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Economic Development, Government Policy, and the Diffusion of Computing in Asia-Pacific Countries

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How effective are government policies in promoting the diffusion of information technology? Kenneth Kraemer, Vijay Gurbaxani, and John Leslie King studied the impact of industrial policies in nine Asia-Pacific nations and found that such efforts did not have the significant direct effects on the diffusion of computer technology that might have been expected. While some government fiscal and trade policies did facilitate increases in computing expenditures, the authors found that the level of economic development was a more important predictor. Whatever policies are adopted should take into consideration the status of the country's economy.

The last 20 years have seen the emergence of several Asia-Pacific countries as significant economic powers. Notable in the accomplishments of these countries are consistent and rapid increases in the level of industrialization, particularly in high-technology industries and in the application of high technology to traditional industries (Amsden, 1989). The theoretical links between technical innovation, industrialization, and economic growth have been established for many years, dating at least from Schumpeter (1935), and argued forcefully ever since (Salter, 1960; Schmookler, 1972; David, 1975). The question of what gives rise to technological innovation, and thence economic growth, has been widely debated. Although the verdict is not yet in on the complete package of factors involved, it is clear that simple neoclassical economic theories of factor price differentials are insufficient to explain innovation, and that social institutions play key roles (Rosenberg, 1982).

A pressing public policy question, particularly since the advent of intense international economic competition from Asian countries in the 1980s, has been whether the institutions of government play a necessary and special role in industrial development and technological innovation. This question has been debated at length since the early 1970s (Pavitt, 1971). The debate has grown more heated in recent years, with prominent economists arguing for and against government involvement and the creation of an industrial policy (Thurow, 1984; Stiglitz, 1987). It has also received increased attention in theoretical and empirical research by various scholars (Amendola and Gaffard, 1988; Dosi *et al.*, 1988; Freeman, 1987). In particular, empirical studies of the remarkable progress of Japan and other Pacific Rim countries have cited government policy as a major factor in that success (Johnson, 1982; Freeman, 1987; Amsden, 1989). These arguments are compelling, but much remains to be done before the empirical case incontrovertibly linking industrial policy to economic growth is established.

This article focuses on the question of economic development, government policy, and technological innovation in a particular technological domain—computing technology—and in a particular region—the Asia-Pacific region. We chose computing technology as our focus because the effective use of this technology has been identified as an important component of industrial growth, and the ability to produce and use computer-related products has been seen as essential for any well-developed economy (Flamm, 1987; Land, 1990). The belief in the importance of proficiency in computer production and use is sufficiently strong to have prompted numerous countries to develop national computer plans as aids in national economic development (Kaul, 1987; Gurbaxani, *et al.* 1990; Odedra, 1990). It is worth noting that many of the national computer plans make specific reference to the linkage between the promotion of computing and economic growth. For example, Cherng and Lin (1990) describe Taiwan's (ROC) rationale as follows:

> Due to the emergence of the information revolution and the increasing competition in the world market, the ROC government has become aware that in order to assure national survival and development, the country must enhance competitiveness by resorting to the promotion of new information technology, enhancement of the government's efficiency and the increase of industrial productivity.
>
> Accordingly, in its "10 year Development Plan for Taiwan's Economy," formulated in 1981, the ROC government specifically designated the information industry as a "strategic" one. In order to promote the development of the industry, the government...formulated the "Sectoral Development Plan for the Information Industry (1980-1989)," in which is mapped out the project for computerizing the operations of government agencies and public and private enterprises, so as to promote the application of computers, expand the domestic computer market, and assist the development of the local information industry.

We selected the Asia-Pacific region as a locus for our study because it provides an excellent array of examples with respect to both economic development and government policy towards computing diffusion. The region has highly developed economies, newly industrializing economies, and developing economies. It also has countries with aggressive government policies for the development of computing technology and countries with a policy of nonintervention in this technical realm.

Two quantitative indicators highlight the growing importance of the Asia-Pacific region. The first is the absolute size of the computing market in the region, which was calculated at $79 billion (U.S. dollars) in 1989, or nearly 30 percent of the world market, with Europe at $94 billion and the United States at $111 billion (McKinsey and Company, 1990).[1] Moreover, the Asia-Pacific region is the fastest growing of these three regions, with a 30 percent growth in the market between 1985 and 1989 compared to 20 percent growth for Europe and 5 percent for North America (McKinsey and Company, 1990). Given the magnitude of Asia-Pacific growth in computing, it is likely that government has been a major contributor, both as a direct result of its spending for government computerization programs (including infrastructure) and its stimulation of private-sector computerization through tariff, tax, training, subsidy, and related policy interventions.

Our analytic approach in this article is to review the arguments for and against such government interventions and to examine aggregate data for any initial evidence that such interventions do play a role in the diffusion of computing technology. The theoretical arguments in favor of government intervention to promote computing are shown to have strong face validity. However, based on a preliminary empirical analysis using a newly aggregated database on economic growth and computing expenditures in nine Asia-Pacific countries, we conclude that empirical support for their efficacy at the aggregate level is lacking. Economic development and investment in computing technology are shown to be associated *regardless* of government policy. Simply put, such investments appear to be related more to the state of economic development in a country than to government policy toward computing. These results raise interesting questions about the rationale for, and real efficacy of, national computer plans.

