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Akihiko Shinozaki

[Abstract]

This study is intended to examine whether information and communications technology (ICT) has contributed to aggregate productivity growth in Japan over the last two decades. Growth accounting analysis yields two observations. First, investment in ICT accelerated in Japan in the 1980s and slowed down in the 1990s. Second, the periodical changes of multifactor productivity growth and the contribution of ICT capital assets have always run in a parallel direction since the 1980s. Therefore, the "Solow paradox" has never been observed in Japan. Nevertheless, another puzzle emerges: why did Japan's investment in ICT slow down in the 1990s in spite of its potential for productivity growth? A possible explanation might be that there have been some impediments in the Japanese economic system to reap the benefits of information and communications technology.

Keywords: Japanese economy, multifactor productivity, growth accounting, Solow paradox, information and communications technology

JEL classification: E22, O47, O53

1. Introduction

Over the last two decades, numerous studies have examined whether or not information and communications technology (ICT) contributes to productivity improvement. As Solow (1987) expressed in his famous quip – "You can see the computer age everywhere but in the productivity statistics"– most empirical studies on the U.S. economy have found no positive evidence up to the early 1990s. More accurately, some have found negative correlations between ICT and productivity (U.S. Department of Labor [1994]). The "Solow paradox" apparently existed there. Notwithstanding, even that situation began to change in the late 1990s. As massive investment in ICT continued to increase, a consensus emerged in the U.S.[1] Major results from recent studies have shown that the paradox finally disappeared in the U.S. (Brynjolfsson & Hitt [2000], Oliner & Sichel [2000], Jorgenson [2001], and Stiroh [2002]).

In contrast, little is known about Japan's aggregate productivity and investment in information and communications technology[2]. Through this study, the author examines whether investment in information and communications technology has contributed to aggregate productivity growth in Japan over the last two decades. For this purpose, this paper first presents a description of the analytical framework and the dataset employed in this paper. Subsequently, it presents an overview of the periodical changes of Japan's ICT investment and accumulation of information and communications technology assets. Finally, the relations between aggregate productivity growth and the contribution of information and communications technology assets

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[1] For detailed argument, see Stiroh (2002), pp. 1559–1560.
[2] Mainly as a result of the lack of officially published investment data available regarding information and communications technology. For further details, see Shinozaki (2003a), chp. 5, in which previous studies and their limitations are reviewed.

are analyzed. This analysis will clarify whether or not the Japanese economy has experienced the "Solow paradox".

2. Framework and dataset

2-1. Analytical framework

Growth accounting method is employed in this productivity analysis. This method, pioneered by Solow (1957), is based on the framework of a neoclassical production function to estimate the contributions to output per hour derived from increases in capital assets per hour worked and multifactor productivity (MFP), where MFP is estimated as a residual for technological or organizational improvements that increase output for a given amount of input. Equation (1) shows the basic concept of growth accounting method with capital assets divided into ICT and non-ICT assets. ICT assets include not only computer hardware. They also include software and network infrastructure because intangible assets have been gaining importance. Moreover, recent remarkable innovations have involved the convergence of computers and telecommunications equipment, as in:

(1) $Q=MK_o^{\alpha}K_i^{\beta}(hrL)^{\gamma},$

where α, β, and γ represent income shares for each input respectively, $\alpha+\beta+\gamma=1$, Q is output, M is multifactor productivity, K_o represents non-ICT capital assets, whereas K_i is ICT capital assets, hr is work hours per employee, and L is the number of employees. Then, eq. (1) can be transformed as

(2) $\dot{Q}-\dot{h}r\dot{L}=\dot{M}+\alpha(\dot{K}_o-\dot{h}r\dot{L})+\beta(\dot{K}_i-\dot{h}r\dot{L}),$

where a dot over a variable indicates the rate of change expressed as a log difference. In eq. (2), $\dot{Q}$-$\dot{hrL}$ represents changes in output per hour, $\dot{M}$ represents changes in multifactor productivity, and $\dot{K}$-$\dot{hrL}$ represents changes in capital assets per hour worked, which is referred to as capital deepening. The capital deepening portion is further divided into the contribution from ICT assets and other non-ICT assets in eq. (2).

The basic equation shown above must be adjusted for the business cycle effect. Productivity is so pro-cyclical that the multifactor productivity is attributable mainly to the business cycle. To remove the influence of the business cycle from multifactor productivity, the utilization rate of capital assets is used as a proxy of business cycle effect in this paper.[3] Therefore, eq. (1) can be modified as:

(3) $Q= M(pK_o)^{\alpha}(pK_i)^{\beta}(hrL)^{\gamma},$

where p is the utilization rate of capital assets assuming that the utilization rate is homogeneous in each asset. Then, eq. (3) can be transformed as

(4) $\dot{Q}-\dot{hrL}=\dot{M}+\alpha(\dot{K_o}-\dot{hrL})+ \beta(\dot{K_i}-\dot{hrL})+(\alpha+\beta)\dot{p}.$

Here, we can estimate the contributions to changes in output per hour by decomposition into four factors; multifactor productivity ($\dot{M}$), non-ICT capital assets per hour worked (capital

[3] In Japan, labor statistics, such as work hours per employee or the unemployment rate, do not exactly represent the business cycle effect because work hours tend to decline during business booms to attract workers by offering higher payments for fewer work hours, whereas in recession layoffs cause longer work hours for remaining employees. As for the unemployment rate, it is apparent that the recent increase in unemployment has resulted from such fundamental changes in labor market, rather than cyclical, as reforming so-called lifetime employment system.

deepening of non-ICT: $\dot{K}_o$-$hr\dot{L}$), ICT capital assets per hour worked (capital deepening of ICT: $\dot{K}_i$-$hr\dot{L}$), and the utilization rate of capital assets ($\dot{p}$) as a proxy of the business cycle effect.

