use of computers for planning and coordination of activities within the firm and externally with suppliers and customers. In the service sector, assets such as airplanes can be used more productively through computerized reservation systems to maximize capacity on flights. Improved capital productivity should also increase labor productivity, as workers with more productive tools should be more productive themselves.

Investment in IT is expected to increase economic growth through productivity growth, which should push wages upward, increasing workers' income and personal consumption (Figure 3). However, IT use might also have a negative effect on economic growth if it leads to, or is linked with, elimination of jobs in the redesign of business processes.

Another way in which investment in IT is expected to increase economic growth is by creating new industries related to IT use. These include software programming, systems integration, maintenance services, information services (e.g. CompuServe, America Online), and production of entertainment and other information content. The potential growth of these industries depends on the level of diffusion of computers in a country.

[Insert Figure 3 about here]

In summary, we expect that economic factors and IT investment are interrelated. We expect that economic factors determine wage rates, the availability of capital and the quality of the IT infrastructure. Depending on these factors, some countries spend relatively more for IT use than other countries. We expect this investment to create greater rates of economic growth and productivity growth.

METHODS AND DATA

The analyses in this paper measure quantitatively the relationships between environmental factors and IT investment, and between IT investment and growth in GDP and productivity. Table 1 presents data for each country on national wealth, infrastructure, wage rates and productivity.

[Insert Table 1 about here]

We use spending on computer hardware, software and services as a measure of IT investment, similar to the approaches of Brynjolfsson and Hitt (1993), Flamm (1987), and Gurbaxani and Mendelson (1990). To compare across countries, we use IT investment as a percent of GDP and as a percent of total capital investment in 1990, as well as growth rates in IT investment from 1984-1990. These provide us with common measures across countries and over time.

We first 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 earlier 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 and labor productivity (GDP per worker) in order to quantify the dynamic relationships among those variables. These correlations measure the extent to which growth in IT investment is related to increases in productivity and GDP, as the proponents of IT-led development suggest it should.

The data for this analysis were collected from secondary sources, from a confidential industry source and from our own case studies of each country. The secondary sources included the International Monetary Fund International Finance Statistics (IMF, 1991), the World Competitiveness Report (IMD, 1990), the U.S. Department of Labor Handbook of Labor Statistics (DOL, 1989), the United Nations Human Development Report (UNDP, 1991), the International Labor Office Yearbook of Labor Statistics (ILO, 1991), the Pacific Economic Cooperation Conference Science and Technology Profile and Pacific Economic Outlook. (PECC, 1991 and 1992), and the Directorate-General for Budget, Accounting and Statistics Statistical Yearbook of the Republic of China (DGBAS, 1991).[3]

The confidential industry source provided 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, consistent database covering ten years.

The case studies were conducted through field interviews and literature reviews. 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 (Dedrick and Kraemer, 1993a and 1993b; Dedrick, Kraemer and Jarman, 1994; Gurbaxani, et al., 1991; King and Konsynski, 1990; Kraemer, Gurbaxani and King, 1992; Kraemer and Dedrick, 1993; Kraemer and Dedrick, 1994a, 1994b, 1994c, 1994d).

FINDINGS FROM QUANTITATIVE ANALYSES

Investment in IT Use

Table 2 shows total IT spending (hardware, software, services) as a percentage of GDP and of total capital investment for twelve Asia-Pacific countries as of 1990, and average annual growth rates in spending from 1984 to 1990.[4] 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 2 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.

[Insert Table 2 about here]

Environment and Investment

Table 1 provides data on environmental variables for the countries. Each of these variables is a measure of one of the factors presented earlier in discussion of the "Conceptual Framework" and Figure 2. National wealth is measured by GDP per capita, growth in GDP, and savings rates. 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). Productivity is measured by the level and growth rate of GDP per employee. Wage rates are measured by average hourly wages in manufacturing and services.

In order to determine the relationship between environmental factors and IT investment, we begin by conducting Pearson 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 in 1990. Table 3 shows the variables which were found to have a statistically significant correlation with IT spending.

