Economical Impacts of IT on Industries in Japan

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Abstract

Investment of IT (Information Technology) came to be positively advanced in various industries after 1980. However, in the late 1980s, as for the improvement in the productivity by the investment of information systems, the economist Robert Solow developed the "paradox of productivity theory" which claims that the introduction of information systems does not lead to higher productivity. On the other hand, as a result of good strategy on the development of IT industries, the U.S. economy after 1991 was in good condition over a span of 10 years, until 2001. The Federal Reserve Bank Chairman Alan Greenspan came to suggest "the New Economy theory", which is caused by the investment of IT. It posed a problem in the1980s about investment of IT in the industries and the companies; it is not clear whether or not it made a good impact on corporate management.

In this paper, we have measured the economical effects of IT investment by industries in Japan. Consequently, in Japan, the effect of IT investment in most industries will be low or minus in the first half of the 1990s, compared with the second half of the 1980s. However, the effect of IT investment is again changed to a rise or plus after 1995. This has a big relation to the advancement of IT, such as evolution of an information network, and there is also change in the management of IT itself. These results will support our objective which is to consider the directions of more effective IT investment, as well as to give the right direction of corporate management for the future in Japan.

1. Introduction

Since 1980, many industrial sectors in the U.S. have promoted the introduction of Information Technology with OA (Office Automation) as its core. However in the late 80s, the economist Robert Solow, among others, warned against the easygoing introduction of IT, with his Paradox of Productivity theory, which claims that the introduction of information system does not lead to the higher productivity. This argument has caused many controversial issues thereafter.

Meanwhile, the U. S. economy since 1991 has enjoyed extreme prosperity for over 10 years until 2001, as the result of the policy efforts focused on cultivating the IT industry such as National Information Infrastructure Plan, and achieved the economic expansion without inflation. Consequently, the New Economy theory -- advocated by the Federal Reserve Bank Chairman Alan Greenspan -- attracted public attention in the late 1990s, which attributed the long-term economic growth with no inflation coming to the surface, to the productivity growth achieved by the aggressive introduction of IT.

Besides, several researches and articles, such as the one by Dr. Eric Brynjolfsson of MIT, reported in the first half of the 1990s that Paradox of Productivity in the U.S. was solved(1).

On the other hand, Japan entered into the bubble economy backed by the extremely low interest rate policies brought about by Plaza Accord since 1986. Firms raised a large sum of funds at a very low cost by equity finance and promoted the excessive capital investments. Investment on IT was no exception and IT capital stock in firms expanded rapidly. However, upon entering into the 1990s, the attitude of firms toward IT introduction changed radically with the collapse of the bubble economy, and IT investment decreased greatly. This can be interpreted as corporate behavior resulting from the management's doubt as to the ability of IT investment to improve the productivity, as pointed out by the Paradox of Productivity theory.

The problem here is the fact that the impacts of introducing IT into the industry on the business management side has not been identified. It is necessary to analyze particularly the effect of IT investment quickly reinforced in the latter half of the 1980s, the impact of the explosive diffusion of PCs with the release of Windows 95 in 1995, and that of the spread of information networks such

as the Internet and LANs. Our research team continually measured since 1997 the economic effects of IT introduction on the industry, by using the various macro-economic statistics and other statistic materials for each industry. This paper presents, as a part of our research outcomes on the issue, the economic impacts of IT introduction since the 1980s measured by two different methods. A part of the analyses presented here is carried out with three different data sources, in order to eliminate the data errors and to allow for a more detached examination.

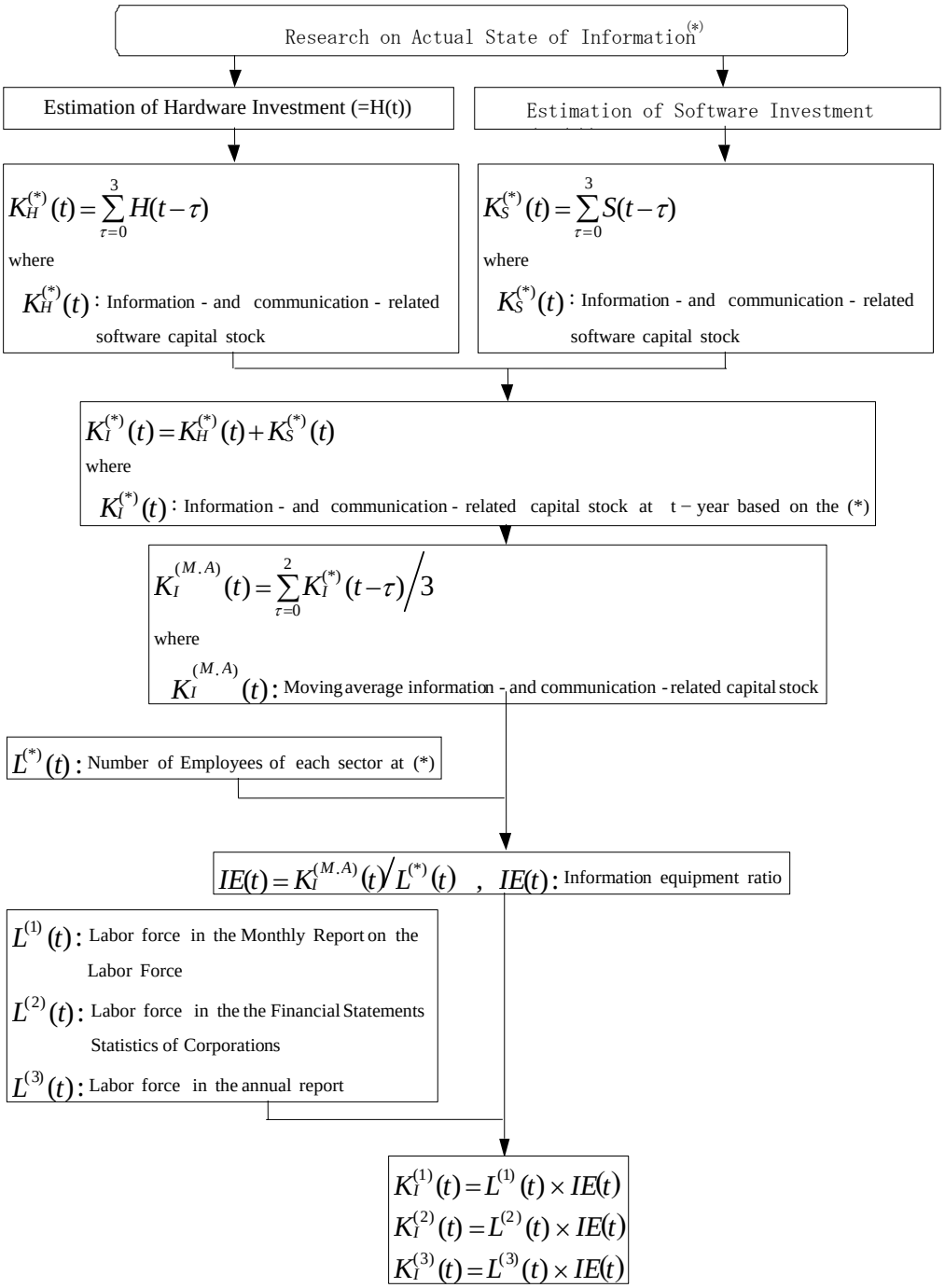
In Japan so far, the research and analyses on the impact of IT investment on the macro-economic level have been published by, among others, the research section of Development Bank of Japan, but no analysis has been done on the economic impact of IT investment on each industry. Therefore, the quantitative analysis of its economic impacts on each industry and the examination of their factors and causes will be a very useful decision-making material for each industry to consider the future IT investment. Each of the following measurement results have been published as papers or presented at academic conferences. In this paper, the results of those different measurement methods will be analyzed and examined comprehensively and the informatization in Japanese industry and its impact since 1980 will be examined with consideration to the overall IT trend which comprises its background.