2-2. Dataset employed

All datasets employed in this paper, except for information and communications technology assets, come from statistics that are published officially by government ministries: output data and overall capital input data from the Cabinet Office (CAO), labor input data from the Statistics Bureau (STAT) of Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT), and utilization rate from the Ministry of Economy, Trade and Industry (METI). To estimate the contribution of information and communications technology assets, this paper relies heavily on data from Shinozaki (2003a). In that study, time series data of investment in information and communications technology and ICT assets were constructed using several primary statistics such as the benchmark input-output table of 1995, the production and international trade statistics for computer hardware and telecommunications equipment, the survey of selected service industries for aggregate annual software sales,[4] and the survey of telecommunications industry for aggregate annual expenditures on telecommunications infrastructures[5]. Time series investment data are shown in Table 1 and ICT assets are shown in Table 2 in this paper.

Consequently, labor market indices may not accurately represent the business cycle effect in Japan.

[4] Primary data were limited. Software includes only package software and custom software (produced when businesses hire outside professionals to write programs), but it does not include own-account software (produced in-house by employees).

[5] For further details, see Shinozaki (2003a), chp. 5. Note that the overall capital assets by the Cabinet Office are constructed only as “productive (gross) stocks”, which incorporate some decline in productive efficiency with age, instead of depreciation that is used for constructing “net stocks”. The information technology assets by Shinozaki (2003a) are constructed both as a “productive (gross)” and “net” stocks. As Oliner and Sichel (2000) explained, the

2-3. Overview of investment in ICT and accumulation of ICT assets

Nominal investment in information and communications technology amounts to 20 trillion yen (162 billion US dollars) in 2001, which accounts for 3.9 percent of GDP and 25 percent of total nonresidential fixed investment. Whereas computers and peripherals are the largest component of hardware including telecommunications equipment and infrastructure, software is larger than computers and peripherals in 2001.

As Fig. 1 shows, it is apparent that the Japanese business sector has poured billions of dollars into computers and network infrastructure in the late 1980s. Competition began in the telecommunications industry right after the privatization of NTT in 1985, while banking industry leaders were enthusiastic about enhancing online transaction systems based on mainframe computers in those days. Until the early 1990s, mainframe computers and exclusive network systems that were customized by each firm were dominant in Japan, rather than personal computers and open network servers. For management, little attention was paid to the “Solow paradox” in those days. Management invested at a furious pace in “legacy” information technology in the 1980s and successfully adapted to it whereas U.S. firms came up against the productivity paradox.

However, the investment boom ended abruptly in the early 1990s, as downsizing from mainframe computers to personal computers and widespread of Internet boom surged around the world. Since that time, Japan’s investment in information and communications technology

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“productive” stock is the appropriate measure for growth accounting analysis (Ibid. pp.6–7).

repeated cyclical up and down movements during the decade. The investment trend change – boom in the late 1980s and slump in the early 1990s – affected the accumulation of information and communications technology assets. Figure 2 shows that the average growth rate of Japan's ICT capital assets accelerated in the 1980s. Nevertheless, the rate slowed drastically in the 1990s. Indeed, it is much clearer to compare the growth rate of Japan's ICT assets to that of the United States. It jumped to more than double the U.S. rate of the latter 1980s; it then slid to a lower level than the U.S. again by the end of the 1990s.

3. Aggregate productivity and contribution from ICT assets

3-1. Japan's "lost decade" of the 1990s

It will be useful to overview changes of Japan's aggregate productivity since the late 1970s before examining details. Table 3 shows an estimate of the decomposition of the increase of productivity, or hourly output after 1976. In this table, the first line shows the growth rate of output, whereas lines 2–9 allocate this growth rate among the contributions from labor input, cyclical effect, two kinds of capital input (non-ICT capital assets and ICT capital assets), and multifactor productivity. The third line represents hourly output growth as a formula of line 1 minus line 2. The last three columns show five-year periodic changes.

Japanese economic performance has changed dramatically over the past two decades. During the 1980s, the economy grew at an average annual rate of more than three and half percent: at 3.7 percent in the first half and at a powerful 5.2 percent in the second half. That growth was accompanied by a rapid advance in labor productivity. Output per hour rose at an annual rate of 2.7 percent in the early 1980s and at a robust 3.9 percent in the late 1980s. This improvement was not driven by a cyclical effect in those days, but by a fundamental trend.

However, during the 1990s, the economy plunged into a deep slump. The growth rate of output was less than two percent. The economy grew at an annual rate of only one and half percent over the decade with sluggish productivity improvement. The “trend” of output per hour rose at 2.6 percent annually in the early 1990s, and at the even worse pace of 2.3 percent in the late 1990s. The fundamental trend of productivity growth fell sharply by one percent or more from the late 1980s. So did the multifactor productivity. These figures represent well the stagnant economic condition that is often referred to as the “lost decade” of the Japanese economy.