[Insert Table 3 about here]

The correlations in Table 3 generally support the relationships hypothesized in Figure 2 between environmental factors and IT investment. In each case, the environmental variable is strongly correlated with IT investment as a percent of GDP. Thus, IT investment is positively related to a country's wealth, infrastructure and wage rates.

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 of the variables are 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 historical factors which determine relative levels of economic development, 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. This relationship, which is at the heart of the productivity paradox debate, is the focus of the following section.

Environmental Change and Growth in IT Investment

We now come to the critical question of whether IT investment has measurable effects on productivity and economic growth, as Figure 3 posits. Table 4 presents the correlation coefficients found by conducting Pearson correlation analyses between average growth rates in total IT investment and growth rates in productivity and GDP.

[Insert Table 4 about here]

Table 4 presents compelling evidence of a strong relationship between investment in IT and growth in productivity and GDP. It shows that both GDP growth and productivity growth are highly correlated with growth in IT investment.

This finding challenges the productivity paradox claim that there is no evidence of a relationship between IT investment and productivity growth. While correlation is not evidence of causality, the findings presented here are consistent with the hypothesis that investment in information technology pays off in gains to productivity and economic growth.

Figure 4 illustrates graphically the relationship between growth in IT investment and growth in productivity by country.

[Insert Figure 4 about here]

Thailand, Korea, India and Taiwan have shown the fastest growth in IT investment , and they have ranked among the leaders in productivity growth. The only countries in which productivity growth appears to lag relative to growth in IT investment are Australia/New Zealand and the Philippines. Case studies of those countries suggest that the problem in Australia and New Zealand is that both depend heavily on exports of agricultural and mineral products which experienced major price drops in the late 1980s. This factor is likely to have overshadowed productivity gains in the manufacturing and service sectors, driving down overall GDP growth. In the case of the Philippines, political upheaval and natural disasters shook the economy for several years.

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.

These findings provide preliminary evidence to challenge 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 supports our findings on the relationship of IT investment to increased productivity. Brynjolfsson and Hitt (1993) 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. Using the same data sets, Lichtenberg (1993) extended and refined their analysis by investigating the existence of excess returns to IT labor and capital. He found significant evidence of excess returns to both IT capital and labor, with the size and significance of the returns to IT capital being larger. Both studies challenge the "productivity paradox" by presenting strong evidence of productivity gains from IT investment. The data sets 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 and Lichtenberg, 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 have 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 development of national industries to produce IT hardware and/or software has been an important goal of government policies in countries within our study such as Japan, Korea, Singapore, 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. The findings in this paper show clearly the benefits of IT use, and the high costs of policies which would depress demand for IT. Flamm (1987) argues that use of IT offers greater economic benefits than IT production. Schware (1992) further argues that the presence of sophisticated users is vital to developing production of IT, both to provide a market and to provide for the close interaction between producers and users that stimulates innovation and improvement. 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 lags behind the U.S. in IT use. One may reasonably ask what the costs have been to the Japanese economy in terms of lost opportunities to apply IT in other sectors in order to support its computer industry.

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 today. Recent trends in countries such as 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 and advanced technologies. 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 Korea, have succeeded largely through attracting multinational computer companies to invest in production facilities or subcontract with local firms. Of these three countries, only Korea has used protectionism as a tool for promoting IT production, and Korea only did so for a limited period, banning imports of microcomputers from 1982 to 1987.

Government officials can be encouraged by the finding that *investment in IT use* on a national level is correlated to productivity gains and economic growth. Given the importance of a strong information infrastructure, governments can encourage IT use by investing in human resources and telecommunications networks. This should include broad-based investments such as support for general education and widespread provision of basic telephone service, both of which provide high economic and social returns in their own right. However, development of a good information infrastructure also requires investments in specialized human resources such as electronics engineers, computer scientists, systems analysts and programmers, as well as specialized telecommunications services such as digital switching, high-speed data transmission and value-added networks. Such investments may be made in cooperation with the private sector, but experience shows that a government role is usually needed in building infrastructure, especially in developing and newly industrializing countries.

