# The Impact of ICT on Economic Growth and the Productivity Paradox

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## Introduction

Investing in information technology capital is widely regarded as having enormous potential for reducing costs, enhancing productivity, and improving living standards. Over the last two decades, firms in the T5 countries have shifted their equipment spending away from heavy machinery towards information processing equipment.

But, despite enormous improvements in the underlying technology, the benefits of such spending have not been found in aggregate output statistics. Empirical studies have typically found that the marginal product of ICT investment has been smaller than the marginal product of investments in more conventional capital. This is the controversial Productivity Paradox of Information Technology.

Recent studies are starting to show that the Productivity Paradox may have disappeared, however. Although there is no clear-cut consensus yet, the working hypothesis that ICT investments are finally boosting productivity is already affecting policies in T5 countries.[1] Although investment in ICT and its impact may mostly be driven by the economic decisions mentioned above, particularly in the maturing and aging T5 countries, it may also have side-effects on income distribution and social cohesion. Thus, understanding the implications (the mechanism and size of the impact) of the development of ICT on economic growth and productivity is becoming a crucial issue, not only for economists but also for business leaders and policy makers.

Here, we review and compare earlier and more recent studies and clarify some of the crucial factors and mechanisms that determine the aggregate productivity of ICT investment. So far, most such studies have focused on the United States. Based on these studies, we look for the existence of the crucial factors regarding the Paradox in other countries, particularly in Japan. Moreover we investigate the impact of the growth of ICT capital in Japan on the industrial structure of the economy and on the global economy.

This chapter focuses on the impact of ICT on aggregate economic growth and productivity (macro-economy) and looks into the following issues:

(1) What questions or issues underlie the Productivity Paradox?

(2) What are the major findings of previous studies regarding the Paradox. In particular, what key factors explain or determine the emergence or disappearance of the Paradox?

(3) What is the status of these factors in Japan and does the Paradox exist there?

(4) What impact has the growth of ICT capital in Japan had on the industrial structure of the economy and on the global economy as indicated by Input-Output analysis and trade statistics?

[1] FRB Chairman, Alan Greenspan made comments along this line in his July (1997) Testimony to Congress. OECD has developed recommendations for policies that fully exploit the contribution of advances in ICT on a global basis in view that the development of a global information society can help government contribute to further enhancement of public goals; *Global Information Infrastructures -- Global Information Society (GII-GIS): Policy Requirements.*

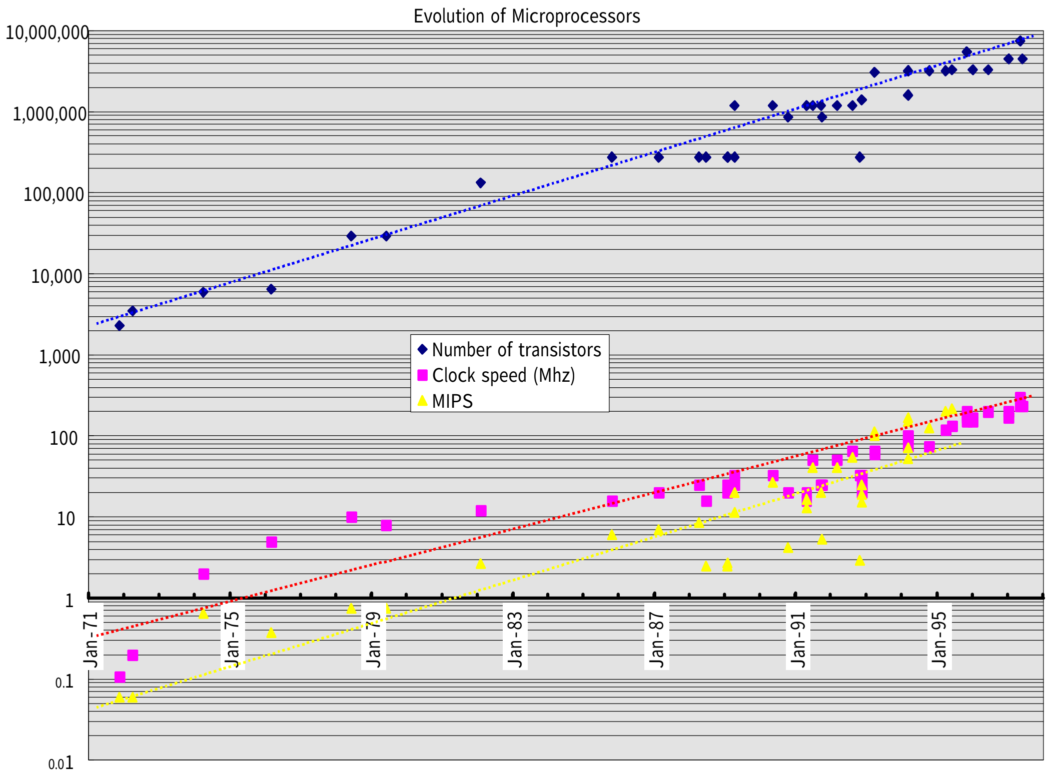
# 1. Background and Definition of the Productivity Paradox

## 1. 1. Growth of ICT investment

In recent decades there has been tremendous improvement in information and communication technology (ICT). For example, the capacity of memory chips has been roughly doubling every two years (Moore's Law); the computing power of microprocessors has also been doubling every two to three years.[2] As a result, the computing power of microprocessor chips has increased by more than two orders of magnitude since the early 1970s (Figure 1).

**Fig. 1 Evolution of Microprocessors**

(Growth of Clock speed, MIPS, and Number of Transistors in Intel Microprocessors)



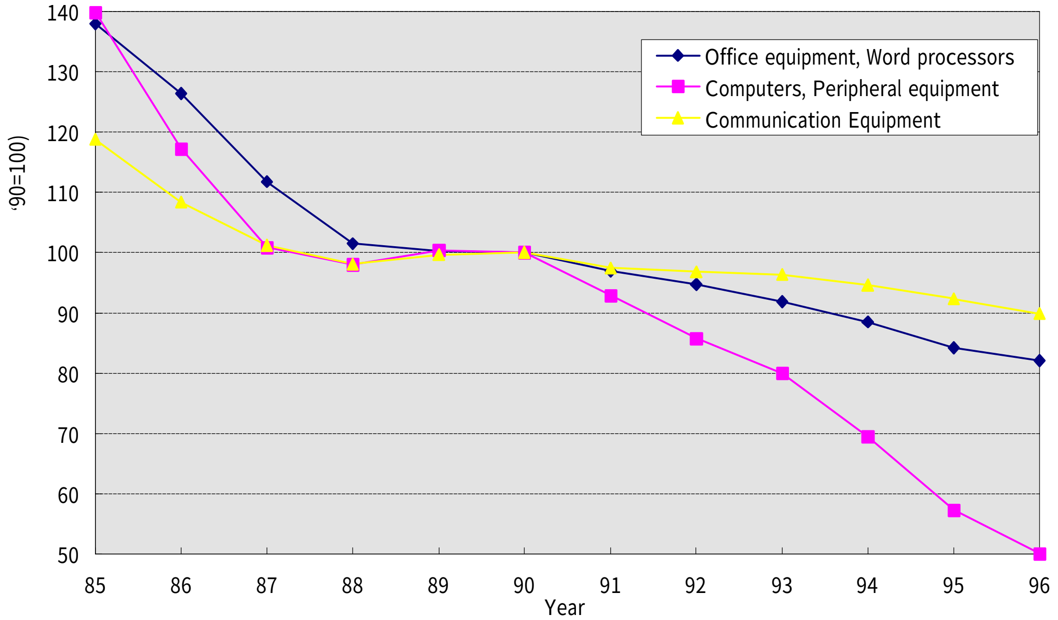

Source: *Intel Microprocessor Quick Reference Guide.*

The development of smaller, faster, and cheaper microprocessors and memory, which started in the mid-1970s, is still continuing in the 1990s. This ongoing technological innovation has been the driving force to reduce the price of ICT-related capital goods. The wholesale price of such capital has been decreasing at the rate of 7-8 percent per year and has halved in just over ten years. Such rapid and ongoing development in ICTs and ICT-based services is expected to enhance innovation in various aspects of the economy.