2. Analysis of the Economic Impact of Information Equipment by Growth Accounting

2.1 Estimation of information- and communication- related capital stock

To start with, the amount of Information- and communication- related capital stock is calculated, using the Research Report on General Index of Informatization by Japan Information Processing Development Center as reference. Then the Information Equipment Ratio is calculated by dividing this amount by the number of employed in relevant industry, which is considered as an index to indicate the progress of informatization. On the other hand, the amount of value added per person is defined as Value-added Productivity and its relationship with Information Equipment Ratio is analyzed.

Fig 1. Estimated Flow of Information- and communication- capital stock



2.2 Analysis by Growth Accounting

Considering Income Per Employee, Information- and communication- capital stock, Capital Stock Other Than Information- and communication capital stock, and External Factor (Technological Progress), as the decisive factors of the amount of value added per person (Value-added Productivity), the growth rate of Value-added Productivity is divided into these factors and then measured. The model of growth accounting adopted here is shown as Equation (1).

$$G(Q/Ln) = A + \alpha G(L/Ln) + \beta G(K_O/Ln) + \gamma G(K_I/Ln)$$
$$\Rightarrow G(Q') = A + \alpha G(L') + \beta G(K_O') + \gamma G(K_I') \quad (1)$$

where

$$\alpha = (\partial Q'/\partial L')/(Q'/L') \quad (2)$$
$$\beta = (\partial Q'/\partial K_O')/(Q'/K_O') \quad (3)$$
$$\gamma = (\partial Q'/\partial K_I')/(Q'/K_I') \quad (4)$$

Q : Amount of Value-added
L : Labor Input
Ko : Capital Stock Other Than Information- and communication- capital stock
K_I : Information- and communication- capital stock
A : Constant Indicating the Impact of External Factor(Technological Progress)
Ln : No. of Employed

Three different data are used to calculate *Q* based upon three different data sources, SNA, the Financial Statements Statistics of Corporations by sector, and the annual reports. This is because the use of different data sources to carry out the same analysis will eliminate the errors and peculiarities and enable the more detached examination of the results.

Equation (1) assumes primary homogeneity, so Eq.(5) holds. Further, by assuming complete competitive equilibrium, Eq.(6)~(8) hold.

$$\alpha + \beta + \gamma = 1 \quad (5)$$
$$\alpha = (Lw/Ln)/Q' \quad (6)$$
$$\beta = (roK_O/Ln)/Q' \quad (7)$$
$$\gamma = (riK_I/Ln)/Q' \quad (8)$$

where

w: Wage Rate
ro: Profit Rate of Capital Stock Other Than Information- and communication- capital stock
ri: Profit Rate of Information- and communication- capital stock

Second, third and fourth members of the right-hand side of Eq.(1) show the growth rate of Value-added Productivity based on the increase of Labor, Capital Stock Other Than Information- and communication- capital stock, and Information- and communication- capital stock respectively. While *A* indicates the growth rate of Value-added Productivity brought about by External Factors.

Ko is calculated as

$$K_O = K - K_I \tag{9}$$

where K : Capital Stock of Each sector

In other words, Information- and communication- capital stock is considered herein as a part of Capital Stock[(2)]. Progress-based values in Estimated Long-term Retroactive Private Business Capital Stock published by the Economic Planning Agency are used as values for *K*. Aggregate working hours for each sector in each year are used as *L*. *L* is calculated as Eq.(10), where the value of *Ln* is taken from Eq.(1).

$$L = Ln \times \left(L_{90} \times C \times 12\right) \tag{10}$$

where

L: Aggregate Working Hours for Each Industry in Each Year
L_{90}: Monthly Total Working Hours in 1990
C: Monthly Total Working Hours Index for each sector (average in the year)
(This data is taken from Annual Report on Monthly Labor Statistics.)

2.3 Results of Analysis

Tables 1~3 show the growth rate of Value-added Productivity for each sector and the contribution rate of their input factors. Each table corresponds to three data sources used to calculate the values for *Q*, which are SNA, the Financial Statements Statistics of Corporations by sector, and the annual reports. First, attention should be paid to Contribution of Information- and

communication-related capital stock in 1990-1994. In Table 3, which is based on SNA, this factor shows the minus values in the rows of Foodstuff, Pulp/Paper, Ceramics, General Machinery, Transport Machinery, Precision Machinery, Construction, Wholesale/Retail, Finance/Insurance, and Transportation/Communication, indicating its negative impact on the growth of Value-added Productivity. Similar 11 sectors in the analysis are based on the Financial Statements Statistics of Corporations by sector, and similar seven sectors in the analysis are based on the annual reports show the minus values. In these sectors, in spite of the minus values for Distribution Factor (or Coefficient) of Information- and communication-related capital stock, Information- and communication-related capital stock itself continues the positive growth. This indicates the possibility that Information- and communication-related capital stock is not utilized effectively in these sectors.