NOTES

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2. Prior to 1986 there were only about 10-15 million PCs worldwide. The installed base of mainframes and minicomputers was too few and not widely available to individual workers to have much of a measurable effect. After the mid-eighties, the adoption of PCs increased tremendously such that by 1993 there were about 140 million units worldwide, one-half of which were in the United States. About one-half of these PCs were connected to networks. As these figures suggest, diffusion and organizational adaptation is still occurring and, consequently, some scholars and practitioners view earlier conclusions about the productivity of IT investments as premature.

3. The Statistical Yearbook of the Republic of China is used for Taiwan data because some international agencies, such as the United Nations, do not include Taiwan. Taiwan is very careful to insure that the Yearbook statistics have the same meanings and are collected in the same manner as the United Nations data. Consequently the Yearbook is considered a valid data source for Taiwan when making comparisons involving international data sets.

4. 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.

REFERENCES

Amsden, Alice H., Asia's Next Giant: South Korea and Late Industrialization (New York: Oxford University Press, 1989).

Applegate, Linda M., James I. Cash Jr. and Donald Q. Mills, "Information technology and tomorrow's manager," Harvard Business Review, Vol. 88, No. 6 (November-December, 1988), pp. 128-136.

APO (Asian Productivity Organization), Information Technology-Led Development. (Tokyo: APO, 1990).

Attewell, Paul, "Information technology and the productivity paradox," Working Paper (New York: Department of Sociology, City University of New York, 1991).

Baily, Martin N., "What has happened to productivity growth?" Science, Vol. 234, No. 4775 (October, 1986), pp. 443-451.

Baily, Martin N., and Robert J. Gordon, "The productivity slowdown, measurement issues and the explosion of computer power," Brookings Papers on Economic Activity, Vol. 2 (1988), pp. 347-420.

Brynjolfsson, Eric, "The productivity paradox of information technology," Communications of the ACM, Vol. 36, No. 12 (December, 1993), pp. 66-77.

Brynjolfsson, Eric, and Loren Hitt, "Is information systems spending productive? new evidence and new results, " Proceedings of the 14th International Conference on Information Systems (Orlando, FL: December, 1993), pp. 47-64.

Brynjolfsson, Eric, Tom Malone and Vijay Gurbaxani, "The impact of information technology on markets and hierarchies," Working Paper No. 2113-88 (Cambridge, MA: Sloan School of Management, MIT, 1988).

Dahlman, Carl J., and Claudio R. Frischtak, "National systems supporting technical advance in industry: the Brazilian experience," Industry Series Paper No. 32 (Washington, D.C.: Industry and Energy Department, The World Bank, 1990).

David, Paul, "Computer and dynamo: the modern productivity paradox in a not-too-distant mirror," Working Paper (Palo Alto: Center for Economic Policy Research, Stanford University, 1989).

Dedrick, Jason, and Kenneth L. Kraemer, "The quest for self-reliance: information technology policy in India," Asian Survey, Vol. 33, No. 5 (May 1993), pp. 463-492.

Dedrick, Jason, and Kenneth L. Kraemer, "Caught in the middle: information technology policy in Australia," The Information Society, Vol. 9, No. 4 (October-December, 1993), pp. 333-363.

Dedrick, Jason, Kenneth L. Kraemer and Sheryl Jarman, "Supporting the free market: information technology policy in Hong Kong," The Information Society (forthcoming, 1994).

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

DOL (Department of Labor), Handbook of Labor Statistics (Washington, D.C.: United States Department of Labor, 1989).

Flamm, Kenneth, Targeting the Computer: Government Support and International Competition (Washington D.C.: Brookings Institution, 1987).

Gurbaxani, Vijay, "The demand for IT capital: an empirical analysis," Decision Support Systems, Vol. 8, No. 5 (December, 1992), pp. 387-403.

Gurbaxani, Vijay, and Haim Mendelson, "An integrative model of information systems spending growth," Information Systems Research, Vol. 1, No. 1 (March, 1990), pp. 23-46.