Should Governments Intervene?

Opponents of government intervention in the production and use of computing technology usually argue from neoclassical economic philosophy that *laissez-innover,* the free spirit of innovation in the private sphere, is a direct relation to *laissez-faire* of the market (Kraemer and King, 1978). Minimal public-goods infrastructure might be required to build a base for private action, but direct governmental intervention in the processes of innovation, they hold, distorts the market for

Table 1
Classification of Countries by Development Status

Country	GDP Per Capita 1987 (dollars)	Human Development Index (1990)
Developed countries		
Australia	11,000	.978
New Zealand	7,750	.966
Newly industrialized countries		
Hong Kong	8,070	.936
Singapore	7,940	.899
South Korea	2,690	.903
Taiwan	5,075	*
Developing countries		
Indonesia	450	.591
Malaysia	1,810	.800
Philippines	590	.714

Source: UNDP (1990)
* The United Nations does not carry statistics for the Republic of China (Taiwan).

Variables and Framework

State of Economic Development

The countries in our data set can be categorized into three classifications based on the state of their economic and social development (Table 1). The source for these data (excluding Taiwan) was the United Nations Development Program (UNDP) 1990.

We used two measures as the basis for classifying the countries. The first, which is the measure most commonly used by economists and others, is gross domestic product (GDP) per capita. The second, which is new, is the Human Development Index created by the United Nations Development Programme (UNDP, 1990). This index is a composite measure, ranging from zero to one, which includes three elements of a decent living standard: longevity (life expectancy at birth), knowledge (adult literacy), and income (logarithm of real GDP per capita). This index was developed because economic growth *per se* does not translate into human development in all societies. Some countries have achieved high levels of human development at modest levels of per capita income. Others have failed to translate their high income levels and rapid economic growth into commensurate levels of human development. We believe that the two measures provide a good basis for classifying the development status of countries because, taken together, they reflect both the economic *and* social aspects of a country.

Government Policy Toward Computing

In addition to their development status, the countries studied can be characterized in terms of government policy toward computing. The sources for these characterizations are the national plans of the countries, papers written on the subject by country experts, and our own continuing field investigations in each country. Table 2 describes the countries in terms of whether they: (1) developed an explicit national plan for computing, (2) appointed a plan coordinator, (3) focused on production and/or use, and (4) targeted promotion of use on the public and/or the private sector.

Computing Diffusion

We quantified the aggregate level of computing diffusion through a surrogate measure: total computing expenditures. This is a widely used measure in studies of computing growth (Gurbaxani and Mendelson, 1987, 1990). Because it is difficult to create accurate measures of "quantities" of computing, it becomes necessary to use a measurable proxy variable that is highly correlated with the "true" variable. Although the use of total computing expenditures has limitations as a diffusion measure—for example, one cannot tell how computers are used or how broadly or narrowly they are diffused in the economy—we believe that the measure is useful for this preliminary investigation.

new ideas and thwarts or misdirects private initiative, thereby damping the underlying engines of creativity that produce innovation in the long run (Stiglitz, 1987). There is also ample evidence that too much of the wrong kinds of government intervention in private economic life can have disastrous consequences for both technological innovation and economic growth (North, 1988).

Proponents of government policies that support both domestic production and use of computing technology extend the connection between social investments in public goods such as basic research and physical infrastructure, to the eventual exploitation of technological innovations enabled or caused by such social investments. Government's role is to provide whatever infrastructure is necessary to get economic development started and to maintain it after it is going. This "priming-the-pump" argument is well-established in the literature on economic development (Todaro, 1989).

The key discriminator between the arguments against and for intervention is this: how does one define the critical infrastructure requiring government involvement? The conservative view described above holds that only those activities, products, and services that are pure public goods can be counted as legitimate infrastructure for government attention. Basically, they argue that government involvement must end where the markets begin. Proponents of intervention stretch the concept of infrastructure to include institutional interventions of many kinds, including those in the markets themselves. This "regulatory" view of economic growth is expounded well in Boyer's (1988) articulation of the "regime of accumulation," which sets the context within which economic growth might proceed. In this view, no intervention is excluded *a priori*. The question is not what is theoretically appropriate, but what is practically required given specific circumstances.