On the other hand, both Distribution Factor of Information- and communication-related capital stock and Contribution of Information- and communication-related capital stock show the positive values in many sectors during the periods of 1982-1986 and 1986-1990, indicating the effective result of informatization in these periods. It seems that the investment on information systems during these periods is focused on improving efficiency of human resources. In other words, the target of informatization during these periods was the labor-intensive segment which existed in any industry. This goal was accomplished more or less as seen in the decrease of Labor Input.

However, since 1990, Distribution Factor of Information- and communication-related capital stock decreased greatly in many industries, showing minus in some industries. Therefore, Information- and communication-related capital stock did not contribute much to Value-added Productivity. Information- and communication-related capital stock seen between 1991 and 1994 was the accumulation of IT Investment from 1988 to 1994, during which the effect of Information- and communication-related capital stock seemed not very great. Not to mention the period with generous fund at hand from 1988 to 1990, firms held IT Investment as sacred even in 1991, immediately after the collapse of the bubble economy, and continued to invest in IT aggressively. However, it is doubtful that such investment activities were driven by the sufficient examination on the effect of informatization. The likelihood of the accumulation of excessive IT equipment which was not

necessarily effective can be pointed out. During the period 1990-1994, while Information- and communication-related capital stock continued to increase, Contribution of Information- and communication-related capital stock to Value-added Productivity was not so great, or even negative in many industrial sectors, indicating the fact that many of Japanese firms could not necessarily make the best use of Information- and communication-related capital stock in their business. Its possible causes were the immaturity of IT at that time, the insufficient employee training for using Information- and communication-related capital stock, and the delay in corporate shift to the leaner organization so as to be able to deal with new IT.

However, the results of analysis for the 1994-97 period show a great change. Distribution Factor of Information- and communication-related capital stock increased in 11 sectors in SNA-based analysis, in 12 similar sectors in the analysis based on the Financial Statements Statistics of Corporations by sector, and in 14 sectors in the analysis based on the annual reports, and Contribution of Information- and communication-related capital stock to Value-added Productivity began to show improvement. Especially in the sectors of Electric Machinery, Precision Machinery, and Finance/Insurance, Contribution of Information- and communication-related capital stock was remarkable, confirming the great positive impact of IT Investment. In these sectors, Amount of IT Investment was relatively great, with early introduction of the fusion of computer and networking technologies since 1994, as represented by the Internet, and the fruit of such efforts seems to have surfaced since the middle of the 1990s. In other words, in the middle of the 1990s, the IT breakthrough brought about by the technological innovations such as the release of Windows 95 and the progress of semiconductors for microprocessors and memories, as well as the widespread commercial use of the Internet, enabled the information systems composed of networks and small computers to improve business management and operation.

Table 1. Contribution of Each Input Factor to Value-added Productivity (based on SNA)