Gurbaxani, Vijay, John Leslie King, Kenneth L. Kraemer, Sheryl Jarman, Jason Dedrick, K.S. Raman and Chee Sing Yap, "Government as the driving force toward the information society:

national computer policy in Singapore," The Information Society, Vol. 7, No. 2 (April-June, 1991), pp. 155-185.

IMD International, World Competitiveness Report (Geneva: IMD International, 1990).

IMF (International Monetary Fund), International Financial Statistics, various issues (Washington, D.C.: International Monetary Fund, 1991).

ILO (International Labor Office), Yearbook of Labor Statistics (Geneva: International Labor Office, 1991).

King, John Leslie, and Konsynski, Benn, "Singapore tradenet: a tale of one city," Harvard Business School Case No. 9-191-009 (Boston: Harvard Business School, 1990).

Kraemer, Kenneth L., and Jason Dedrick, "National technology policy and computer production in Asia-Pacific countries," Working Paper (Irvine, CA: Center for Research on Information Technology and Organizations, 1994a).

Kraemer, Kenneth L., and Jason Dedrick, "Industry coordination as a problem in national information technology policy: the case of the Philippines," Working Paper (Irvine, CA: Center for Research on Information Technology and Organizations, 1994b).

Kraemer, Kenneth L., and Jason Dedrick, "Information technology policy in Taiwan," Working Paper (Irvine, CA: Center for Research on Information Technology and Organizations, 1994c).

Kraemer, Kenneth L., and Jason Dedrick, "From nationalism to pragmatism: computer policy in China," Working Paper (Irvine, CA: Center for Research on Information Technology and Organizations, 1994d).

Kraemer, Kenneth L., and Jason Dedrick, "Turning loose the invisible hand: information technology policy in New Zealand," The Information Society, Volume 9, No.4 (October-December, 1993), pp. 365-390.

Kraemer, Kenneth L., Vijay Gurbaxani and John Leslie King, "Economic development, government policy, and the diffusion of computing in Asia-Pacific countries," Public Administration Review, Vol. 52, No. 2 (March/April, 1992), pp. 146-156.

Lall, Sanjaya, "Trade in technology by a slowly industrializing country: India, " in Nathan Rosenberg and Claudio Frischtak (Eds.), International Technology Transfer: Concepts, Measures and Comparisons (New York: Praeger, 1985), pp. 45-76.

Lichtenberg, Frank R., "The output contributions of computer equipment and personnel: a firm level analysis," Working Paper No. 4540 (Cambridge, MA: National Bureau of Economic Research, November 1993).

Loveman, Gary W., "An assessment of the productivity impact of information technologies," Working Paper No. 88-054 (Cambridge, MA: Management in the 1990s Project, MIT, 1988).

McKersie, Robert B., and Richard Walton, "Implementation of information technology: human resource issues," Working Paper (Cambridge, MA: Sloan School of Management, MIT, 1988).

Mody, Ashoka, and Carl Dahlman, "Performance and potential of information technology: an international perspective." World Development, Vol. 20, No.12, (1992), pp. 1703-1719.

OECD (Organization for Economic Cooperation and Development), Usage Indicators: A New Foundation for Information Technology Policies (Paris: OECD, 1993).

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

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

PECC (Pacific Economic Cooperation Conference), Pacific Economic Outlook 1992-1993 (Washington, D.C.: PECC, 1992).

Rahim, Syed A. and Anthony J. Pennings, Computerization and Development in Southeast Asia (Singapore: Asian Mass Communications Research and Information Center, 1987).

Ranis, Gustav, "Science and technology policy: lessons from Japan and the East Asian NICs," in Robert E. Evenson and Gustav Ranis (Eds.), Science and Technology: Lessons for Development Policy (Boulder, CO: Westview Press, 1990), pp. 157-178.

Roach, Steven, "America's technology dilemma: a profile of the information economy" (New York: Morgan Stanley, 1987).

Roach, Steven, "White-collar productivity: a glimmer of hope?" (New York: Morgan Stanley, 1988).