3-2. You can *not* see the “Solow paradox” in Japan

In each period, capital assets largely account for the labor productivity improvement. For example, the growth rate of labor productivity trends during 1981–1985, 1986–90, 1991–95, and 1996–2000 were 2.8, 3.6, 2.6, and 2.3 percent respectively (see line 5 of Table 3), of which capital deepening contributed 1.6, 1.8, 1.8, and 1.4 percentage point respectively (see line 6 of Table 3). Although the overall contribution of capital deepening seems to have changed little, the composition of the capital deepening shifted substantially. The capital deepening of ICT assets gained in influence, from 0.2 to 0.5 (see line 7 of Table 3), whereas non-ICT assets became less important, from 1.5 to 0.8 percent (see line 8 of Table 3).

The contribution from information and communications technology capital assets became relatively large in the latter 1980s. The larger contributions in the late 1980s reflected the increased importance of information and communications technology (see increase of income share in addendum of Table 3) and the faster growth in the information and communications technology assets (see growth rate of input in addendum of Table 3). Then, the capital deepening in ICT assets became slightly unproductive in the first half of the 1990s and recovered in the second half of the 1990s, whereas the capital deepening in non-ICT assets had been remarkably unproductive in the early 1990s. The contribution of ICT assets increased by 0.2 percentage point to 0.5 percent in the late 1990s, accounting for a quarter of the 2.3 percent growth of the productivity trend.

The last three columns of Table 3 present notable data. Acceleration of the multifactor productivity (line 9) and contribution from ICT assets (line 7) are described as periodical changes in each of five years. The remarkable fact is that the changes of multifactor productivity and contribution of ICT capital assets ran in the same direction instead of in opposite directions. This differs greatly from the fact that the growth rate of multifactor productivity and the contribution of ICT assets ran in opposite directions in the U.S. until the early 1990s (Table 4). Therefore, "economists were puzzled as to why productivity growth was so slow despite the widespread use of information technology"[6] in the United States. It was, demonstrably, the "Solow paradox".

The Japanese economy, by contrast, shows the same periodical changes in multifactor productivity and the contribution of ICT capital assets. For example, during 1981–85, multifactor productivity increased by 0.5 percentage points from the previous five years with a 0.1 percentage point contribution of ICT capital assets; 0.7 percentage point MFP growth with a 0.3 percent point ICT capital assets contribution during 1986–90; -0.9 percentage point MFP growth with a -0.1 percent point ICT capital assets contribution during 1991–95; 0.1 percent point MFP growth with

[6] Baily (2002), p. 4.

a 0.2 percent point ICT capital assets contribution during 1996–2000. Accordingly, multifactor productivity was positive when capital deepening of ICT capital assets contributed positively, whereas MFP was negative when ICT capital assets contributed negatively. In other words, the "Solow paradox" has not been evident in Japan over the last two decades, even though that country has endured the stagnant "lost decade" of the 1990s.

4. Conclusion

This study demonstrated that investment in information and communications technology has contributed importantly to aggregate productivity growth. Therefore, it can be concluded that there is no "Solow paradox" in Japan. However, this is "only part of the story,"[7] which raises two salient issues.

First, there is no decomposition of aggregate multifactor productivity growth in this study. As Jorgenson (2001) pointed out, the "use" of information and communications technology must be carefully distinguished from the "production" of information and communications technology.[8] It is apparent that multifactor productivity represents efficiency gains from either "use" or "production" of the technology, or both of them, whereas capital deepening of ICT assets represents only the effects of the use of information and communications technology. Therefore, it remains unclear whether changes of multifactor productivity (marked improvement in the late 1980s, deterioration in the early 1990s, and slight recovery in the late 1990s) have arisen from the "use" of information and communications technology across industries or just from the limited

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[7] Oliner and Sichel (2000), p. 15.
[8] Jorgenson (2001), pp. 26–27.

“producers” of information and communications technology such as semiconductor industry. For this reason, it is important to identify the part of multifactor productivity changes that is attributable to improvement or deterioration in information and communications technology producers. This question remains open.

Another issue that must be addressed is why investment in information and communications technology, which first began to accelerate in the late 1980s, slowed down in the 1990s, even though investment in information and communications technology could have paid off in productivity growth. Although the solution of this question needs more comprehensive and fundamental analysis, a possible explanation might be that there have been some impediments in the Japanese economy to reap the benefits of information and communications technology, by which Japan plunged into its “lost decade” in the emerging information age (see Addendum in this paper). This question remains as a conundrum for many economists.

[Addendum]

Strengths and weaknesses of the Japanese economic system

This addendum section is intended to reexamine the features of Japanese economic system that made the economy prosperous through the 1980s and conversely made it stagnant in the 1990s. These arguments should be taken into consideration for analyzing possible impediments that prevent the Japanese economy from reaping the benefits of information and communications technology.

We first review the strengths of Japanese system, then consider how that strength became weakness in the midst of innovation in information and communications technology.

A-1. Integrality versus modularity

According to the Economic Planning Agency (1990), which analyzed the strengths of the 1980s Japanese economy, Corporate Japan had several striking features in its organizational structure. Those features facilitated its success in technological improvement and in transforming the structure toward a well-advanced R&D economy until the late 1980s. They were (1) intensive face to face communications based on an intimate human network; (2) shared business information by *informal* communications; and (3) overlapping missions in some parts of jobs under a flexible organizational structure and unrestricted job descriptions.