		$G(Q/L_n)$	A	α	$G(L/L_n)$	$\alpha G(L/L_n)$	β	$G(K_o/L_n)$	$\beta G(K_o/L_n)$	γ	$G(K_I/L_n)$	$\gamma G(K_I/L_n)$
		(%)	(%)		(%)	(%)		(%)	(%)		(%)	(%)
Food products	1982-86	-2.0	-3.7	0.5	-0.3	-0.1	0.7	6.9	4.6	-0.2	14.6	-2.8
and beverages	1986-90	-3.7	3.9	0.6	-0.8	-0.5	1.1	1.0	1.1	-0.7	12.5	-8.3
	1990-94	-2.0	4.0	0.7	-2.0	-1.3	0.7	1.7	1.2	-0.4	16.7	-5.9
	1994-97	-1.1	-0.4	0.7	0.6	0.5	0.4	1.8	0.8	-0.2	12.8	-2.0
Textiles	1982-86	-0.7	-0.5	0.7	0.4	0.3	0.4	3.1	1.3	-0.1	11.7	-1.7
	1986-90	-3.3	2.1	0.8	-1.2	-0.9	0.8	2.6	2.0	-0.6	11.2	-6.6
	1990-94	0.2	0.5	0.9	-1.4	-1.2	0.1	6.0	0.6	0.0	14.0	0.3
	1994-97	-3.4	-0.9	1.1	0.1	0.1	0.0	6.5	-0.2	-0.1	20.7	-2.5
Pulp, paper	1982-86	0.2	-1.4	0.5	0.5	0.3	0.5	3.4	1.8	0.0	12.0	-0.4
and paper products	1986-90	5.5	0.5	0.5	-1.1	-0.5	0.3	4.1	1.2	0.2	20.4	4.3
	1990-94	-2.3	-1.4	0.5	-1.1	-0.6	0.9	4.6	3.9	-0.4	10.8	-4.2
	1994-97	2.0	-0.8	0.6	0.3	0.2	0.4	4.5	1.8	0.0	19.7	0.7
Chemicals	1982-86	10.1	0.2	0.4	0.2	0.1	-0.1	4.4	-0.5	0.7	14.9	10.3
	1986-90	5.4	-0.6	0.4	-0.5	-0.2	0.3	4.0	1.1	0.3	16.5	5.1
	1990-94	3.0	-0.9	0.4	-1.0	-0.4	0.3	3.1	0.9	0.3	12.8	3.4
	1994-97	3.4	-2.3	0.5	0.0	0.0	0.3	4.2	1.3	0.2	19.0	4.4
Petroleum	1982-86	-3.0	-3.3	0.2	-0.3	-0.1	1.9	6.5	12.3	-1.1	11.2	-12.0
and coal products	1986-90	-0.4	1.0	0.2	-0.1	0.0	1.1	5.9	6.4	-0.3	26.2	-7.7
	1990-94	3.0	-0.2	0.2	-1.1	-0.2	0.8	3.9	3.1	0.0	17.0	0.4
	1994-97	7.9	121.2	0.2	-0.2	0.0	-11.4	5.3	-60.2	12.2	-4.4	-53.1
Non-metallic	1982-86	2.9	-4.3	0.6	0.2	0.1	-0.6	4.4	-2.7	1.0	9.4	9.9
mineral products	1986-90	1.0	0.1	0.6	-0.3	-0.2	0.4	2.8	1.2	0.0	17.5	-0.1
	1990-94	3.0	1.8	0.7	-1.6	-1.0	0.4	8.1	3.3	-0.1	14.9	-1.1
	1994-97	0.9	-0.5	0.7	0.2	0.1	0.3	4.5	1.1	0.0	21.3	0.1
Basic materials	1982-86	3.0	-0.5	0.6	0.2	0.1	0.3	3.9	1.1	0.2	13.8	2.3
and fabricated metal	1986-90	4.7	1.2	0.5	0.3	0.2	0.3	4.0	1.3	0.2	13.0	2.1
products	1990-94	1.4	-0.3	0.5	-2.2	-1.2	0.4	4.9	1.8	0.1	11.3	1.0
	1994-97	3.6	-1.0	0.6	0.6	0.3	0.1	4.4	0.6	0.3	12.8	3.7
General machinery	1982-86	5.7	6.6	0.6	-0.2	-0.1	0.9	6.2	5.6	-0.5	13.2	-6.3
	1986-90	4.5	-0.1	0.6	0.3	0.2	0.1	3.6	0.3	0.3	12.7	4.1
	1990-94	-3.9	-3.0	0.6	-2.3	-1.5	0.6	6.6	4.1	-0.3	13.6	-3.5
	1994-97	2.8	6.3	0.7	1.2	0.9	0.6	3.3	2.1	-0.3	18.5	-6.4
Electrical machinery,	1982-86	14.1	0.9	0.6	0.0	0.0	-0.4	5.6	-2.4	0.9	17.9	15.5
equipment and	1986-90	11.5	1.9	0.6	-0.1	-0.1	-0.3	6.3	-1.8	0.7	15.9	11.6
supplies	1990-94	7.4	1.8	0.6	-1.8	-1.2	-0.3	8.3	-2.1	0.6	14.1	8.9
	1994-97	14.2	-18.2	0.7	0.2	0.1	-6.1	6.1	-37.1	6.4	10.8	69.3
Transport equipment	1982-86	4.7	-0.4	0.7	0.1	0.1	0.0	7.0	0.3	0.3	17.0	4.7
	1986-90	5.2	-0.8	0.7	0.9	0.6	0.0	5.6	0.2	0.3	18.1	5.2
	1990-94	-0.7	0.1	0.7	-2.8	-1.9	0.4	5.0	1.8	0.0	17.3	-0.7
	1994-97	-0.3	7.7	0.7	1.0	0.7	1.7	5.5	9.2	-1.4	12.7	-17.9
Precision instruments	1982-86	5.2	-0.3	0.7	0.1	0.1	0.0	10.1	0.4	0.3	19.2	5.0
	1986-90	6.6	1.1	0.7	0.1	0.0	-0.2	11.1	-1.7	0.5	15.8	7.2
	1990-94	-3.8	-3.7	0.7	-1.7	-1.3	0.5	10.1	5.0	-0.2	15.2	-3.8
	1994-97	6.0	1.1	0.8	0.3	0.2	-0.6	7.0	-4.3	0.8	11.1	9.1
Construction	1982-86	0.8	-0.3	0.6	0.0	0.0	0.4	4.4	1.8	0.0	15.6	-0.7
	1986-90	2.2	-8.7	0.6	-0.7	-0.4	-1.1	1.8	-1.9	1.5	8.6	13.2
	1990-94	-4.1	2.0	0.6	-1.6	-0.9	0.7	0.0	0.0	-0.3	18.8	-5.2
	1994-97	-7.0	7.8	0.6	0.0	0.0	1.0	-2.5	-2.5	-0.6	20.3	-12.4
Wholesale	1982-86	2.1	1.3	0.6	-0.6	-0.4	0.4	4.8	2.1	-0.1	10.4	-0.9
and retail trade	1986-90	1.3	9.7	0.7	-0.8	-0.5	1.1	1.4	1.6	-0.8	11.9	-9.4
	1990-94	0.0	1.5	0.7	-2.1	-1.4	0.5	3.6	1.6	-0.1	12.2	-1.6
	1994-97	0.6	-2.4	0.7	-0.2	-0.1	0.1	0.9	0.1	0.1	25.4	3.0
Finance and insurance	1982-86	8.6	1.5	0.6	-0.1	0.0	-0.5	2.9	-1.3	0.8	9.9	8.5
	1986-90	7.6	1.4	0.6	-1.6	-1.0	0.0	7.0	0.0	0.4	17.5	7.2
	1990-94	-0.8	-1.7	0.6	-0.1	0.0	0.4	2.8	1.1	0.0	14.2	-0.1
	1994-97	2.6	-3.9	0.6	0.1	0.1	0.0	2.7	-0.1	0.4	16.4	6.5
Transportation	1982-86	5.5	0.8	0.7	0.5	0.3	0.0	28.6	-1.3	0.3	16.7	5.6
and communications	1986-90	0.9	-2.0	0.7	-0.4	-0.3	0.2	5.8	1.1	0.2	13.1	2.1
	1990-94	-1.7	-1.3	0.7	-1.2	-0.8	0.4	4.9	1.9	-0.1	21.1	-1.5
	1994-97	3.0	1.7	0.7	-0.9	-0.6	-0.3	5.5	-1.7	0.6	5.9	3.6
Electricity, gas,	1982-86	3.2	-2.8	0.3	0.5	0.1	0.7	7.3	5.0	0.0	19.9	0.9
and water supply	1986-90	3.2	0.0	0.3	-0.8	-0.2	0.6	1.9	1.2	0.1	20.4	2.3
	1990-94	0.7	-1.6	0.3	-1.5	-0.4	0.7	3.5	2.4	0.0	17.4	0.4
	1994-97	6.0	-2.0	0.3	-0.1	0.0	0.3	7.2	1.9	0.4	14.1	6.1