Investing in information technology capital is widely regarded as having enormous potential for reducing costs and enhancing productivity, and hence for improving living standards. Over the last two decades, firms have shifted their equipment spending away from heavy machinery towards information processing equipment.

2 Performance of computers is no longer measured by these simple benchmarks, since the operating systems, applications, and features that determine final performance became obsolete within a decade. However, even these overly simplistic measures have doubled every 2 to 3 years.

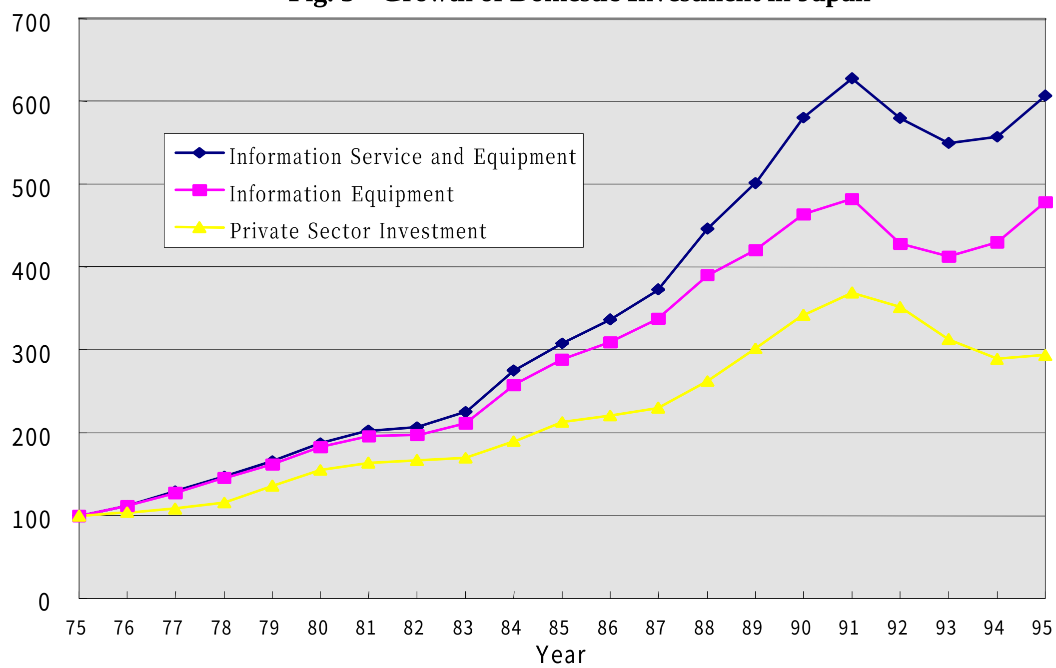
**Fig. 2 Price Movements of ICT Capital Goods**




Source: Bank of Japan *Report on Wholesale Price Indexes*.

For example, in Japan, while total private sector investment has tripled over the last two decades, domestic investment for information equipment has increased around five times and investment in information services and equipment has increased more than six times in nominal yen, even before taking into account technology improvement (real price deflator). (The annual rate of growth of investment in these three categories is 5.5, 8.1, and 9.4 percent, respectively.)

**Fig. 3 Growth of Domestic Investment in Japan**




Note: Information Equipment includes domestic demand for office equipment, computers and peripheral equipment, communication equipment and facilities, and cables. Private Sector Investment includes non-residential investment.

Source: Economic Planning Agency *Estimates of National Expenditure*, Japan Electronic Industry *Year Book*

The ratio of information investment to private domestic investment increased from 16 percent in 1975 to 33 percent in 1995. This shows that the investment that took place in Japan has shifted dramatically towards information processing and services.

Although Japan has experienced a bubble economy and the turmoil associated with the bursting of the bubble, the trend that investment in information goods and services outpaces overall private sector investment still persists in the post-bubble years.

### 1. 2. Definition of the Productivity Paradox

This rapid change in technological innovation and investment has brought world-wide expectations of higher productivity and prosperity. However, Robert Solow's quip that we can see the computer age everywhere but in the productivity statistics indicates the concern that the investment in and diffusion of ICT may not be bearing the expected fruit.

This concern has become known as the Productivity Paradox of Information Technology. The paradox is that despite enormous improvement in the underlying technology through rapid computerization, aggregate output statistics such as productivity growth do not record any corresponding benefit. In short, it is a puzzle why productivity growth has remained sluggish in the midst of rapid computerization.

### 1. 3. Issues of the Productivity Paradox

There have been many attempts to verify the existence of the Productivity Paradox and to explain this puzzle. The results have been mixed as we will see in the next section. However, past studies vary not only in their conclusions, but also in their definitions of ICT capital and productivity and in their levels of data aggregation. These are the factors that characterize the Paradox.

#### 1. 3. 1. Scope/definition of ICT

ICT has many interpretations. If we concentrate on the hardware side, ICT could cover just computing equipment used primarily in office settings in the business sector, which would include personal computers, workstations, servers, mainframes, and related equipment. Or, it could cover the entire microelectronic revolution, which includes all products that contain semiconductors, from computers to telecommunication/broadcasting equipment, to microprocessors used in transportation vehicles and home electrical appliances.

If we incorporate the software side, ICT could cover all hardware and software programs (computer systems). In addition, we can include the know-how and technologies that are used to gather, process, and transmit information. Therefore, under the broadest interpretation, ICT development would cover the entire information revolution. It would include the micro-electronics revolution and the social change to intensive use of information goods throughout the so-called digital economy. It would also comprise the New Economy in which business processes are re-engineered to achieve productivity gains and the production functions of some industries exhibit increasing returns to scale.

The different ways in which past studies have measured ICT has sometimes resulted in seemingly conflicting results. We intend to classify the way ICT has been defined and measured in previous studies and to indicate how our measurement of ICT compares with the others.

Previous studies have measured information technology capital in one of the following ways:

- Office, Computing, and Accounting Machinery (OCAM), which consists primarily of computers (U.S. Bureau of Economic Analysis's category frequently used for "computers")
- Information Processing Equipment (IPE), which includes communications equipment, scientific and engineering instruments, photocopiers and related equipment in addition to OCAM
- Information (and Communications) Technology (ICT), which adds software and related services as well to IPE

Most U.S. studies have been based on IPE statistics (Sichel 1997), however, we exclude from our analysis traditional office automation equipment, such as photocopy machines and mimeographs, that was introduced before the 1980s and which is normally not connected to computers today. In this chapter, we focus on the recent development of ICT and therefore restrict our analysis to technologies associated with computers and communications. This is the technologically dynamic part of the micro-electronic revolution. Our definition highlights ICT's ability to process information in ways that approximate human thought and intelligence and thus its ability to improve the productivity of labor in a mostly service economy.

Another challenge arrives in trying to measure ICT in real terms. The problem is how to define a real price or price deflator for a product that has improved its performance by more than two orders of magnitude.

There are two possible approaches to calculating real prices or deflators for ICT:

- The real price can be calculated the usual way, eliminating just the effects of inflation and ignoring improvements in performance (Sales/Units sold).
- The real price can be calculated to take into account the effects of technology improvements and the improvements in quality or functionality (a hedonic index). This type of real price deflator would evaluate the efficiency of today's equipment in terms of speed, size, and maintenance cost and determine the cost of the same combination of functionality in a base year.