Herein, we refer to these above-mentioned features as an “integrated system” or “integrated organization.”[9] In an integrated organization, information circulates by means of *informal* traffic.

[9] Policy Research Institute (2000) refers to a Japanese system as an integrated system.

Information is also shared in a tacit manner. Accordingly, an integrated system is quite appropriate for technological improvement through "learning by doing"[10] because invisible and tacit skills can be shared and transferred easily among employees: they are accumulated within an organization day by day. For that reason, Corporate Japan has performed well through continuous improvement such as *kaizen* and total quality management in its production line (see Figure A-1).

In contrast, Corporate America has different features in its organizational structure. Here, we call them a "modular system," or "modular organization."[11] In a modular organization, the mission of each job position is obvious through means of formal job descriptions. Moreover, borders separating job units or divisions are much clearer than those in an integrated organization. However, such a modular system sometimes makes it difficult to understand the internal activities of other job units and to share information that covers an entire organization. Therefore, a standard format for the open interface is created to promote smooth *formal* communications among the units. This common interface and simple protocol ease communication, even with newcomers, in a modular organization. A sharp contrast exists with communication outcomes in an integrated organization.

A-2. From matured industrial age to emerging information age

The dynamic changes of the economic environment should be considered before rethinking the Japanese system (see Table A-2). In fact, it seems reasonable to presume that economies are going to change from those favoring an integrated system toward those favoring a modular system. With the open network and digital technology prevailing, what have been emerging are not only "network

[10] Arrow (1962) argues the implication of learning by doing.
[11] Langlois and Robertson (1992) argue the nature of modularity.

effects," but also "economies of outsourcing."

Table A-2 clarifies the notion of "economies of outsourcing" and incorporates it into other concepts of economies. "Economies of outsourcing" is the obverse of "economies of scope" just as "network effects" are the obverse of "economies of scale."[12] Under economies of outsourcing, economic benefits arise from resources outside the organization, rather than in-house resources under economies of scope, inducing a synergy effect of dynamic new combinations. With the open network and digital technology prevailing, modularity has come to gain advantage over integrality, where some of the strength of integrated systems turns into weakness. That is considered to be what happened in the 1990s.

A-3. The Japanese system revisited

In the 1990s, information technology has progressed and changed its nature from simple high-performance automatic transaction machinery to effective business communications tools. Modular organizations easily adapt the technology to a standard format of formal communications and thereby reap the benefits of that technological change.

In contrast, integrated organizations tend to fail in adapting the technology. Their intimate human networks perform so efficiently and effectively that management does not easily understand the importance of using the technology. Therefore, it takes time for integrated organizations to fully implement new technology as a communications tool, and then they lose their advantages over time.

Taking intensive face-to-face communications as one example, that preference engenders a

[12] Network effects represent the scale merits of the demand-side (consumption), whereas economies of scale represent those of the supply-side (production). Katz and Shapiro (1985) argue the nature of network externalities.

locational constraint when the organization expands its business globally. Too much dependence on face-to-face and *informal* communications of the human network implies less, perhaps inadequate, attention to creating a *formal* means of information traffic and consequent reluctance toward building and using an information technology network. Lacking appropriate technology, a global organization will fail to make prompt decisions.

Another problem arises from overlapping missions and unclear borders of job units that lent Japanese firms their advantages in the 1980s. Such complexity renders it impossible to reap benefits from economies of outsourcing or recent trends of *offshoring* because it is so hard to identify the job units that should be outsourced. In addition, the complexity in integrated organizations must be confronted during restructuring the organization through mergers and acquisitions. Thereby, it forces the expenditure of time for making decisions and business opportunities will bypass such time-wasting firms in the agile digital economy.

The arguments in this section are not intended to reject all features of the Japanese system by any means. The integrated system works quite well in some businesses such as high-quality consumer products industries that depend heavily on technological improvement through "learning by doing." Nevertheless, it can be concluded at least that the integrated system of the Japanese economy, which performed excellently in the 1980s, is unsuitable for the emerging information age. In some cases, information and communications technology performs far more efficiently and effectively than intimate human networks do. Corporate Japan has hesitated to introduce such technology that erodes its advantages of human networks.

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Table 1. Investment in information and communications technology in Japan

(millions of current yen)