Schware, Robert, "Software industry entry strategies for developing countries: a 'walking on two legs' proposition," World Development, Vol. 20, No. 2 (February, 1992), pp. 143-164.

UNDP (United Nations Development Programme), Human Development Report 1991 (Oxford, England: Oxford University Press, 1991).

TABLE AND FIGURE HEADINGS

Table 2. IT Investment in Asia-Pacific Countries

Country	IT Investment as % of GDP, 1990	IT Investment as % Total Investment, 1990	Average Growth in IT Investment, 1984-1990
Japan	2.18	6.52	13.90
Australia/New Zealand	2.03	8.24	15.43
Singapore	1.84	3.89	18.06
Hong Kong	1.19	5.18	15.22
South Korea	0.91	2.19	24.49
Taiwan	0.83	3.60	21.64
Malaysia	0.67	2.30	10.77
India	0.37	1.36	22.21
Thailand	0.36	0.83	25.00
Philippines	0.25	2.43	12.21
Indonesia	0.23	0.56	18.09

Source: Confidential industry sources

Table 3. Pearson 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
NATIONAL WEALTH		
GDP per capita, 1990	.9437**	.8982**
INFRASTRUCTURE		
Human Resources		
Secondary school enrollment	.7530**	.7702**
Scientists/Engineers per 1,000	.8921**	.7500*
Telecommunications		
Telephones per 1,000	.9343**	.9079**
Structure of Economy		
Services as % of GDP	.7568**	.7825**
R&D Capacity		
R&D as percent of GDP	.7355**	.5924
WAGE RATES		
Average wage in manufacturing	.8740**	.8987**

* Significance level = .05

** Significance level = .01

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

Variable	Correlation with Avg. Annual Growth in IT Investment (1984-90)
Avg. annual GDP growth (1984-90)	.7557**
Avg. annual productivity growth (1984-90)	.6061*

* Significance level = .05
** Significance level = .01

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
		Indonesia

Figure 2. Determinants of IT Investment

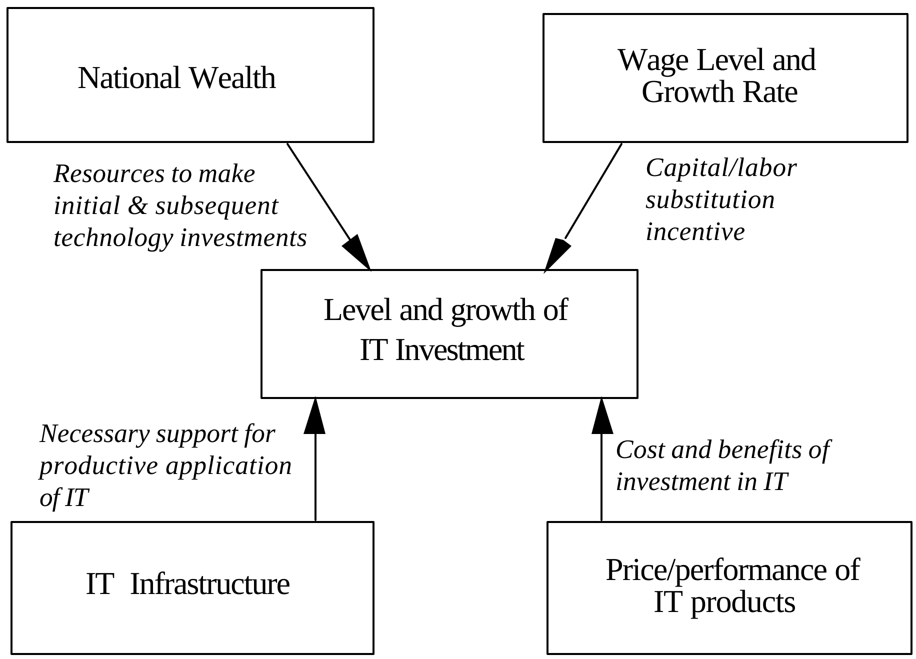

Figure 3. Economic Returns from IT Investment