A hedonic price index is not available for Japan so we cannot take technological improvements fully into account in calculating the real price of ICT in Japan. Although the value of computers does not necessarily fall to zero when they have become outdated, we have depreciated the value of ICT capital evenly to its maturity, assuming that computers may be used until maturity and their resale value is almost nil.

### 1. 3. 2. Definition of Productivity

The different measures of productivity used in past studies have also contributed to their seemingly conflicting results. Aggregate productivity has been measured as:

- Labor productivity: the level of output divided by a given level of labor input
- Multifactor productivity (or, total factor productivity): the level of output for a given level of several inputs, typically labor, capital and materials
- Productivity of information systems staff and/or of workers who use computers: level of output divided by number of information systems staff or workers who use computers

## 2. Summary of Previous Studies on the ICT Productivity Paradox

The topic of the Productivity Paradox of investment in information technology has been revisited periodically in both the academic and business press (Zachary 1991, Metcalfe 1992, Brynjolfsson 1994, Battles, Mark and Ryan 1996, Brynjolfsson and Yang 1996). Most studies of the Productivity Paradox have concerned the United States, although there are studies in other T5 countries with similar findings.

Empirical studies have typically found that the marginal product of ICT investment has been smaller than the marginal product of investment in more conventional capital. However, recent studies have found evidence of significant increases in productivity associated with investment in information technology using firm-level data, and indicate that the Productivity Paradox might be disappearing (Brynjolfsson and Hitt 1996, Greenwood and Yorukoglu 1996). Although several interesting explanations for the Paradox have been proposed in formal and case studies, there is no clear-cut academic consensus yet (Sichel 1997).

### 2. 1. Studies of Aggregate Productivity

Review of earlier and more recent studies suggests some of the crucial factors and mechanisms that determine the productivity of ICT investment at the aggregate or macroeconomic level.

Economists have measured a slowdown in productivity growth in the United States during the 1970s, despite the build-up of ICT capital. One study found that labor productivity grew about 2.5 percent per year from 1953 to 1968, but dropped to about 0.7 percent per year from 1973 to 1979; multi-factor productivity growth declined from 1.75 percent to 0.32 percent (Baily 1986, Brynjolfsson and Yang 1996). These estimates are subject to error in measurement, however. They follow the standard growth accounting practice of assuming neoclassical competitive equilibrium and equating the marginal product of each input factor to real user cost.

A study based on more recent U.S. data found a positive contribution of computer hardware to the economy, but the contribution amounted to only 0.16 percent of gross output annually between 1970-92 (Oliner and Sichel 1994, Brynjolfsson and Yang 1996). Adding in software and computer services labor roughly doubled the contribution and information processing equipment such as communications hardware boosted the rate even more.

One factor determining the effect of ICT investment on aggregate economic growth is the size of the stock of such technology. As long as ICT capital comprises a small share of total capital stock, its contribution to productivity growth will necessarily remain small. We can easily estimate the order of magnitude as follows (Brynjolfsson 1993). Information capital stock is about 10 percent of GNP. Assuming a 20 percent return on ICT investment, then information technology contributes 2 percent of current GNP ($10\% \times 20\%$). But in terms of impact on GNP growth, this 2 percent is spread out over the length of time that the capital stock has been accumulated, say 20 years. Hence, the order of magnitude for the impact of ICT is only about a tenth of a percent of GNP per year. A contribution of this magnitude could easily be masked by other factors in the economy. In other words, information technology stock must increase at the rate of 5 percent of GNP each year, just to increase growth of GNP by 1 percent.

These estimates are also subject to error in the measurement of the return on ICT investment. If GNP statistics do not fully capture the benefits from ICT investments, such as faster and better quality service for the same price, the real return on ICT investment could easily be underestimated. Increases in the implicit information content of products and services are likely to be under-reported compared to increases in materials content, because information is intangible, it is hard to measure objectively, and it does not have a direct market price.

To sum up, it seems safe to say that the observed impact of ICT investment at the aggregate level is small (or negligible) today because the stock of ICT capital is still small and because measurement is imprecise.

## 2. 2. Studies of Firm-Level Productivity

A number of studies using firm-level data concluded that the massive investment in ICT in the mid-1980s had no noticeable effect on productivity. Most of these studies used simple correlation. Roach (1991) cited statistics showing flat service sector productivity growth in the 1980s and early 1990s. He argued that although ICT is effectively used to substitute for labor in manufacturing industries, it has been associated with bloating the white collar work force in the service sector, especially in finance. Strassman (1990) concluded from firm-level statistics that no correlation existed between computer spending and profitability.

Many hypotheses for such micro-mismanagement have been proposed but they have not been thoroughly examined. For example, the issue of the ability to measure the effects of computers on organizations was raised in the early 1980's, and this theme is still raised today (Brynjolfsson and Yang 1996). Another issue is the lags or learning curve effect which may cause mis-measurement of the returns from ICT investments. For example, it usually takes two to three years before the strongest organizational impacts of IT are felt (Brynjolfsson,1993).

More recent researchers, however, contend that businesses are indeed receiving significant returns on ICT investments. For example, Brynjolfsson and Hitt (1994) studied the ICT expenditure and financial performance (ROA, ROE, total shareholder return) of 367 firms for 1987 to 1992 and concluded that while ICT may have negative impact on company profitability due to intense competition introduced by lowering the barriers to entry, ICT is also creating enormous value in terms of gross rate of return on ICT capital.[3]

## 2. 3. Implications for Future Studies

Thus, while researchers have found no evidence of significant productivity gains from ICT investment at the macro level, they have found that productivity in terms of gross return on ICT investment at the firm level improved enormously in the 1990s. This discrepancy suggests that while ICT investment is finally improving productivity at some firms with sufficient ICT expenditure, other factors may have dwarfed the impact on aggregate productivity, since ICT investment is small relative to total GNP.

Three factors could explain the discrepancy between the firm-level and macro-level productivity findings:

1) mis-measurement of returns to ICT at the macro-level, due to such problems as intangible service evaluation, time-lags, and TFP evaluation.

2) redistribution of value towards ICT capital intensive companies without adding much value to the economy as a whole

3) canceling out of firm-level productivity increases by macro-level side effects of ICT investment. One factor that fits this conjecture is the effect of information technology on the acceleration of globalization. At the same time that ICT improved the performance of individual firms that invested in it, it enhanced globalization of the macroeconomy through better communication. In the short run, the indirect effect of ICT-induced globalization may be a decline in the performance of the domestic economy as a whole as some output shifts abroad.

Taking all this into account, further analysis of the impact of ICT on aggregate productivity should concentrate on measuring the growth of returns from ICT investment, taking account of the lags and accounting issues mentioned above, and isolating the pure effect of ICT productivity gains by taking account of globalization effects.

[3] They used data from International Data Group which outlined ICT expenditure from 1987 to 1992 for 367 mostly large firms and matched with financial information from S&P's Compustat II database.

# 3. Relationship between ICT Investment and Aggregate Productivity Growth

Here, we analyze the mechanism by which ICT investment results in productivity growth. By comparing the traditional analytical framework that links economic growth and capital investment with the particular characteristics of ICT we show the limitations of the traditional framework and thus provide some explanation for the existence of the Paradox(Brynjolfsson 1993; Sichel 1997).

## 3. 1. Neoclassical Framework

### 3. 1. 1. Assumptions

In the neoclassical world, businesses make only optimal investment decisions (the marginal product of each factor is equated to its user cost) and all types of capital earn the same competitive return net of depreciation, say $r_{COMP}$, at the margin. We refer to all ICT capital, $K_C$, as “computers.” Furthermore we assume that there are no taxes, depreciation, market friction, or changes in relative prices.

Under these assumptions, an increase in ICT capital stock ($K_C{}^2$-$K_C{}^1$) should bring about an increase in total output (GDP) equal to:

$$r_{COMP} * (K_C{}^2 - K_C{}^1)$$

or an increase in output (GDP) growth equal to:

$$S_C * (\dot{K}_C),$$

where $S_C$ = share of total income generated by computers = (gross rate of return) x (nominal stock of computers) / (total income).