Table 2. Contribution of Each Input Factor to Value-added Productivity (based on Financial Statements Statistics of Corporations by sector)

		$G(Q/L_n)$	A	α	$G(L/L_n)$	$\alpha G(L/L_n)$	β	$G(K_o/L_n)$	$\beta G(K_o/L_n)$	γ	$G(K_I/L_n)$	$\gamma G(K_I/L_n)$
		(%)	(%)		(%)	(%)		(%)	(%)		(%)	(%)
Food products	1982-86	-0.1	-2.1	0.6	-0.3	-0.2	0.5	6.9	3.1	-0.1	14.6	-1.0
and beverages	1986-90	-0.1	0.1	0.6	-0.8	-0.5	0.4	1.0	0.4	0.0	12.5	-0.2
	1990-94	0.2	3.2	0.6	-2.0	-1.2	0.6	1.7	1.0	-0.2	16.7	-2.8
	1994-97	-0.1	-2.2	0.6	0.6	0.4	0.3	1.8	0.5	0.1	12.8	1.3
Textiles	1982-86	6.6	-0.8	0.7	0.4	0.3	-0.4	3.1	-1.4	0.7	11.7	8.5
	1986-90	2.7	0.3	0.7	-1.2	-0.8	0.0	2.6	0.1	0.3	11.2	3.2
	1990-94	2.8	-0.1	0.7	-1.4	-1.0	0.0	6.0	0.0	0.3	14.0	3.9
	1994-97	-1.1	-1.7	0.8	0.1	0.1	0.3	6.5	2.2	-0.1	20.7	-1.6
Pulp, paper	1982-86	0.6	-4.8	0.6	0.5	0.3	0.0	3.4	0.1	0.4	12.0	5.0
and paper products	1986-90	6.0	-0.2	0.6	-1.1	-0.6	0.1	4.1	0.6	0.3	20.4	6.2
	1990-94	-3.8	-2.5	0.6	-1.1	-0.6	0.9	4.6	4.0	-0.4	10.8	-4.7
	1994-97	4.6	-1.5	0.6	0.3	0.2	0.2	4.5	0.8	0.3	19.7	5.2
Chemicals	1982-86	8.3	-0.5	0.5	0.2	0.1	-0.1	4.4	-0.5	0.6	14.9	9.1
	1986-90	8.9	0.5	0.5	-0.5	-0.3	0.0	4.0	-0.1	0.5	16.5	8.7
	1990-94	3.0	-0.3	0.5	-1.0	-0.5	0.3	3.1	0.8	0.2	12.8	2.9
	1994-97	6.9	-1.6	0.5	0.0	0.0	0.1	4.2	0.3	0.4	19.0	8.2
Petroleum	1982-86	-17.3	18.9	0.3	-0.3	-0.1	9.3	6.5	60.4	-8.6	11.2	-96.6
and coal products	1986-90	7.9	-0.5	0.3	-0.1	0.0	0.5	5.9	2.7	0.2	26.2	5.8
	1990-94	-1.8	-0.5	0.3	-1.1	-0.4	1.0	3.9	3.8	-0.3	17.0	-4.8
	1994-97	-5.5	14.8	0.4	-0.2	-0.1	-1.8	5.3	-9.6	2.4	-4.4	-10.6
Non-metallic	1982-86	1.9	-6.1	0.6	0.2	0.1	-0.8	4.4	-3.5	1.2	9.4	11.3
mineral products	1986-90	6.5	0.5	0.6	-0.3	-0.2	0.1	2.8	0.3	0.3	17.5	5.9
	1990-94	1.3	-1.1	0.6	-1.6	-0.9	0.4	8.1	3.1	0.0	14.9	0.2
	1994-97	4.3	-3.3	0.6	0.2	0.1	0.1	4.5	0.3	0.3	21.3	7.1
Basic materials	1982-86	2.4	-0.8	0.6	0.2	0.1	0.2	3.9	0.9	0.2	13.8	2.2
and fabricated	1986-90	5.4	-0.1	0.6	0.3	0.2	0.1	4.0	0.2	0.4	13.0	5.1
metal products	1990-94	0.1	-0.3	0.6	-2.2	-1.3	0.5	4.9	2.2	0.0	11.3	-0.5
	1994-97	4.1	-1.6	0.6	0.6	0.3	-0.1	4.4	-0.2	0.4	12.8	5.6
General machinery	1982-86	3.5	2.6	0.7	-0.2	-0.1	0.5	6.2	3.2	-0.2	13.2	-2.2
	1986-90	7.1	0.6	0.6	0.3	0.2	-0.2	3.6	-0.6	0.5	12.7	6.9
	1990-94	-5.3	-3.7	0.7	-2.3	-1.5	0.7	6.6	4.5	-0.3	13.6	-4.6
	1994-97	5.0	-2.7	0.7	1.2	0.8	-0.1	3.3	-0.2	0.4	18.5	7.0
Electrical machinery,	1982-86	8.0	-0.7	0.6	0.0	0.0	-0.1	5.6	-0.5	0.5	17.9	9.2
equipment and	1986-90	16.9	3.6	0.6	-0.1	-0.1	-0.7	6.3	-4.5	1.1	15.9	17.9
supplies	1990-94	5.6	0.7	0.6	-1.8	-1.1	-0.1	8.3	-1.0	0.5	14.1	7.0
	1994-97	18.5	-24.6	0.6	0.2	0.1	-8.3	6.1	-50.3	8.7	10.8	93.3
Transport equipment	1982-86	5.4	-1.4	0.6	0.1	0.1	0.1	7.0	0.4	0.4	17.0	6.3
	1986-90	6.5	-1.5	0.6	0.9	0.5	0.0	5.6	0.1	0.4	18.1	7.3
	1990-94	-3.6	-1.5	0.6	-2.8	-1.6	0.6	5.0	3.1	-0.2	17.3	-3.6
	1994-97	4.5	4.6	0.6	1.0	0.6	0.8	5.5	4.4	-0.4	12.7	-5.1
Precision instruments	1982-86	2.8	-2.4	0.6	0.1	0.1	0.2	10.1	2.3	0.1	19.2	2.7
	1986-90	9.2	2.1	0.6	0.1	0.0	-0.2	11.1	-2.6	0.6	15.8	9.7
	1990-94	-1.4	-3.7	0.6	-1.7	-1.1	0.4	10.1	3.7	0.0	15.2	-0.3
	1994-97	8.6	1.8	0.6	0.3	0.2	-0.6	7.0	-4.1	1.0	11.1	10.7
Construction	1982-86	-2.8	-0.4	0.7	0.0	0.0	0.6	4.4	2.6	-0.3	15.6	-5.0
	1986-90	6.4	-2.2	0.7	-0.7	-0.5	-0.9	1.8	-1.6	1.2	8.6	10.7
	1990-94	-2.4	1.7	0.7	-1.6	-1.1	0.5	0.0	0.0	-0.2	18.8	-3.0
	1994-97	-3.0	4.5	0.7	0.0	0.0	0.6	-2.5	-1.4	-0.3	20.3	-6.1
Wholesale	1982-86	3.6	0.1	0.7	-0.6	-0.4	-0.2	4.8	-0.8	0.5	10.4	4.8
and retail trade	1986-90	6.3	2.9	0.7	-0.8	-0.6	0.0	1.4	0.0	0.3	11.9	4.0
	1990-94	-0.7	1.7	0.7	-2.1	-1.5	0.5	3.6	1.9	-0.2	12.2	-2.8
	1994-97	1.7	-2.1	0.7	-0.2	-0.1	0.1	0.9	0.1	0.1	25.4	3.8
Finance and insurance	1982-86											
	1986-90											
	1990-94											
	1994-97											
Transportation	1982-86	4.7	-1.9	0.7	0.5	0.3	0.1	28.6	1.8	0.3	16.7	4.4
and communications	1986-90	5.4	4.1	0.6	-0.4	-0.2	0.5	5.8	2.8	-0.1	13.1	-1.2
	1990-94	-1.1	-1.4	0.6	-1.2	-0.7	0.4	4.9	2.2	-0.1	21.1	-1.2
	1994-97	1.8	0.2	0.6	-0.9	-0.5	0.3	5.5	1.6	0.1	5.9	0.6
Electricity, gas,	1982-86	3.0	-5.7	0.2	0.5	0.1	0.6	7.3	4.5	0.2	19.9	4.1
and water supply	1986-90	3.7	-1.3	0.2	-0.8	-0.1	0.6	1.9	1.2	0.2	20.4	3.8
	1990-94	0.2	-2.3	0.2	-1.5	-0.3	0.8	3.5	2.8	0.0	17.4	0.0
	1994-97	4.8	-3.4	0.2	-0.1	0.0	0.5	7.2	3.3	0.3	14.1	4.9