The arguments in favor of and against intervention are backed with case-specific empirical evidence. Opponents have long pointed out the drastic consequences of government involvement which can throttle both technological innovation and economic development (von Hayek, 1945). The serious problems seen in radical intervention create a "slippery-slope" argument against significant interventions of any kind. In much the same way, however, proponents point to the presence of government policy and contemporaneous economic growth in certain countries, arguing that the former causes, or at least facilitates, the latter. Japan's industrial policies are usually cited as the premier examples, but the national industrial plans of South Korea, Taiwan, and Singapore are held up as examples of ways in which government policy can dramatically help economic growth (Johnson, 1982; Amsden, 1989). This specific argument is made forcefully in the case of computing technology by Flamm (1987) and by Matley and

Table 2
Summary of Government Policy Toward Computing, Circa 1988[a]

Country	Explicit Plan for Computing	Central Coordinator Production	Central Coordinator Use	Focus of Plan Production	Focus of Plan Use	Target of Use Public Sector	Target of Use Private Sector
Australia[b]	Yes	Yes	No	Yes	No	No	No
New Zealand	No	No	No	No	No	No	No
Hong Kong	No	No	Government sector only	No	Yes	Yes	No
Singapore	Yes	Yes	Yes	No	Yes	Yes	Yes
South Korea	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Taiwan	Yes	No	Yes	Yes	Yes	Yes	Yes
Indonesia	No	No	Government sector only	No	No	No	No
Malaysia	No	No	Government sector only	No	Yes	Yes	No
Philippines	No	No	Government sector only	No	Yes	Yes	No

a The status of several countries has changed since 1988. For example, Hong Kong adopted a plan for government computer use in 1990, and Malaysia created a central coordinator for production and use in 1990. However, these actions occurred beyond the period of our data set, and, therefore, were not included in Table 2.
b At first glance, Australia should be included in the set of countries with a national computer plan. However, it is not included because Australia's national policy was only announced in September 1987 and focused mainly on computer production rather than use. Therefore, it would have had little or no effect on the data used in this study.

McDannold (1987), and for better or worse, the argument has strong support in countries that wish to emulate Japan's great economic surge forward.

In this article, we address three empirical questions that provide a preliminary assessment of the relation between government computing policies and their consequences. These questions are: Do the newly industrialized countries spend proportionately more for computing than developed or developing countries? Do they have higher rates of spending growth than do developed countries? Do they have government policies that promote spending more and faster?

Table 3
Compound Annual Growth Rates of Computing Expenditures for Each Country

Country	Hardware	Software	Services	Total
Australia	14.2	16.5	6.4	11.9
New Zealand[a]	17.8	24.2	20.8	19.4
Hong Kong	6.5	12.0	10.9	7.8
South Korea	7.9	36.1	22.0	10.8
Taiwan	9.6	21.1	10.8	10.8
Singapore[b]	-0.9*	13.6	11.4	3.8
Indonesia	-0.6*	16.9	7.0	2.2*
Malaysia	-4.4*	14.1	5.6	0.5*
Philippines	3.5	27.5	3.7*	5.4

a New Zealand's overall growth rate is exaggerated by rapid growth in the period 1984 to 1986, when the sales tax on computer hardware was reduced, foreign exchange controls were lifted, and tariffs reduced.
b Singapore's growth rate is depressed by the major recession it experienced during 1985 to 1986.
c The coefficients are not statistically significant at the 95 percent level.

Preliminary Empirical Investigation

The relationship between interventions and their consequences is best revealed by careful, longitudinal study that links together specific policies and actions with particular results. Such study is badly needed and in some limited instances has begun, but to date the best assessments are limited to cross-sectional evaluations of the correspondence between policies and economic measures of computer-related activity in given countries (Gurbaxani *et al.*, 1990; Odedra, 1990).

This analysis examines the relationship between three elements: economic development, government policy, and computing diffusion. It uses data from nine Asia-Pacific countries for the period from 1983 through 1988. The three elements of the general framework are shown in Figure 1 and are described in the grey box on page 148. The data being analyzed is described in the grey box on page 150.

Based on the data in Table 2, we concluded that three countries had instituted explicit government plans to promote computing production and/or use: Singapore, South Korea, and Taiwan.[1]

Singapore's national computer plan (Gurbaxani *et al.*, 1991) is aimed at developing a local software and services industry through pilot programs in the public sector and at intensive promotion of computing adoption and use in both the public and private sectors. The plan also provides for strong educational programs in computer science, information systems, and computer use in order to build a base of needed computer professionals and computer users. Singapore has a single central industry coordinator with exceptional control—the National Computer Board (NCB). The NCB works with other government agencies to develop a local software and services industry and to attract multinational computer firms

Data and Analysis

We used data on aggregate spending in constant 1982 U.S. dollars for three major categories of computing budgets—hardware, outside software, and services (excluding telecommunications)—for the years 1983 to 1988 to examine the level of computerization and the rate of diffusion of the technology in each of the countries studied. The trends in computing expenditures in these countries are presented and compared with what other studies have indicated are the corresponding trends in the United States.

We believe that the data reasonably reflect overall trends and the relative state of computing diffusion among countries. There is no standard set of systematically collected statistics on computing expenditures across countries. Reliable data on information-technology spending is difficult to obtain due to discrepancies among the data collection instruments used and the time frames sampled. However, we have confidence in our data because they were assembled from different data sets that allow triangulation. The data used in this analysis were obtained from various sources: published reports of the International Data Corporation, Dataquest, and Infocorp, etc.; government statistics; and interviews with marketing experts at major computer manufacturers. Although the data were obtained from a variety of sources, we believe that the data set is the best available for the Asia-Pacific region. These data should be interpreted as indicative of broad trends rather than as point estimates of the level and growth rates of computing in each country.