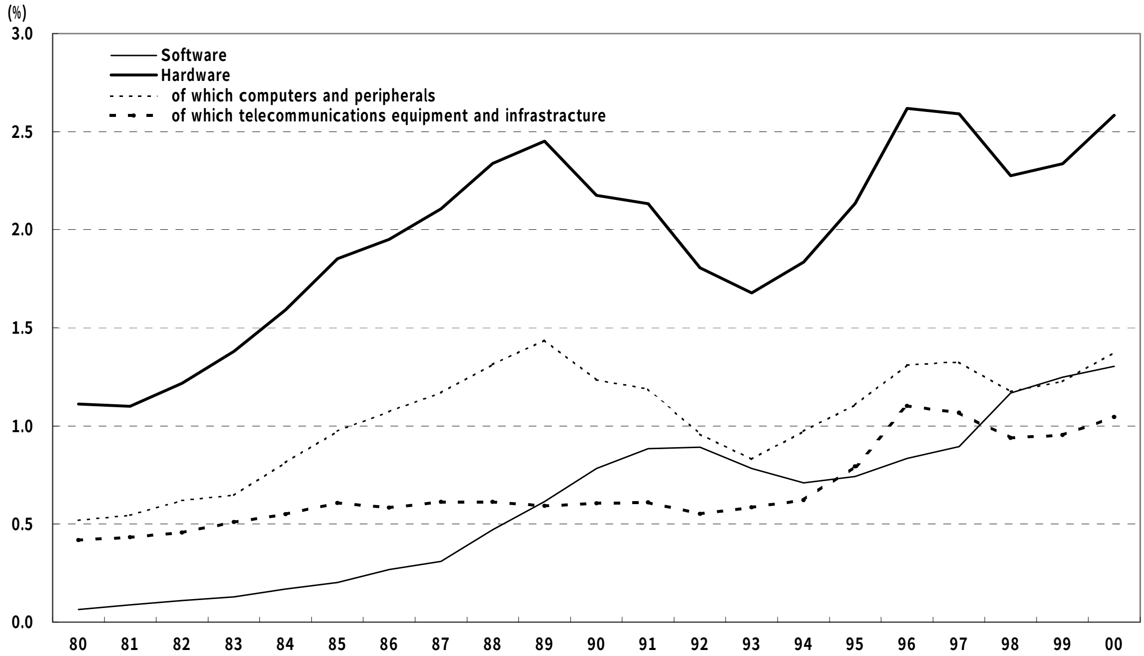
year	computers and peripherals	telecommuni-cations equipment	office equipment	telecommuni-cations infrastracture	softwares	total
75	663,199	291,972	312,986	468,859	42,082	1,779,098
76	715,188	314,691	342,612	499,072	46,990	1,918,553
77	805,614	332,197	385,032	531,232	77,307	2,131,382
78	913,167	344,331	474,525	565,464	88,973	2,386,461
79	1,069,766	342,902	389,359	601,903	128,945	2,532,875
80	1,263,557	374,640	422,854	640,689	153,985	2,855,725
81	1,423,419	476,539	317,631	652,720	227,549	3,097,858
82	1,698,989	588,565	384,498	664,977	300,098	3,637,127
83	1,846,369	776,613	643,976	677,463	364,377	4,308,798
84	2,483,594	986,818	689,430	690,185	512,398	5,362,424
85	3,172,930	1,271,385	888,268	703,145	658,030	6,693,757
86	3,655,517	1,347,151	1,006,486	640,355	912,747	7,562,255
87	4,164,814	1,597,491	1,148,643	583,172	1,104,504	8,598,623
88	5,008,691	1,809,272	1,569,455	531,095	1,799,131	10,717,644
89	5,887,830	1,944,491	1,726,544	483,669	2,512,535	12,555,068
90	5,452,243	2,232,756	1,487,095	440,478	3,457,947	13,070,518
91	5,576,466	2,376,439	1,563,410	491,843	4,146,498	14,154,657
92	4,617,867	2,119,258	1,422,717	536,851	4,295,891	12,992,584
93	4,040,302	2,243,488	1,274,570	604,355	3,813,288	11,976,003
94	4,788,815	2,434,490	1,185,695	620,893	3,485,844	12,515,737
95	5,514,300	3,168,879	1,156,058	780,808	3,697,132	14,317,177
96	6,699,453	4,658,648	1,041,012	972,765	4,259,115	17,630,992
97	6,920,412	4,636,975	1,026,900	935,722	4,668,517	18,188,526
98	6,061,148	3,971,010	830,030	874,900	6,025,265	17,762,353
99	6,279,008	4,083,055	791,564	801,409	6,387,786	18,342,822
00	7,066,100	4,540,317	834,269	830,259	6,695,168	19,966,113
01	6,050,134	4,596,864	644,940	870,112	7,550,873	19,712,923

(millions of 1995 yen)

year	computers and peripherals	telecommuni-cations equipment	office equipment	telecommuni-cations infrastracture	softwares	total
75	182,399	205,961	75,921	806,644	69,160	1,340,084
76	199,106	224,642	107,798	801,725	70,248	1,403,519
77	234,811	235,936	133,815	796,837	107,657	1,509,056
78	292,028	246,051	182,428	791,979	118,333	1,630,819
79	379,349	249,086	170,413	783,958	165,628	1,748,433
80	419,566	260,944	180,629	782,351	183,992	1,827,481
81	495,026	328,412	146,664	793,581	259,104	2,022,787
82	616,551	407,239	198,819	804,971	332,656	2,360,236
83	697,398	541,140	364,788	816,526	394,870	2,814,722
84	1,029,931	713,904	448,857	807,422	540,632	3,540,746
85	1,514,439	887,424	566,816	840,134	681,779	4,490,592
86	2,139,232	1,055,249	701,010	745,793	945,934	5,587,217
87	2,832,783	1,339,467	904,716	662,046	1,147,338	6,886,350
88	3,503,961	1,564,794	1,360,452	587,703	1,850,165	8,867,074
89	4,021,461	1,655,684	1,515,149	521,708	2,463,672	10,177,674
90	4,108,537	2,065,005	1,307,614	463,124	3,258,116	11,202,395
91	4,388,381	2,258,204	1,409,013	503,427	3,768,687	12,327,713
92	3,794,082	2,027,572	1,311,162	540,479	3,880,368	11,553,664
93	3,447,458	2,157,586	1,208,376	605,516	3,509,699	10,928,635
94	4,376,476	2,379,914	1,152,597	622,086	3,370,679	11,901,752
95	5,514,300	3,168,879	1,156,058	780,808	3,697,132	14,317,177
96	7,109,267	4,786,167	1,046,953	978,636	4,269,789	18,190,813
97	7,479,400	4,814,441	1,043,823	932,923	4,526,315	18,796,903
98	6,832,265	4,231,011	868,026	895,497	5,697,650	18,524,450
99	7,290,274	4,737,994	877,737	833,065	6,000,269	19,739,339
00	8,869,658	5,588,137	941,474	858,593	6,273,289	22,531,151
01	8,538,951	6,004,990	735,632	911,657	6,994,787	23,186,018