Table 3. Contribution of Each Input Factor to Value-added Productivity (based on Annual Report)

		$G(Q/L_n)$ (%)	A (%)	α	$G(L/L_n)$ (%)	$\alpha G(L/L_n)$ (%)	β	$G(K_o/L_n)$ (%)	$\beta G(K_o/L_n)$ (%)	γ	$G(K_I/L_n)$ (%)	$\gamma G(K_I/L_n)$ (%)
Food products	1982-86	-4.0	-2.8	0.5	-0.3	-0.1	0.8	4.5	3.6	-0.3	14.6	-4.6
and beverages	1986-90	3.8	-0.9	0.6	-0.8	-0.5	0.0	7.8	-0.2	0.4	12.5	5.3
	1990-94	1.9	-0.1	0.7	-2.0	-1.3	0.3	7.4	1.9	0.1	16.7	1.4
	1994-97	1.7	-0.5	0.7	0.6	0.5	0.1	0.3	0.0	0.1	12.8	1.7
Textiles	1982-86	3.7	-1.3	0.7	0.4	0.3	-0.2	5.5	-1.4	0.5	11.7	6.1
	1986-90	5.2	3.0	0.8	-1.2	-0.9	-0.2	6.1	-0.9	0.4	11.2	4.0
	1990-94	0.4	0.6	0.9	-1.4	-1.2	0.1	4.2	0.3	0.0	14.0	0.6
	1994-97	7.3	0.4	1.1	0.1	0.1	-0.5	0.5	-0.2	0.3	20.7	7.0
Pulp, paper	1982-86	3.1	-3.2	0.5	0.5	0.3	-0.1	8.9	-0.6	0.6	12.0	6.6
and paper products	1986-90	2.8	-1.9	0.5	-1.1	-0.5	0.4	7.9	3.0	0.1	20.4	2.3
	1990-94	-3.7	-3.7	0.5	-1.1	-0.6	0.4	0.7	0.3	0.0	10.8	0.3
	1994-97	5.9	3.1	0.6	0.3	0.2	0.3	0.8	0.3	0.1	19.7	2.3
Chemicals	1982-86	8.2	-0.5	0.4	0.2	0.1	0.0	4.6	0.1	0.6	14.9	8.6
	1986-90	7.7	-0.3	0.4	-0.5	-0.2	0.1	4.4	0.6	0.5	16.5	7.7
	1990-94	3.9	-0.5	0.4	-1.0	-0.4	0.3	3.3	0.9	0.3	12.8	3.9
	1994-97	6.6	-1.3	0.5	0.0	0.0	0.1	0.5	0.1	0.4	19.0	7.9
Petroleum	1982-86	-16.4	28.9	0.2	-0.3	-0.1	8.1	4.5	36.4	-7.3	11.2	-81.6
and coal products	1986-90	9.1	0.7	0.2	-0.1	0.0	0.5	3.7	2.0	0.2	26.2	6.4
	1990-94	-3.9	-3.0	0.2	-1.1	-0.2	1.3	5.6	7.2	-0.5	17.0	-7.9
	1994-97	-1.7	124.3	0.2	-0.2	0.0	-12.8	5.2	-66.7	13.6	-4.4	-59.3
Non-metallic	1982-86	2.9	-5.0	0.6	0.2	0.1	-0.6	3.1	-1.8	1.0	9.4	9.6
mineral products	1986-90	3.8	0.1	0.6	-0.3	-0.2	0.3	3.0	0.8	0.2	17.5	3.1
	1990-94	-2.4	-0.9	0.7	-1.6	-1.0	0.6	5.2	3.0	-0.2	14.9	-3.6
	1994-97	5.3	-0.4	0.7	0.2	0.1	0.0	0.5	0.0	0.3	21.3	5.6
Basic materials	1982-86	-0.4	-1.4	0.6	0.2	0.1	0.5	3.7	2.0	-0.1	13.8	-1.1
and fabricated	1986-90	11.8	1.8	0.5	0.3	0.2	-0.3	0.1	0.0	0.8	13.0	9.9
metal products	1990-94	-1.2	-0.9	0.5	-2.2	-1.2	0.6	4.6	3.0	-0.2	11.3	-2.0
	1994-97	7.3	-0.5	0.6	0.6	0.3	-0.2	2.3	-0.4	0.6	12.8	7.9
General machinery	1982-86	-2.0	3.8	0.6	-0.2	-0.1	1.7	6.5	10.7	-1.2	13.2	-16.4
	1986-90	6.6	-0.2	0.6	0.3	0.2	-0.2	5.5	-1.1	0.6	12.7	7.7
	1990-94	-2.3	-2.1	0.6	-2.3	-1.5	0.3	2.2	0.7	0.0	13.6	0.5
	1994-97	7.5	-8.2	0.7	1.2	0.9	-0.5	-2.4	1.1	0.7	18.5	13.7
Electrical machinery,	1982-86	2.2	-3.9	0.6	0.0	0.0	0.2	9.1	1.7	0.2	17.9	4.3