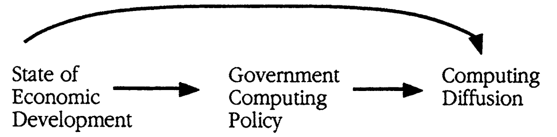
The main purpose of the empirical analysis is to summarize the aggregate growth trends in the various computing categories and to determine their fit with established economic models of computing growth (Gurbaxani and Mendelson, 1987). These models formally develop the rationale for growth patterns. Specifically, they note that price trends in computing display an exponential decline, and that when the demand for computing is of constant price elasticity, then the pattern of growth is an exponential increase in spending over time. Empirical studies have shown that in the United States the observed growth pattern of information systems is consistent with the predicted pattern (Gurbaxani and Mendelson, 1990). The resulting specification for each of the categories of computing expenditures is a regression of the logarithm of the annual expenditure in the given category against time. The details of the analysis are described in a technical appendix (available from the authors), and the results of the empirical analyses are summarized in Table 3.

Our data, which are shown in Table 3, are lower than those of the McKinsey report because: (1) Japan was not included in our data set, and (2) our figures were for 1987 but expressed in 1982 dollars, whereas the McKinsey figures were for 1989 and expressed in 1989 dollars.

to produce locally for export. The NCB houses the computer industry associations and computer societies, coordinates education and training by all public institutions, promotes computing careers, and generally promotes computing use within the country. The NCB is the provider of computing applications and services for all government agencies, and recently it has taken the lead in developing systems that link the public and private sectors.

Although South Korea has emphasized the electronics industry since the 1960s, it first targeted the computing industry for development as part of its fifth Five-Year Economic Development Plan, 1982-87 (Amsden, 1989; Matley and McDannold, 1987). The plan focused on the creation of a local computer manufacturing industry, particularly in the areas of mini- and micro-computers, and the production of software to support industry with applications. Industry coordination is provided by two main institutions, although there are many other institutional actors as well. The Ministry of Trade and Industry coordinates research and development in the computer industry, including the education and training of computer scientists and computer engineers. The National Computerization Board coordinates computer use in all sectors of the economy and has heavily targeted both the public and private sectors for the promotion of computing use.

Figure 1
General Framework



Taiwan's national plan (Cherng and Lin, 1990) is aimed at both production and use. Production of computer technology is oriented towards niche markets (personal computers, monitors, PC motherboards) and components for multinational computer vendors. The plan also is aimed at increasing the number of computer professionals and information systems users in order to provide sufficient skilled labor for effective domestic production and use of the technology. Industry coordination is provided by the Institute for Information Industry, which was created in 1979. The institute promotes the development of the local computer industry by training the high-level manpower needed by the industry, conducting research and development, introducing advanced techniques, providing capital for the industry, and giving preference to locally made computers in government procurements. The institute promotes the use of computing in both the public and the private sectors through the development of plans for computerization, the development of application software, the improvement of government computer centers and staff, the education and training of computer professionals and computer users, and the promotion of computing within the population as a whole.

Table 4
Income Levels and Computing Expenditures (Excluding Telecommunications) by Country, 1987

Country	GDP Per-Capita (1987 US dollars)	Computing Expenditure as Percentage of GDP
Australia	11,100	2.8
New Zealand	7,750	2.3
Hong Kong	8,070	1.1
South Korea	2,690	0.6
Taiwan	4,133	0.6
Singapore	7,940	1.3
Indonesia	450	0.2
Malaysia	1,810	0.7
Philippines	590	0.2
United States	18,530	2.2

Results

The Pattern of Computing Growth

Our first major finding was that, *overall*, the data were well described by an exponential growth model.[2] The average growth rate for total computing expenditures was 8.1 percent. New Zealand had the highest annual rate at 19.4 percent and Malaysia, the lowest at 0.5 percent. (Table 3)

The exponential model further held for all *categories* of computing expenditures—hardware (excluding telecommunications), outside software and services. Hardware expenditures in the region grew at an average annual rate of 7.6 percent during the period 1983 to 1988, although the growth rate varied from 3.5 percent for the Philippines to 17.8 percent for New Zealand. The average growth rate for software expenditures was 20.2 percent, and ranged from 12.0 percent for Hong Kong to 36.1 percent for South Korea. For services expenditures, the average growth rate was 10.6 percent, and ranged from 3.7 percent for the Philippines to 22.0 percent for South Korea. (Table 3)

Total computing expenditures for all countries, other than Indonesia and Malaysia, displayed excellent fits. In these countries, all coefficient estimates were statistically significant at the 95 percent level. Software expenditures fit the model in all countries without exception. Services expenditures fit well for all countries except the Philippines. The trends in hardware expenditures were consistent with the model in all countries except Singapore, Indonesia, and Malaysia, which experienced recessions in the period of analysis. Like most capital goods, investments in hardware decreased considerably during a recession.