Source: Shinozaki (2003a), pp. 86–87, Table 5–4.

Figure 1. Share of investment in information and communications technology to GDP



Source: Shinozaki (2003a), pp. 89, figure 5–1.

Table 2. Information and communications technology assets in Japan

(millions of 1995 yen)

end of year	gross assets	net assets	software	computer and peripherals	telecommuni-cations	office equipment
74	12,320,055	9,471,753	166,187	369,837	8,730,139	205,591
75	13,009,277	9,665,926	202,109	436,883	8,782,428	244,505
76	13,709,531	9,882,681	231,935	499,725	8,842,728	308,292
77	14,466,321	10,161,293	293,205	578,672	8,902,801	386,614
78	15,298,052	10,504,084	352,897	690,212	8,961,523	499,452
79	16,200,901	10,890,992	447,945	854,284	9,008,799	579,963
80	17,130,255	11,267,071	542,348	1,007,399	9,061,126	656,199
81	18,163,085	11,752,341	692,982	1,188,217	9,186,394	684,747
82	19,433,055	12,469,618	887,042	1,434,163	9,388,101	760,311
83	21,046,593	13,490,068	1,104,503	1,684,245	9,713,076	988,244
84	23,268,580	15,038,275	1,424,235	2,188,860	10,165,964	1,259,217
85	26,244,359	17,216,400	1,821,166	3,020,594	10,775,266	1,599,374
86	30,066,573	20,024,094	2,402,867	4,217,702	11,391,029	2,012,497
87	34,811,805	23,499,108	3,069,631	5,734,984	12,139,529	2,554,964
88	41,122,352	28,168,273	4,305,870	7,450,204	12,956,677	3,455,522
89	48,149,333	33,113,825	5,908,368	9,147,946	13,708,834	4,348,678
90	55,543,023	37,990,569	7,984,810	10,403,238	14,728,991	4,873,530
91	63,305,459	42,979,125	10,156,535	11,546,850	15,870,433	5,405,307
92	69,530,177	46,181,317	12,005,596	11,739,470	16,692,736	5,743,515
93	74,528,714	48,177,258	13,114,176	11,525,387	17,619,637	5,918,058
94	80,028,635	50,857,996	13,862,020	12,307,095	18,683,477	6,005,404
95	87,505,641	55,428,031	14,786,748	13,982,812	20,577,982	6,080,490
96	98,331,902	62,942,190	16,099,188	16,730,840	24,079,207	6,032,955
97	108,915,369	69,566,261	17,405,666	18,991,891	27,177,859	5,990,846
98	118,391,471	74,618,091	19,622,183	19,900,586	29,314,802	5,780,520
99	128,193,856	79,960,879	21,698,015	20,983,868	31,661,233	5,617,763
00	139,838,183	87,113,626	23,631,701	23,308,657	34,625,228	5,548,040

Source: Shinozaki (2003a), p. 123, Table 6–7.

Figure 2. Growth of information and communications technology assets

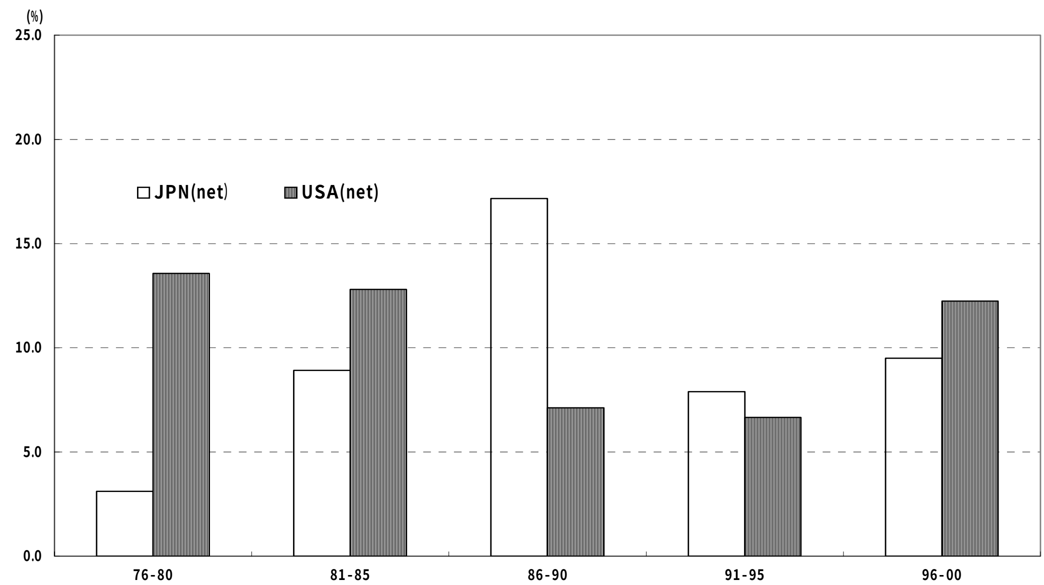


Table 3. Labor productivity, MFP, and contribution of ICT

(annual rate of percentate, percentage point change)