### 3. 1. 2. Implications

This model has two important implications regarding investment in ICT capital. First, computer prices fall over time, computers will be applied to tasks with lower and lower payoffs. (The marginal product of computers must also decline over time, or, computers will be used for less productive work).

Second, to generate faster rates of growth in output, either the rate of price decline or the rate of increase in computer use has to pick up.

## 3. 2. Peculiar Technological Characteristics of Investment in ICT Capital

Several features that distinguish ICT capital from conventional capital must be taken into account to evaluate the impact of ICT investment on productivity (Yorukoglu 1996):

- Rapid pace of technological improvement

As we saw in Fig 1,the performance of ICT capital has improved more than tenfold within a decade without an increase in size or cost. Such significant technological improvement requires paying special attention to such issues as the vintage of ICT capital and the price deflator of products that use ICT as an input. Moreover, it leads to problems of standardization or compatibility between old and new equipment. In any case, it suggests that ICT equipment should be depreciated quite fast, while some ICT application software that is independent from the hardware may have a longer lifetime.

This raises the issue of the proper treatment of ICT equipment and application software. Of course ICT equipment is handled as capital, but ICT software, or the information service that is required to develop it, is counted as service, a non-durable good (and hence not usually counted as capital) in the GNP statistics.

- Long learning curve

ICT capital may require significant training and experience to operate efficiently. Furthermore, because of the rapid pace of change training is necessary just to keep up-to-date with the latest technology available. As noted earlier, the time lag before the organizational impacts of ICT become fully operative may be two or three years.

The nature of the learning curve associated with ICT raises some doubts about the methodology of some studies of the Productivity Paradox, especially those whose conclusions are based on estimates of some form of production function without taking this time lag into account.

- Lumpy ICT capital investment

ICT typically requires large up-front fixed investment. This requirement conflicts with the patterns of returns suggested by the two previous characteristics of ICT, namely fast depreciation and long time lags before generating revenues. This makes ICT investment a risky business.

The lumpy investment requirement amplifies the effects of the time-lags and makes it extremely difficult to estimate a production function precisely.

- Network economies

ICT can offer substantial economies of scale and scope through network economies, but the externalities are difficult to estimate.

This characteristic of ICT raises the hypothesis that it is only when stand-alone PCs start communicating with each other through telecommunications networks that their impact or performance increases drastically.

- Spill-over effects

By increasing the technological sophistication of the economy ICT investment creates social returns on top of the private returns to investors. Such externalities raise the question of whether standard output measures capture the total benefits of ICT investment.

### 3. 3. Explanations for the Productivity Paradox

These characteristics of ICT have led to several macro- or micro-economic explanations for the Productivity Paradox (Sichel 1997).

#### 3. 3. 1. Low Rate of Return on Computers

The first set of explanations are micro-economic and focused on measurement and related issues.

- The Mismeasurement Hypothesis

This hypothesis suggests that we can never reveal the whole truth about the Paradox because our measurement tools (statistics) are so blunt.

For example, there are only a few micro-level statistics on ICT investment stock, productivity, or quality improvement and therefore aggregate productivity statistics are heavily biased by business cycles and other macroeconomic investment factors. Real price deflators are difficult to derive because the quality improvements from ICT investment are not directly measured. Moreover, it is difficult to measure the ICT capital stock, not only because of the rapid technological improvements and fast depreciation, but also because some software and software development services and labor should be counted as part of ICT capital, not as nondurable goods. There is also the problem of measurement of the contribution of ICT during the initial implementation period when the equipment is installed, but the training and organizational change have not yet been accomplished.

Up to five years ago, ICT was used to automate certain routine labor. Now, ICT is being applied to doing tasks that could not have been done by human labor. It is creating more value for customers and making that value more visible by tailoring products to specific market segments. As ICT is increasingly being applied to the thinking-intensive tasks--planning, design, analysis and decision making--it becomes even more difficult to measure.

The existing system of national accounting does not capture many of the benefits of computers, such as quality, variety, and convenience, that are difficult to measure.

As the price of ICT drops, it will be applied to tasks that had previously not been worth the investment. This means that ICT will soon replace tedious, low-skilled support jobs (such as secretarial and clerical jobs). The displaced workers will be challenged to do more creative work at higher pay.

■ Learning Curve Lag Hypothesis

It takes a long time for people and organizations to learn how to use new technology effectively (and to generate higher rates of return). This means that there is a considerable lag between when an investment in ICT is made and when the investment improves productivity.

According to this hypothesis, the existence of the long time-lag distorts the estimation of productivity gains from ICT investment.

■ Redistribution Hypothesis

ICT can improve a corporation's productivity by attracting business away from competitors due to the comparative advantage generated by the new technology. However, this hypothesis emphasizes that the social rate of return may differ from this private rate of return on such an ICT investment.

ICT investment that generates private value by attracting business from competitors does not create value to society; it simply brings about a redistribution of profits, in the same way that traders do. Furthermore, competitors could snatch this business back by making additional investments or investments, later on, in more advanced technology (which may even cost less than the forerunner's investment due to rapid technology development in the ICT area). Such survival investment for the purposes of preserving competitiveness should be considered as a cost of doing business, a market entry cost; it is not productive to the society, except for the jobs it creates in the ICT business.

■ Mismanagement Hypothesis

This hypothesis suggests that companies may over-allocate their resources towards information technology because they have inadequate information and about the costs and returns of ICT investment and inadequate skill in managing such investment. Management may have too high expectations for improvements in efficiency, too low expectations for the training, maintenance, operations and depreciation costs of information technology, or unsophisticated criteria for "Black Box" investing. In any case, excessive investment would cause the company to earn less than a competitive return on its ICT capital investments.

Estimates of some of the hidden costs associated with PC investment include:

- Maintenance (help desk support and down time) costs $3,830 per PC per year (source: Forrester Research, Inc. 1995);
- Down time costs the top 1,000 U.S. firms $3.5 million per year (source: Gallup survey 1994);
- Learning time ("futzing") by PC users costs U.S. business 5.1 hours per week or $100 billion per year (source: Software Business Technology, Inc. 1993).

### 3. 3. 2. Broader Issues

Apart from these micro-economic explanations for the Productivity Paradox, there are some macro-economic explanations which focus on the insignificant accumulation of ICT capital stock (due to fast depreciation) relative to the total capital stock

- Small Capital Stock Hypothesis

This hypothesis suggests that the Paradox holds true as long as the ICT capital stock has only a small share in total capital stock and hence returns are relatively small compared to GNP.

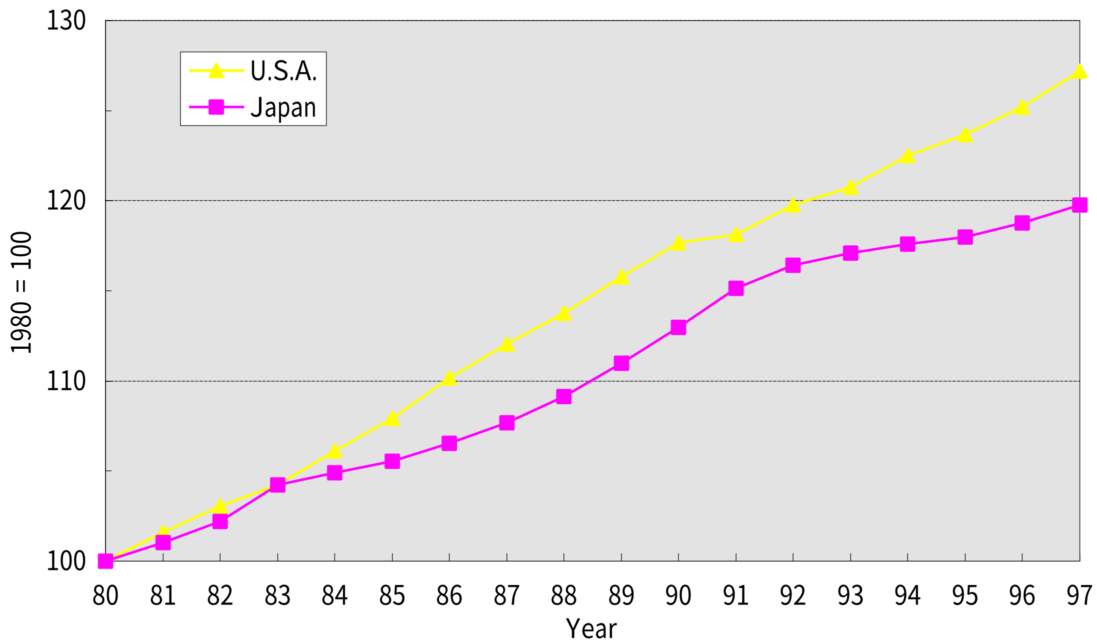
ICT still makes up only a small share of computers in capital stock. If computers were earning close to competitive rate of return, then the modest size of ICT relative to overall capital limits its impact on the overall economy.