This finding—that the overall pattern of growth in the Asia-Pacific region is exponential—is significant. Basically, it says that computing expenditures in the region are not highly erratic over time; rather they follow a pattern of more or less steady growth. This pattern in the Asia-Pacific region corresponds to Gurbaxani and Mendelson's (1987, 1991) finding in the United States that expenditure growth on computing has been exponential since the early 1970s. The primary alternative pattern is the commonly used S curve, or logistic curve, in which expenditures start off slowly, then rise quickly during a takeoff period, and eventually flatten out at some equilibrium level. This curve has not worked well as a pattern for describing diffusion in the IT sector in the United States. Another alternative is the price-adjusted diffusion pattern, in which the initial process of computing budget growth is S shaped, but a steady-state growth period emerges where computing prices decline and computing budgets continue to grow. This pattern appeared to hold until the early 1970s, but then was displaced by the exponential pattern (Gurbaxani and Mendelson, 1990).

Moreover, this finding of "steady growth" suggests that government computing policy might *not* make a difference in overall spending. If government policy made a difference, we would have expected to see a shift in the spending pattern after the introduction of such policy. No such pattern is present in the data for the three countries that adopted national computer plans in the early 1980s (Singapore, South Korea, and Taiwan). Although it might be argued that the data simply are not refined enough to show the influence of government policy, the general correspondence of the data with the U.S. pattern, where there is no national computer plan, calls this argument into question.

The Influence of Economic Development

Our second major finding is that both the level and the growth rate of computing expenditures correspond directly to the level of economic development in a country, regardless of whether it is developed, newly industrialized, or developing. By level of computing expenditures, we mean the proportion of the overall economy spent for computing, i.e., computing expenditures taken as a percent of GDP. Table 4 shows that spending levels correspond to development status, with the developed countries of Australia and New Zealand highest and the developing countries of the Philippines and Indonesia lowest. Malaysia is the only country that does not fit the pattern, probably because it is really between the Newly Industrialized Countries (NIC) and the developing countries in terms of development status. Thus, its spending level is more characteristic of the NICs than the other developing countries.

This pattern, in which total computing expenditures correspond directly to the level of economic development in a country, also held for the compound annual growth rate (Table 3). Two developed countries, Australia and New Zealand, had the highest annualized growth rates of 11.9 percent and 19.4 percent respectively.[3] The newly industrialized countries showed the next highest annualized growth rates, at 3.8 percent for Singapore, 7.8 percent for Hong Kong, and 10.8 percent for Taiwan and South Korea. Finally, the developing countries experienced a lower growth rate with Malaysia at 0.5 percent, Indonesia at 2.2 percent, and the Philippines at 5.4 percent.

This finding has important implications because it fails to support the argument that developed countries would show

Table 5
Average Growth in GDP and Computing Expenditures by Country, 1984-1988

Country	Average GDP Growth (Percent)	Average Computing Expenditure Growth (Percent)
Australia	3.9	11.9
New Zealand	1.8	19.4
Hong Kong	8.2	7.8
South Korea	10.6	10.8
Taiwan	9.2	10.8
Singapore	6.1	3.8
Indonesia	5.0	2.2
Malaysia	4.7	0.5
Philippines	0.5	5.4

Sources: International Monetary Fund (1990) for all countries except Taiwan; Asian Development Bank (1988) for Taiwan.

high levels of computer technology penetration, but developing countries would show high growth rates in computing investments as they attempted to catch up. In fact, the opposite is true. Developed countries are high in both the total level and rate of increase in spending for computing. Moreover, although computing expenditures in the NICs were growing at roughly the same rate as economic growth, in Australia and New Zealand computing expenditures far outpaced economic growth (Table 5).

The above findings further reinforce the argument that a country's level of computing expenditure is strongly correlated to its stage of economic development. Two factors may help explain this finding. One is that as economies develop, the bulk of the output tends to shift from agriculture to manufacturing to services. Computing applications are generally service oriented, with the heaviest users being the financial (i.e., banking, insurance), distribution (transportation, wholesale, retail), and government sectors. Thus, computing use should be highest in service-dominated economies. Second, as economies develop to the point where unemployment decreases, wages begin to rise, increasing the gains from substituting capital for labor. In other words, the potential returns on investment in computing are greater. Table 6 and Figures 2 and 3 show that the highest levels of computing expenditure are in the countries with high wages and where services make up the highest proportions of GDP.

These two factors may explain the high levels of computing expenditure in Australia and New Zealand compared to Hong Kong and Singapore, which have comparable per capita incomes but much lower wage rates. They also add a stronger causal link between level of development and computing diffusion using economic factors of demand creation (the move to a services-dominated economy) and costs of substitutes (wage rates).