equipment and	1986-90	8.0	-0.1	0.6	-0.1	-0.1	-0.1	3.8	-0.4	0.5	15.9	8.6
supplies	1990-94	-2.3	-0.1	0.6	-1.8	-1.2	0.4	-1.2	-0.5	0.0	14.1	-0.6
	1994-97	6.1	-7.7	0.7	0.2	0.1	-1.5	3.9	-5.7	1.8	10.8	19.4
Transport equipment	1982-86	12.4	0.5	0.7	0.1	0.1	-0.5	4.8	-2.5	0.8	17.0	14.2
	1986-90	17.4	-0.1	0.7	0.9	0.6	-0.7	2.5	-1.8	1.0	18.1	18.7
	1990-94	5.1	1.6	0.7	-2.8	-1.9	0.0	1.8	0.0	0.3	17.3	5.5
	1994-97	19.0	-39.8	0.7	1.0	0.7	-4.2	-0.4	1.6	4.4	12.7	56.6
Precision instruments	1982-86	2.6	-0.7	0.7	0.1	0.1	0.2	4.7	0.8	0.1	19.2	2.4
	1986-90	8.3	0.1	0.7	0.1	0.0	-0.3	3.1	-0.8	0.6	15.8	9.0
	1990-94	-3.0	0.8	0.7	-1.7	-1.3	0.4	-1.3	-0.5	-0.1	15.2	-2.0
	1994-97	6.1	2.0	0.8	0.3	0.2	-0.1	-1.3	0.2	0.3	11.1	3.8
Construction	1982-86	4.0	-0.7	0.6	0.0	0.0	0.1	0.9	0.1	0.3	15.6	4.6
	1986-90	12.8	10.0	0.6	-0.7	-0.4	-0.4	10.1	-4.3	0.9	8.6	7.5
	1990-94	-1.0	-5.7	0.6	-1.6	-0.9	0.5	13.8	6.7	-0.1	18.8	-1.1
	1994-97	-1.9	2.0	0.6	0.0	0.0	0.5	-4.4	-2.1	-0.1	20.3	-1.9
Wholesale	1982-86	-0.3	1.0	0.6	-0.6	-0.4	0.6	3.1	2.0	-0.3	10.4	-2.9
and retail trade	1986-90	3.8	0.3	0.7	-0.8	-0.5	0.0	7.9	0.4	0.3	11.9	3.6
	1990-94	-3.8	-2.7	0.7	-2.1	-1.4	0.7	6.8	4.5	-0.3	12.2	-4.2
	1994-97	1.6	2.5	0.7	-0.2	-0.1	0.3	0.1	0.0	0.0	25.4	-0.8
Finance and insurance	1982-86											
	1986-90											
	1990-94											
	1994-97											
Transportation	1982-86	12.2	6.8	0.7	0.5	0.3	-0.5	16.4	-7.7	0.8	16.7	12.7
and communications	1986-90	4.6	4.5	0.7	-0.4	-0.3	0.3	-0.5	-0.1	0.0	13.1	0.5
	1990-94	1.1	0.0	0.7	-1.2	-0.8	0.3	3.6	1.0	0.0	21.1	0.9
	1994-97	6.0	7.5	0.7	-0.9	-0.6	-0.6	10.4	-6.3	0.9	5.9	5.4
Electricity, gas,	1982-86	8.1	-3.8	0.3	0.5	0.1	0.2	7.5	1.7	0.5	19.9	10.1
and water supply	1986-90	-1.8	-2.2	0.3	-0.8	-0.2	0.8	3.1	2.5	-0.1	20.4	-1.9
	1990-94	1.8	-2.3	0.3	-1.5	-0.4	0.6	4.0	2.3	0.1	17.4	2.2
	1994-97	3.2	-1.7	0.3	-0.1	0.0	0.4	2.2	0.9	0.3	14.1	4.0

The analysis based on the annual reports (Table 3) shows a rapid increase of Contribution of Information- and communication-related capital stock in Transportation Machinery in the 1994-97 period, conflicting with the results of other two analyses. This can be interpreted that the large-scale firms representing this sector influenced the result greatly, since the annual reports only include the listed companies. In addition, Finance/Insurance is included only in the SNA-based analysis.