- Offsetting Factors Hypothesis

This hypothesis suggests that factors other than ICT have masked ICT's contribution to economic growth. This hypothesis is complementary to the Small Capital Stock Hypothesis.

Many factors may affect the overall performance of the economy that might offeset the contribution of ICT to productivity growth. For example, the following figure depicts the rapid growth (1.4 percent per year) in the U.S. labor force since 1980. If this growth is comprised of lower skilled workers, the contribution of ICT to labor productivity may be offset by an overall decline in labor quality.

**Fig. 4 Growth of the Labor Force in the United States and Japan**




**(Source) U.S.: Bureau of Labor Statistics; Japan: Management and Coordination Agency *Labor Force Survey*.**

### 3. 4. Implications for Future Studies

The foregoing review of previous studies of the Productivity Paradox suggests ways in which future studies should be designed to yield useful insights:

- Measurement of ICT should take software and information services into account
- Measurement of service/goods quality should be improved and be reflected in the deflator (hedonic index)
- Time-lags for ICT implementation should be taken into account
- The “small capital” effect should be measured
- Offsetting factors should be eliminated before measurement of the impact of ICT on aggregate productivity.

# 4. Empirical Analysis of the Impact of ICT on Japanese Industry

### 4. 1. Estimation of the Macro-economic Impact of ICT Capital

#### 4. 1. 1. Computer's share of capital stock

Like other T5 countries, Japan has been investing heavily in computers and ICT equipment. Japan's investment in Computers and Peripheral Equipment is 8.5 trillion yen, or 7.6 percent of total investment, while ICT Equipment investment amounts to 12.6 trillion yen and is growing at 14 percent per year in real terms. In 1995 Japan's share of computer-related equipment within total investment had reached the 1993 U.S. level (Figure 5).

**Fig. 5a Investment in Computers and peripherals in Japan and the US, 1970-95**

Percent of Total Investment in Nonresidential Equipment and Structures

| | Nominal | | Real | |
|---|---|---|---|---|
| | Japan | United States | Japan | United States |
| 1970 | 0.7 | 2.6 | 0.1 | 0.1 |
| 1975 | 1.9 | 2.1 | 0.5 | 0.2 |
| 1980 | 2.5 | 3.5 | 1.0 | 1.0 |
| 1985 | 5.3 | 6.4 | 3.3 | 4.7 |
| 1990 | 6.0 | 6.3 | 6.0 | 8.7 |
| 1993 | 4.4 | 7.6 | 5.5 | 17.8 |
| 1994 | 6.0 | | 7.8 | |
| 1995 | 7.6 | | 10.4 | |

**Fig. 5b ICT Capital Stock in Japan and the United States, 1970-95**

Percent of Nominal Stock of Nonresidential Equipment and Structures

| | Total ICT | Data Processing Equipment | | | Communications Equip. | |
|---|---|---|---|---|---|---|
| Year | | Total | Office Equipment | Computers and peripherals | Total | Cables |
| | | | Japan | | | |
| 1970 | -- | -- | -- | 0.7 | | |
| 1975 | 2.5 | 1.0 | 0.2 | 1.9 | 1.0 | 0.5 |
| 1980 | 2.4 | 1.2 | 0.2 | 2.5 | 0.8 | 0.4 |
| 1985 | 3.3 | 1.9 | 0.2 | 5.3 | 1.2 | 0.2 |
| 1990 | 4.4 | 2.9 | 0.3 | 6.0 | 1.3 | 0.2 |
| 1993 | 3.7 | 2.4 | 0.3 | 4.4 | 1.1 | 0.2 |
| 1994 | 3.6 | 2.3 | 0.2 | 6.0 | 1.0 | 0.2 |
| 1995 | 3.7 | 2.5 | 0.2 | 7.6 | 1.0 | 0.2 |
| | | | United States | | | |
| 1970 | 7.5 | 1.7 | 0.8 | 2.6 | | |
| 1975 | 7.5 | 1.4 | 0.8 | 2.1 | | |
| 1980 | 8.0 | 1.6 | 0.7 | 3.5 | | |
| 1985 | 10.5 | 2.1 | 0.3 | 6.4 | | |
| 1990 | 11.4 | 2.3 | 0.3 | 6.3 | | |
| 1993 | 11.6 | 2.0 | 0.2 | 7.6 | | |

(Source) Input-Output Tables, Annual Reports on National Accounts, NRI

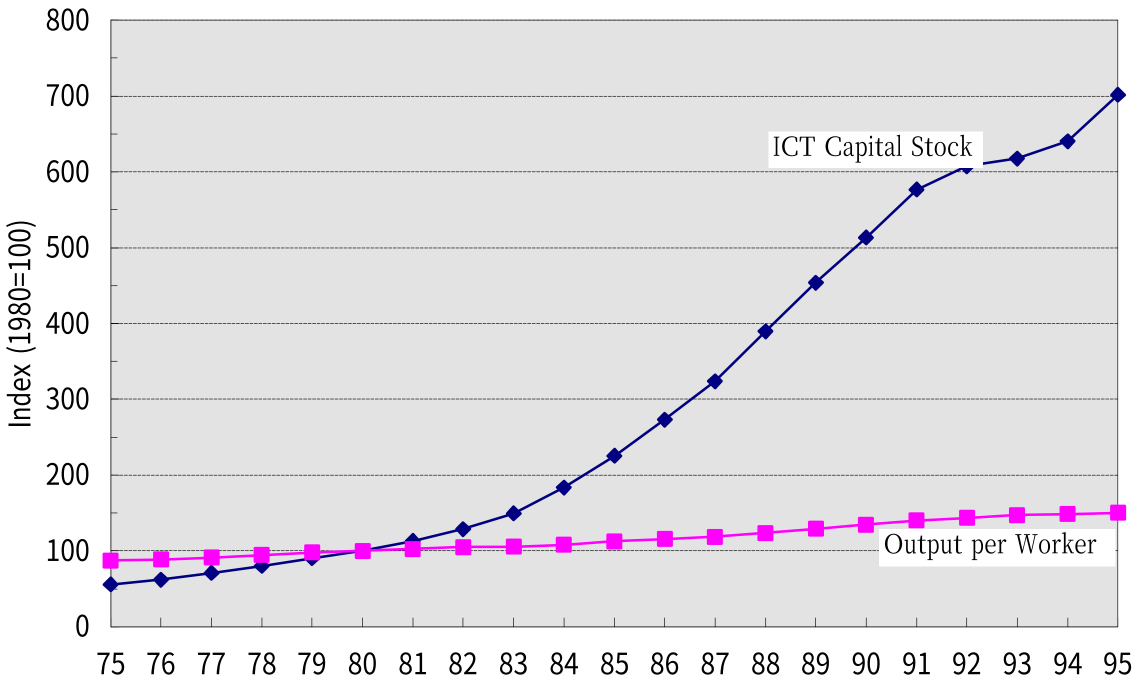
However, computers account for only 2.3 percent of Japan's capital stock and ICT accounts for 3.7 percent, or 7.1 percent of Japan's GNP. Although Japan's investment (flow) figures are about 2 years behind the United States levels, it is difficult to compare the capital stock due to the different depreciation measures used in the two countries.