Other factors associated with high levels of development include: high levels of education; reliable infrastructure in power, transportation and telecommunications; and a pool of managerial and technical expertise. All of these factors are necessary for the assimilation of a "network" technology such as computing. Also, the developed countries have (for the reasons detailed above) been using computers for a longer time than the NICs, and thus have developed a computing-specific infrastructure, including computer education programs with qualified instructors, computer literate workers and managers, organizational experience with computing, and both intra- and inter-organizational networks. These factors actually lower the cost and increase the productivity of new computing investment.

The Influence of Government Policy

What of the question of whether government intervention associates with computing investment and economic growth? To examine this question, we looked at the particular profiles of the countries with national computing plans, in the context of the other countries in the study.

There is no clear evidence linking computing expenditures to the existence of a formal national computer plan. The three NICs with such plans had the following growth rates: South Korea, 10.8 percent; Taiwan, 10.8 percent; and Singapore, 3.8 percent.

However, we found higher growth rates among the developed countries and the one NIC *without* national computer plans: Australia, 11.9 percent; New Zealand, 19.4 percent; and Hong Kong, 7.8

Leaving out the three developing countries, we found insufficient evidence to conclude a correlation between national computing plans and computing diffusion.

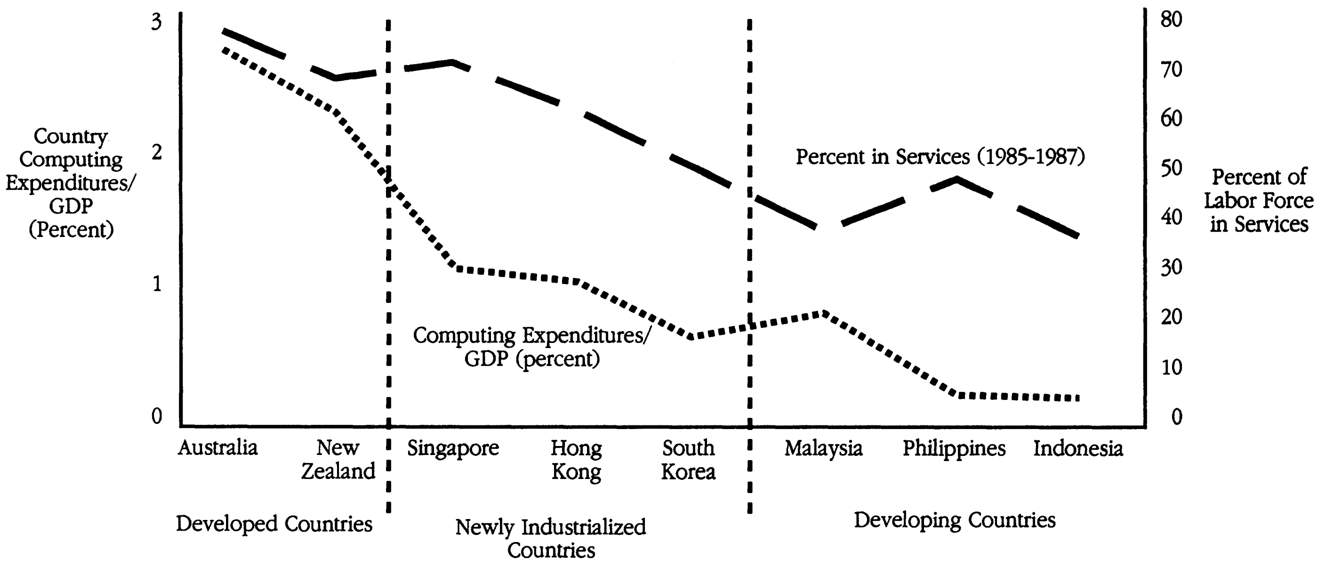
However, this is not to say that policy does not matter. What it might indicate is that what matters most in terms of government policy is the range of policy decisions that affect the cost of labor versus the cost of computers. For example, if

Table 6
Services Orientation, Wage Rates, and Computing Expenditures as Percent of GDP, by Country

Country	Percent Labor Force in Services, 1985-1987[a]	Hourly Wage Rate in Manufacturing, 1987, U.S. dollars[b]	Computing Expenditure as Percentage of GDP, 1987
Australia	77	9.20	2.8
New Zealand	70	5.68 (clothing)[c] 10.20 (pulp, paper)[c]	2.3
Hong Kong	64	2.10	1.1
South Korea	51	1.80	.6
Taiwan	—	2.20	.6
Singapore	73	2.40	1.3
Indonesia	36	—	.2
Malaysia	39	—	.7
Philippines	46	—	.2

a Source: UNDP (1990).
b Source: World Economic Forum (1989), cited in Australian Government Industry Commission (1990, p. 57).
c Source: New Zealand Department of Statistics (1989), cited in New Zealand Ministry of Commerce (1990, p. 14).