line		76-80 (a)	81-85 (b)	86-90 (c)	91-95 (d)	96-00 (e)	changes from the previous five years (b)-(a)	(c)-(b)	(d)-(c)	(e)-(d)
1	Growth rate of output	4.81	3.65	5.21	1.56	1.45	-1.16	1.56	-3.64	-0.11
2	Growth rate of labor input	1.37	0.92	1.29	-0.27	-0.83	-0.45	0.36	-1.56	-0.55
3	Output per hour	3.44	2.73	3.92	1.84	2.28	-0.71	1.19	-2.08	0.44
4	Business cycle factor	1.15	-0.02	0.29	-0.81	0.00	-1.17	0.31	-1.10	0.81
5	Trend	2.29	2.75	3.63	2.64	2.28	0.46	0.88	-0.98	-0.37
6	Capital deepening	1.66	1.62	1.83	1.76	1.35	-0.05	0.21	-0.07	-0.41
7	of ICT assets	0.09	0.17	0.48	0.38	0.53	0.08	0.31	-0.10	0.15
8	of non-ICT assets	1.57	1.45	1.35	1.38	0.81	-0.13	-0.10	0.03	-0.57
9	Multifactor productivity	0.63	1.13	1.80	0.88	0.93	0.50	0.67	-0.92	0.05
	Addendum:									
	Income shares (percentage)									
	Labor hours	67.0	68.6	67.2	70.3	72.8	-	-	-	-
	ICT assets	2.1	2.1	3.3	3.9	5.0	-	-	-	-
	Non-ICT assets	30.9	29.3	29.6	25.8	22.2	-	-	-	-
	Growth rate of inputs (annual rate of percentage)									
	Labor hours	1.4	0.9	1.3	-0.3	-0.8	-	-	-	-
	ICT assets	0.1	0.2	0.5	0.4	0.5	-	-	-	-
	Non-ICT assets	2.0	1.7	1.7	1.3	0.6	-	-	-	-

Source: Author's calculations based on the data from CAO, STAT, METI, and Shinozaki (2003a).