At less than 10 percent of GNP, Japan's level of ICT capital indicates that the impact of ICT capital would be expected to be rather limited, as we discussed earlier.

We can verify the existence of the Productivity Paradox in Japan by comparing GDP labor productivity and ICT capital. Between 1980 and 1995 ICT capital increased seven times while labor productivity barely changed (Figure 6).

**Fig. 6 Trends in Labor Productivity and ICT capital stock in Japan**

(Source) Input-Output Tables, Annual Reports on National Accounts, NRI.




**Estimation of the Impact of ICT on the Macro-economy**

We estimated the impact of Japan's ICT capital stock on the macro-economy controlling for changes in ordinary capital and the labor force. For the reasons discussed in the previous section, we also took software and information services into account by including in the measure of ICT capital the flow output of information services which we assumed was investment to develop software capital.

The Cobb-Douglas formulation of the production function is:

$$V = AKo^{a} Ki^{b} L^{g},$$

where Ko is ordinary capital (adjusted by the capacity utilzation rate),

Ki is ICT capital including information service (adjusted by labor hours), and

L is labor (adjusted by labor hours).

The estimating equation for aggregate labor productivity is:

$$\ln V / L = C + (a + b)\ln(Ko / L) + b\ln(Ki / Ko).$$

Standard linear regression on annual data for 1980 to 1995 yielded the following parameter estimates:[4]

$$\ln V / L = -1.26045 + 0.603192 \ln(Ko / L) + 0.04985 \ln(Ki / Ko)$$

t-values: (-27.14) (14.33) (2.56)

$R^2 = 0.99285$

From the estimates of the production function we calculated a marginal return on ordinary capital of around 30 percent while the return on ICT capital was more than 50 percent (Figure 7). These estimates indicate that ICT capital has a higher gross return than ordinary capital, but because it also has a higher depreciation rate the net return on ICT capital may be similar to that of ordinary capital.

**Fig. 7 Marginal Returns on Ordinary and ICT Capital**

| | Marginal Return | V/K ratio | Elasticity |
|---|---|---|---|
| Ko | 32.5% | 0.5873 | 0.5533 |
| Ki | 52.9% | 10.6134 | 0.0498 |

(Source) Input-Output Tables, Annual Reports on National Accounts, NRI.

In any case, the gross marginal returns are significantly large, indicating that ICT does have a positive impact on output. But, given that ICT capital comprises only seven percent of GNP, the impact on the economy is small.

4 We tried lags on the ICT capital stock, but there was no significant improvement over the estimates given here.

### 4. 2. I/O Analysis of the ICT Industry

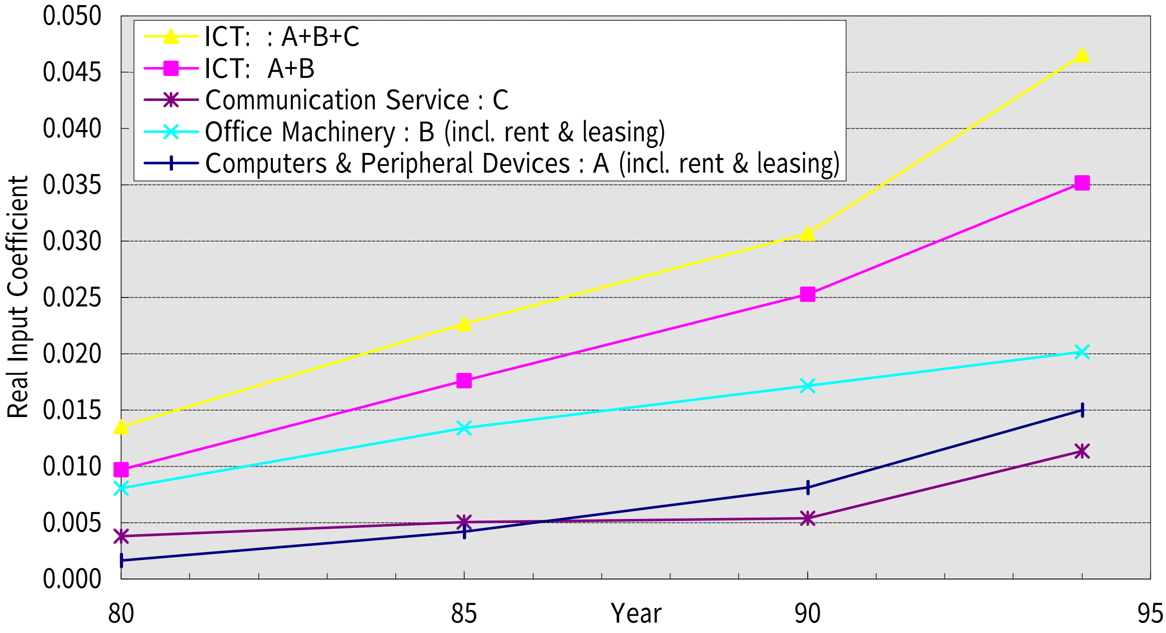
In order to understand the impact of the ICT industry on the growth of the Japanese economy, we investigated the impact of ICT on industrial structure. In particular, we focused on the following issues:

- How large is ICT as an input in the overall economy? Is its importance as an input rising?
- Is growth in ICT utilization distributed evenly across the economy, or is the utilization of ICT limited to particular sectors of the economy? Which industry has been affected the most?
- How large is the total effect of the growth of ICT industries? Does it have larger repercussions on the national economy than other industries?

#### 4. 2. 1. ICT as an Input to the Macro-economy

The importance of ICT as an input in the overall economy is steadily increasing, particularly since 1990 (Figure 8). Including computers (including peripheral devices), office machinery and communication services, the ICT industry accounted for roughly 5 percent of all inputs in 1994.[5] Although the office machinery industry, which excludes computers and peripheral devices from the data processing industry, has the largest share among the ICT inputs at 2 percent, computers and communication services are growing at a faster rate than office machinery.

**Fig. 8 Growth of ICT Input in Overall Production**




(Source) Management and Coordination Agency *1980-1985-1990 Linked Input - Output Tables, 1994 Input-Output Updated Table.*

#### 4. 2. 2. Impact of ICT in Specific Industries

Significant growth in the utilization of ICT input has occurred in the financial sector and the