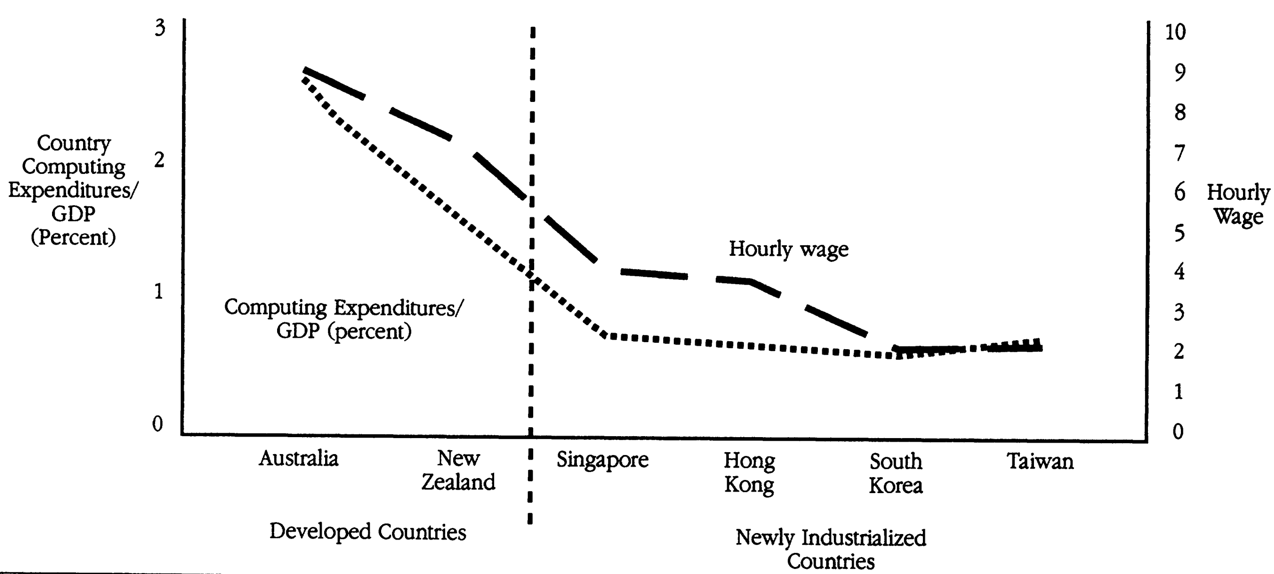
Figure 2
Service Orientation and Computing Expenditures



a government drives down wage rates, it may discourage computing investment. The case of New Zealand shows how broader economic policies might affect the price of computers and therefore the demand for computing. In October 1983, the New Zealand government reduced the sales tax on computer hardware from 40 percent to 10 percent; in 1984, they removed foreign exchange controls and lowered tariffs. These moves greatly reduced the cost of all types of computers and related equipment. Immediately, computing expenditures increased by 20.4 percent in 1984, 33.1 percent in 1985, and 34.7 percent in 1986. This satisfied the pent-up demand for computing until a new equilibrium was reached at the new relative prices. The growth rate leveled off in 1987 and 1988 at around 7 percent.

Government programs aimed directly at computing, especially those for education and infrastructure (e.g., power, telecommunications), may have an effect on diffusion, but such an effect may be felt more slowly and is harder to quantify. Finally, if government substantially increases its own rate of expenditures on computing, this will obviously have an effect on total expenditures.

Figure 3
Wage Rates and Computing Expenditures



Policies *most likely to cause a discreet shift in spending patterns on computing technology appear to be those that significantly change the relative costs of computing or its substitutes.*

What this might suggest from a policy perspective is that government policy can have a short-term effect if policies substantially change the cost of the technology (e.g., through tax or tariff changes), but the computing promotion activities usually contained in a national computer plan (education, public awareness, infrastructure) will be more marginal in their effects. If that is the case, then policies must be implemented that conform to and support the broader economic trends driving computing diffusion. For example, it will be of little use to offer tax incentives for computing purchases at the same time as the currency is being devalued (thereby raising the cost of imported computers and lowering relative wage rates).

Conclusion

What can we conclude at this point? First, our study reaffirms the presence of a relationship between economic development and investment in computing technology. The higher the level of development the higher the level of computing expenditure in a country. Although this relationship has often been posited in the literature, the unambiguous nature of the results of this study provide solid empirical support for the proposition. Moreover, our analysis suggests specific variables as causal linkages between the level of economic development and computing diffusion. These variables include the demand for computing (affected by the move to a service-dominated economy in more developed countries), the cost of computer technology, and the cost of substitutes (i.e., wage rates).

However, we must leave open the claim, neither supported nor contradicted, that investment in computing technology "leads" to economic growth. It is not possible, given our data, to demonstrate causality in the relationship, and we are not aware of any data or studies that do provide such demonstration. Nevertheless, the weight of historical evidence is on the side of a causal relationship between investment in technology and economic growth (Rosenberg, 1982). Our findings do not contradict this tradition; rather they support it indirectly via the associations found.