Figure 3. Sources of Average Labor Productivity Growth

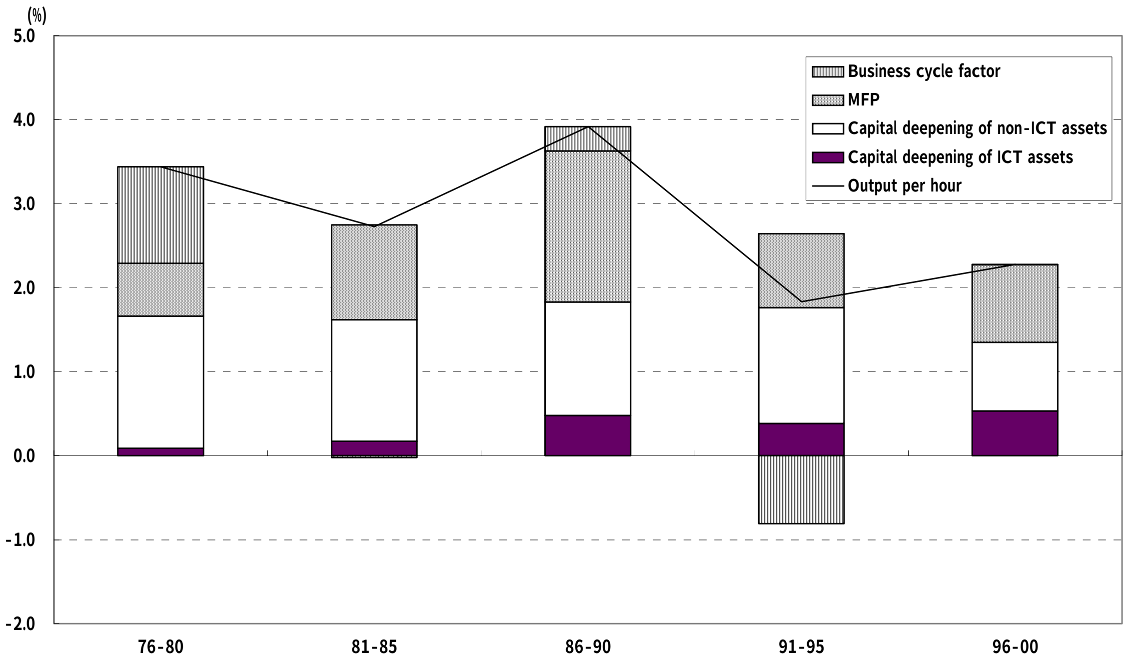


Figure 4. Acceleration of Labor Productivity Growth

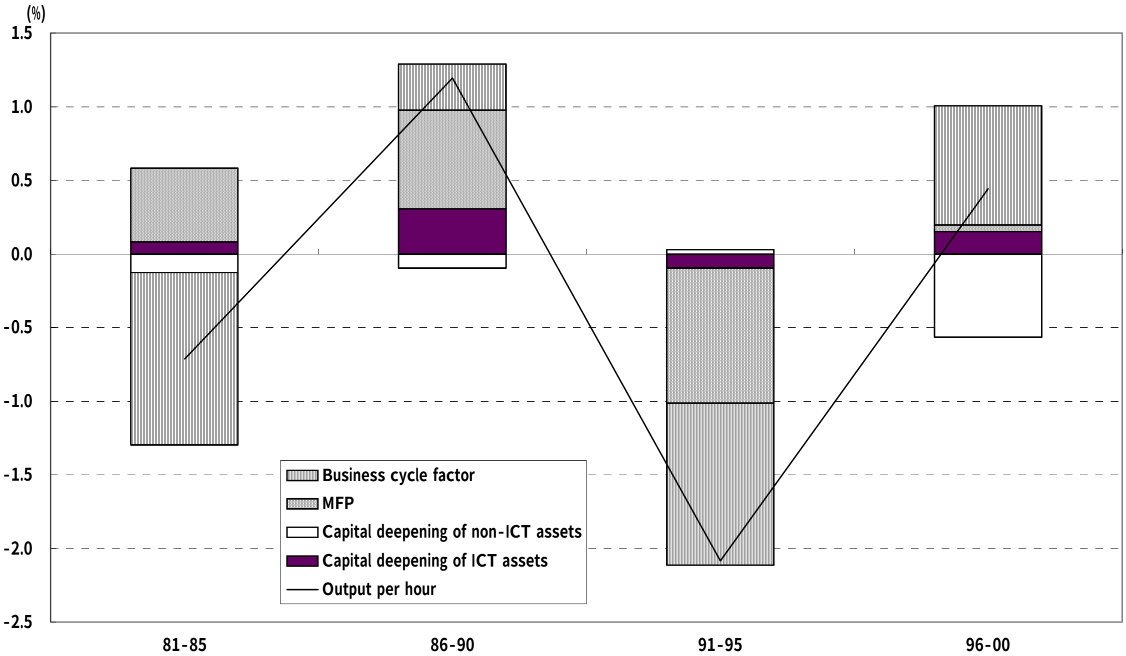
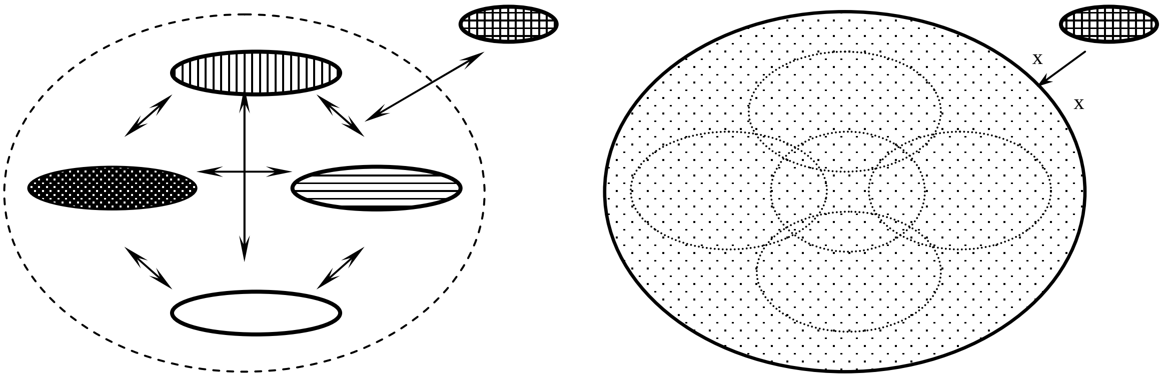


Table 4. The “Solow paradox” in the U.S.

	1948–1973 (a)	1973–1995 (b)	Changes (b)-(a)
Output per hour	2.9	1.4	-1.5
Capital deepening	0.8	0.7	-0.1
of ICT assets	0.1	0.4	***0.3***
of non-ICT assets	0.7	0.3	-0.4
Multifactor productivity	1.9	0.4	***-1.5***

Source: Selected data from Baily (2002), p.5, Table 1.

Figure A-1. Modularity versus Integrality



Modular Organization

(Corporate USA Type)

Integrated Organization

(Corporate Japan Type)

Table A-2. Economies of the Information Age and the Industrial Age

	Emerging Information Age	Matured Industrial Age
Scale Merit	Network Effects (Externalities) - consumer's scale merit	Economies of Scale - producer's scale merit
Resource Merit	Economies of Outsourcing - outside resources - multiple organizations - synergy effect - innovations (new combinations)	Economies of Scope - in-house resources - single integrated-organization - cost saving - learning by doing
Industrial Organization	Multiple small players Competitive market Compatibility Modularity	Larger organization Oligopoly, or monopoly Continuity Integrality

Source: Shinozaki (2003a), p.169, Figure 9-1, with some modifications.