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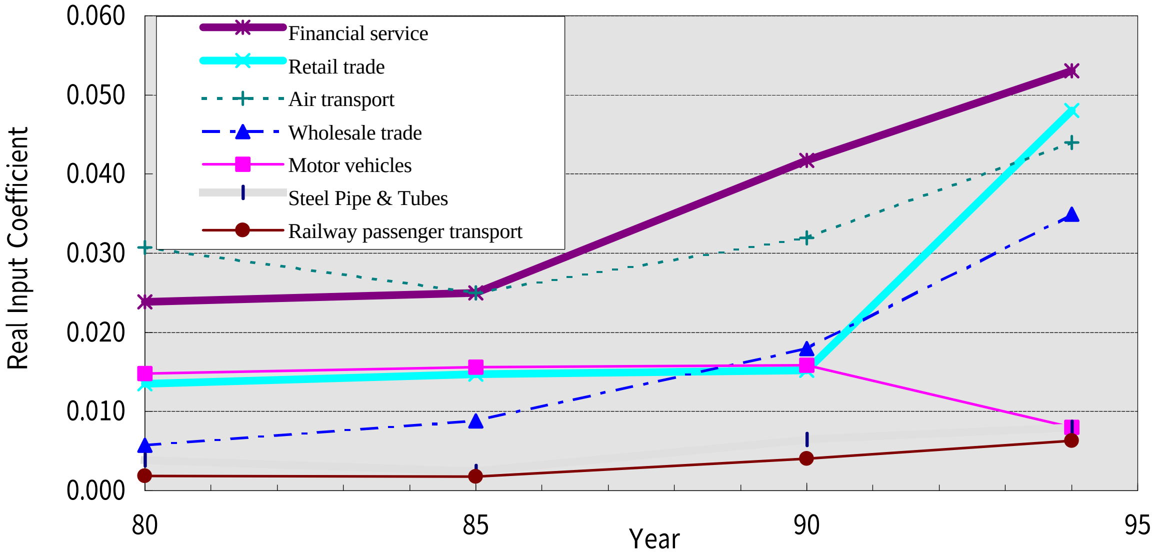
[5] Here we use to the industry classifications used by MITI for the Input-Output matrix.

distribution sector (i.e., the network service industries facing international competition) while the ICT input ratio has been dropping in some manufacturing industries such as motor vehicles (Figure 9).

**Fig. 9 Growth of ICT Input in Japanese Industries**




(Source) Management and Coordination Agency *1980-1985-1990 Linked Input - Output Tables, 1994 Input-Output Updated Table*.

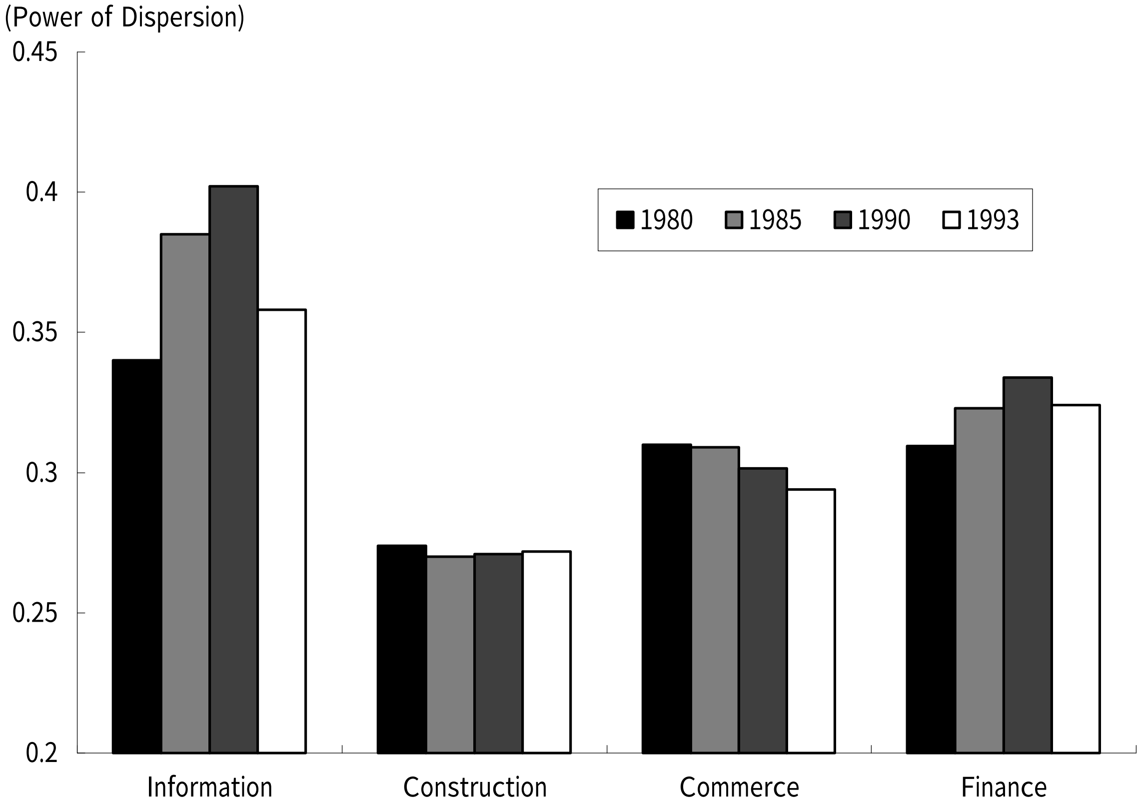
Although the use of ICT may not be uniform across industries, this pattern of ICT utilization suggests that as we move more to a service economy or post-industrial society, input requirements from the ICT industries may increase further.

### 4. 2. 3. The Effect of ICT on Macroeconomic Growth

As ICT industries grow they also require inputs from other industries. Another characteristic of ICT industries is the fact that increased demand for their final output has greater repercussions throughout the economy than does growth in demand in other service industries, such as finance, commerce, or construction (Figure 10).

This suggests that demand for (new) ICT services, such as satellite TV/communication, may have a strong positive effect on the growth of the economy.

**Fig. 10 Demand Effect on the National Economy by Industry**




(Notes) The "demand effect" is the amount of production induced when demand in the specific industry increases by one unit. Power of Dispersion (1990 prices) measures the deviation from average of all industry's "demand effect". Data are from annual I/O tables for 1980, 1985, 1990 and 1993.
(Source) NRI estimate based on MITI *Linked Input/Output Tables*, *1993 Input/Output Tables* data.

The analysis of the demand effect of ICT together with the fact that Japanese labor productivity is not growing suggests that perhaps ICT has a positive effect on economic growth, but at the cost of labor input.

## 5. Impact of ICT on the Global Economy

So far we have investigated the impact of ICT on Japan's domestic economy. In this final section we examine the impact of ICT on Japan's international trade and discuss the impact on the global economy.

### 5. 1. Exports

Japan's export of ICT equipment amounted to ¥2.3 trillion in 1996 and made up 5.2 percent of total exports, but ICT exports have been declining during the 1990s due to the "hollowing-out", particularly to other places in Asia (Fig. 11). However, exports of computers and peripheral devices, which is 4.2 percent of total exports, surpasses exports of steel (3.7 percent of total exports). If we include exports of integrated circuits with ICT goods and services, the combined sector emerges as Japan's leading export industry, surpassing even automobiles. The growth area of ICT exports is the service area (telecommunications) which has a 36 percent annual growth rate.

**Fig. 11 Japan's ICT-related Exports**

| | 1970 | 1980 | 1985 | 1990<br>100 million yen | 1995 | 1996 | 1990-96 Growth Rate % |
|---|---|---|---|---|---|---|---|
| **Core ICT Industry** | 1,456 | 7,121 | 20,601 | 26,991 | 22,371 | 23,305 | -2.4 |
| Communication Equip. | 350 | 1,713 | 5,059 | 6,929 | 4,462 | 3,813 | 9.5 |
| Computers & peripherals | 66 | 2,143 | 11,450 | 18,287 | 17,069 | 18,714 | 0.4 |
| Office machinery | 918 | 2,985 | 3,749 | 1,504 | 352 | 321 | -22.7 |
| Cables | 122 | 280 | 343 | 271 | 488 | 457 | 9.1 |
| **Other ICT equipment** | 1,466 | 9,774 | 27,110 | 33,115 | 28,620 | 29,606 | -1.8 |
| Copiers, registers, etc. | 10 | 2,653 | 6,509 | 6,124 | 6,249 | 6,301 | 0.5 |
| **Broad ICT Industry** | 7,241 | 30,736 | 67,955 | 62,812 | 44,825 | 46,024 | -5.1 |
| AV equipment | 5,751 | 20,382 | 40,467 | 28,752 | 15,211 | 14,876 | -10.4 |
| Video games | 24 | 579 | 378 | 946 | 994 | 1,541 | 8.5 |
| **ICT Services** | | | | | | | |
| Telecom services | | | | | 474 | 1,499 | 36.3 |
| Information services | | | | | | 1,329 | |
| **Total ICT Goods & Services** | | | | | | 48,852 | |

(Note) Electronic parts not included.
(Source) Compiled by NRI from Bank of Japan, International Balance of Payments Monthly and Ministry of Finance, Trade Statistics.