Our findings regarding government policy are mixed. Policies most likely to cause a discreet shift in spending patterns on computing technology appear to be those that significantly change the relative costs of computing or its substitutes. These are generally fiscal policies, such as sales taxes and tariff rates or depreciation allowance schedules. They may also be macroeconomic policies such as exchange-rate policy, controls on foreign exchange, or monetary policy. The New Zealand case clearly shows the degree to which computing expenditures can shift dramatically due to broad policy changes in these areas.

Regarding national computer policies, the results are less clear. A comparison of the computer expenditures of the three countries with such policies to the three without them (not including developing countries), shows no evidence that the existence of national computer policies leads to increased spending overall. Thus, in terms of the data set used in this study, we cannot claim any such association.

However, two points should be made as caveats to this conclusion. First, the national computer plans of South Korea, Taiwan, and to a lesser extent Singapore, were largely aimed at increasing production of computing products and services within those countries. It may be that such policies are more effective in promoting *production* than *use* of computers. Even Australia, a heavy user of computers, announced an Information Industries Strategy in 1987 that targets production and exports of information technology as key goals.

Still, raw data on production could be misleading as a measure of technology diffusion, especially in a case like Singapore, where a number of multinational computer companies manufacture products for export but transfer very little technology and generally do not carry out research and development. This production may provide jobs, investment, and export earnings to Singapore but is not in itself evidence of diffusion of computing within the country. And Australia's policies are driven as much by balance of trade problems as by technology concerns (Dedrick and Kraemer, 1991).

The second point regarding national computer policies is that their effects may be more subtle than those of macroeconomic policy changes and may not be easily discernible in a measure such as total computing expenditures. As mentioned before, the effects are likely to be felt more gradually over a longer period of time and thus would not cause a discreet shift that could be easily correlated to the introduction of the policy. Also, some of the initiatives generally included in a national computer policy (training, increased coordination, and data sharing among government and research institutions) may result in qualitative improvements in computer applications without much increase in computer spending. For example, training tax collectors in computer skills and improving data sharing with other agencies may improve the efficiency and effectiveness of tax collection without any need for new hardware or even purchased software (new programs might be written by existing staff and not show up in any market data).

These two caveats do not contradict the broader findings of this study but rather suggest avenues for further, more fine-tuned research. As to the question of whether governments should adopt policies to support production and use of computing, one answer is that many are doing so without waiting for empirical evidence to support the value of such actions. Even the developing countries are moving in this direction. The Philippines announced a National Information Technology Plan in 1989, and Malaysia and Indonesia are formulating such policies as well. Only New Zealand is moving in the opposite direction, having dismantled its coordination apparatus for government computing and corporatized its government computing bureaus.

On the other end of the scale, most of the developed countries (especially the European Community and Japan) have national strategies to promote information technology, while the United States mostly limits its computer policies to areas of military concern. The poor performance of the European "national champions" and the so-far limited output of Japan's Fifth Generation Computer Project also suggest limits to the value of government intervention.

In contrast, the aggregate data from our empirical analysis show no negative relationship between computing growth and the kinds of intervention found in South Korea, Singapore, and Taiwan. In fact, controlling for the early spending surge in New Zealand and for the sharp recession in Singapore (1985-1986) which depressed demand across the economy, we find virtually no difference in performance between countries with national computer plans and those without. This suggests that if computer policies have any effect, it is likely to be more qualitative than quantitative and more long term than immediate. Also, even if government intervention can be shown convincingly to pay off in some cases, it is doubtful that the same policies would work well for all countries at all times. Given the importance of economic factors in determining diffusion rates, policies must take into careful consideration the country's development status in order to be effective.

Some developed countries with an established computing industry are likely to need no special policies at all, or at best to need only a focused policy in the area of research and development or policies to ensure a "level playing field" in the global marketplace. Developing countries, however, might need to concentrate on building an infrastructure capable of supporting information technology as economic development spurs diffusion. We believe our results fail to support the arguments for either *laissez innover* or for targetted industrial policy as generally superior. Rather they indicate that government has an important role to play, especially through its macroeconomic policies. Targetted policies may have to be judged on narrower, often qualitative merits rather than in terms of overall computing diffusion.

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Notes

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1. At first glance, Australia should be included in the set of countries with a national computer plan, but it is not included because its national policy was only announced in September 1987 and focused mainly on computer production rather than use. Therefore, it would have had little or no effect on the data used in this study. Australia has had piecemeal programs to promote computer production since 1977, but their effects have been slight. Australia first announced a comprehensive Information Industries Strategy in 1987, which focuses on production rather than use (Dedrick and Kraemer, 1991).
2. The data showing the fit of the exponential model are not included in this article but are presented in a technical appendix available from the authors. The fit is evidenced by the high values for the coefficient of determination, or the R^2 term, and the t statistics corresponding to the coefficient estimates.
3. Australia's growth rate is probably understated because of the unmeasured products of a large pool of software development professionals who develop software in-house. In spite of this, software purchases account for Australia's largest single component of growth.

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