### 5. 2. Imports

Total imports of core ICT equipment stood at 1.7 trillion yen in 1996, growing at an annual rate of 21 percent (Fig. 12). ICT equipment now comprises 4.5 percent of total imports, but this share is quite small compared to the share of mineral fuel. The interesting thing is that the same items that show as exports are also quite significant in imports. ICT imports come mainly from Asia and the United States. For example, more than half of computer imports come from Asia Telecommunications service payments are also growing fast, at 20 percent a year.

**Fig. 12 Japan's ICT-related Imports**

| | 1970 | 1980 | 1985 | 1990 | 1995 | 1996 | 1990-96 Growth Rate |
|---|---|---|---|---|---|---|---|
| | | | | 100 million yen | | | % |
| **Core ICT Industry** | 821 | 1,836 | 2,703 | 5,438 | 12,471 | 17,282 | 21.3 |
| Communication Equip. | 19 | 91 | 198 | 858 | 2,258 | 3,152 | 24.2 |
| Computers & peripherals | 501 | 1,651 | 2,455 | 4,394 | 9,892 | 13,715 | 20.9 |
| Office machinery | 301 | 91 | 46 | 165 | 234 | 287 | 9.7 |
| Cables | 0 | 4 | 3 | 21 | 87 | 128 | 35.4 |
| **Other ICT equipment** | 874 | 1,965 | 2,759 | 5,591 | 12,937 | 17,952 | 21.5 |
| Copiers, registers, etc. | 53 | 129 | 56 | 153 | 466 | 670 | 27.9 |
| **Broad ICT Industry** | 1,215 | 2,438 | 3,207 | 6,733 | 16,576 | 22,508 | 22.3 |
| AV equipment | 116 | 413 | 424 | 1,088 | 3,499 | 4,372 | 26.1 |
| Video games | 225 | 60 | 24 | 54 | 140 | 184 | 22.7 |
| **ICT Services** | | | | | | | |
| Telecom services | | | | | 799 | 2,033 | 20.7 |
| Information services | | | | | | 2,658 | |
| **Total ICT Goods & Services** | | | | | | 27,199 | |

(Note) Electronic parts not included.
(Source) Compiled by NRI from Bank of Japan, International Balance of Payments Monthly and Ministry of Finance, Trade Statistics.

### 5. 3. Trade Balance

The balance of ICT trade has been improving over the years, due to large scale exports of AV equipment (16 percent of the total trade balance). However, growing imports in the equipment sector have decreased the trade balance (Fig. 13).

**Fig. 13 Japan's ICT-related Trade Balance**

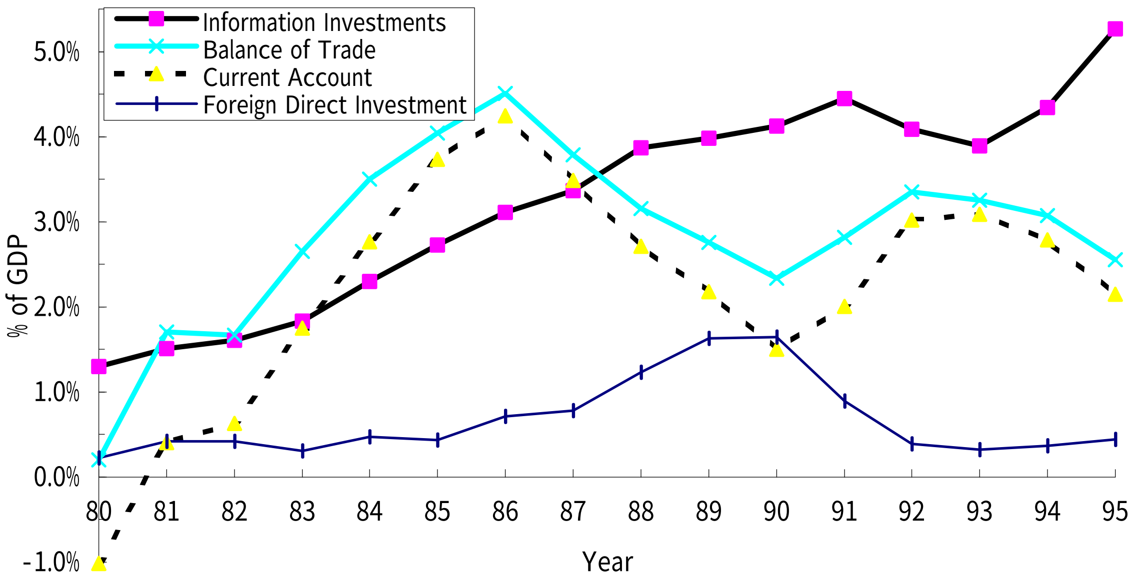
| | 1970 | 1980 | 1985 | 1990 | 1995 | 1996 |
|---|---|---|---|---|---|---|
| | | | | 100 million yen | | |
| **Core ICT Industry** | 635 | 5,285 | 17,898 | 21,553 | 9,900 | 6,023 |
| Communication Equip. | 330 | 1,622 | 4,861 | 6,071 | 2,205 | 661 |
| Computers & peripherals | -435 | 492 | 8,994 | 13,892 | 7,177 | 4,999 |
| Office machinery | 617 | 2,895 | 3,703 | 1,339 | 117 | 34 |
| Cables | 122 | 275 | 340 | 251 | 401 | 328 |
| **Other ICT equipment** | 592 | 7,809 | 24,351 | 27,524 | 15,683 | 11,655 |
| Copiers, registers, etc. | -43 | 2,525 | 6,452 | 5,971 | 5,783 | 5,631 |
| **Broad ICT Industry** | 6,026 | 28,298 | 64,748 | 56,079 | 28,249 | 23,516 |
| AV equipment | 5,635 | 19,969 | 40,043 | 27,664 | 11,712 | 10,504 |
| Video games | -201 | 520 | 355 | 892 | 855 | 1,357 |
| **ICT Services** | | | | | | |
| Telecom services | | | | | -325 | -534 |
| Information services | | | | | | -1,329 |
| **Total ICT Goods & Services** | | | | | | 21,653 |

(Note) Electronic parts not included.
(Source) Compiled by NRI from Bank of Japan, International Balance of Payments Monthly and Ministry of Finance, Trade Statistics.

If ICT improves aggregate productivity, then it could enhance international competitiveness and hence improve the balance of trade. However, what we just saw was the situation that even though ICT investment has been increasing since the 1980s, Japan's balance of trade did not necessarily improve.

These changes in the share of ICT trade point to the existence of another paradox. That is, despite the growth of ICT investment, neither the balance of trade nor the balance on the current account has shown corresponding improvement (Figure 14).

**Fig. 14 Trends in Information Investment and International Accounts**




(Source) Bank of Japan *Balance of Payment and* EPA *Annual Report on National Accounts.*

We can easily expect that international telecommunication services will increase as entry of new firms and expansion of Internet communications reduce costs. However, although this will enhance direct investment and services associated with telecommunications, growth of international telecommunication services does not guarantee improvement in the balance of payments.Telecommunications service can be counted as exports or as imports depending on the origin of the call.

Telecommunications services include data processing, games, and "tele-shopping" which are all growth areas of trade. We can call this growth area telecommunication-related service trade or 'telecom' service trade for short. This new trade growth sector may not show up in the trade statistics, however. That is because services provided over the Internet are difficult to identify and hence to subject to customs. This reinforces the conclusion that growth of international telecommunication services does not necessarily improve the balance of payments.

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