In Tables 4~6, all the sectors are categorized roughly into Consumption-related Manufacturing, Material Manufacturing, Processing Manufacturing, and Non-manufacturing, and Contribution of Information- and communication-related capital stock to Value-added Productivity in each category is shown. Each table corresponds to three data sources used to calculate the values for Q, which are SNA, the Financial Statements Statistics of Corporations by sector, and the annual reports. The results for All Industries are also included in these tables. The values for this All Industries in Tables 6~8 show the great decrease of Contribution of Information- and communication-related capital stock to Value-added Productivity from the latter half of the 1980s to the first half of the 1990s, falling into negative figures in the analyses based on SNA and the Financial Statements Statistics of Corporations by Sector. Then after the middle of the 1990s, they show a recovery, with the above-mentioned negative figures turning positive again. This confirms the situation possibly called Paradox of Productivity in the first half of the 1990s, where Contribution of Information- and communication-related capital stock decreased greatly or even turned negative, but also acknowledges the situation recognized as New Economy Theory in the latter half of 90s, where Contribution of Information- and communication-related capital stock greatly improved, and/or turned to positive by the introduction of new information technologies. Besides, while this trend was quite outstanding in Processing Manufacturing, Contribution of Information- and communication-related capital stock in the sectors of Consumption-related Manufacturing and Non-manufacturing was still at the low level or even in the negative, though general improvement was seen, and the analysis of further movement was found to be necessary.

Also noted should be the large negative figure of Contribution of Information- and communication-related capital stock in the sector of Fossil Fuel Products in 1994-97, as well as that of

Capital Stock Other than Information- and communication-related capital stock in the same sector and period. The cause of this phenomenon is suspected to be the exposure of excessive capital due to the change of economic environment of this sector owing to the fluctuation of crude oil prices.

Table 4. Contribution of Each Input Factor to Value-added Productivity (based on SNA, Summary)

		$G(Q/L_n)$ (%)	A (%)	α	$G(L/L_n)$ (%)	$\alpha G(L/L_n)$ (%)	β	$G(K_o/L_n)$ (%)	$\beta G(K_o/L_n)$ (%)	γ	$G(K_l/L_n)$ (%)	$\gamma G(K_l/L_n)$ (%)
Manufacturing	1982-86	-1.4	-2.8	0.6	0.1	0.0	0.6	5.7	3.2	-0.1	13.4	-1.9
(Related to	1986-90	-2.8	0.8	0.6	-1.0	-0.6	0.7	2.0	1.4	-0.4	12.4	-4.4
consumption)	1990-94	-0.2	0.8	0.7	-1.8	-1.2	0.4	3.8	1.4	-0.1	16.5	-1.2
	1994-97	0.0	-0.7	0.8	0.3	0.3	0.3	3.9	1.0	0.0	15.9	-0.6
Manufacturing	1982-86	3.4	-1.1	0.5	0.2	0.1	0.3	4.0	1.0	0.3	13.3	3.4
(Related to raw	1986-90	3.8	-0.3	0.5	-0.1	0.0	0.3	3.6	1.1	0.2	14.4	3.0
materials)	1990-94	2.0	-0.5	0.5	-1.8	-0.9	0.4	4.9	1.8	0.1	12.2	1.6
	1994-97	3.3	-1.4	0.5	0.3	0.2	0.2	4.4	1.0	0.2	14.6	3.4
Manufacturing	1982-86	6.8	0.0	0.6	0.0	0.0	0.0	5.7	-0.1	0.4	16.7	7.0
(Related to machinery)	1986-90	7.2	0.1	0.6	0.2	0.1	-0.1	5.1	-0.3	0.5	15.8	7.3
	1990-94	1.8	-0.6	0.7	-2.2	-1.4	0.2	7.0	1.3	0.2	14.8	2.4
	1994-97	8.2	-2.2	0.7	0.6	0.5	-0.8	5.1	-4.0	1.1	12.8	14.0
Non-manufacturing	1982-86	3.1	-0.9	0.6	-0.2	-0.1	0.1	8.7	1.3	0.2	12.1	2.8
	1986-90	2.2	7.3	0.6	-0.8	-0.5	0.9	2.2	2.0	-0.5	13.0	-6.7
	1990-94	-1.2	-0.2	0.6	-1.5	-0.9	0.5	3.3	1.7	-0.1	14.1	-1.8
	1994-97	-0.4	-0.9	0.7	-0.2	-0.1	0.4	2.8	1.0	0.0	17.9	-0.4
Industries covered	1982-86	3.4	-0.8	0.6	-0.1	-0.1	0.2	6.6	1.1	0.2	13.0	3.2
	1986-90	2.9	2.2	0.6	-0.6	-0.3	0.4	2.5	1.0	0.0	13.6	0.0
	1990-94	-0.3	-0.4	0.6	-1.7	-1.0	0.4	3.9	1.7	0.0	14.2	-0.6
	1994-97	1.7	-1.2	0.6	0.0	0.0	0.2	3.4	0.7	0.1	16.7	2.2

Table 5. Contribution of Each Input Factor to Value-added Productivity (based on Financial Statements Statistics of Corporations by Sector, Summary)

		$G(Q/L_n)$ (%)	A (%)	α	$G(L/L_n)$ (%)	$\alpha G(L/L_n)$ (%)	β	$G(K_o/L_n)$ (%)	$\beta G(K_o/L_n)$ (%)	γ	$G(K_l/L_n)$ (%)	$\gamma G(K_l/L_n)$ (%)
Manufacturing	1982-86	3.2	0.2	0.7	0.1	0.1	0.2	5.7	1.2	0.1	13.4	1.8
(Related to	1986-90	1.3	0.1	0.6	-1.0	-0.6	0.3	2.0	0.5	0.1	12.4	1.3
consumption)	1990-94	1.2	0.5	0.7	-1.8	-1.1	0.3	3.8	1.2	0.0	16.5	0.7
	1994-97	-0.4	-1.4	0.7	0.3	0.2	0.4	3.9	1.5	0.0	14.6	-0.6
Manufacturing	1982-86	2.2	-0.8	0.6	0.2	0.1	0.3	4.0	1.3	0.1	13.3	1.6
(Related to raw	1986-90	6.6	1.4	0.5	-0.1	0.0	0.1	3.6	0.5	0.3	14.4	4.7
materials)	1990-94	0.7	-0.7	0.6	-1.8	-1.0	0.4	4.9	2.1	0.0	12.2	0.3
	1994-97	4.9	-0.3	0.6	0.3	0.2	0.1	4.4	0.5	0.3	13.9	4.4
Manufacturing	1982-86	4.8	-0.5	0.6	0.0	0.0	0.1	5.7	0.7	0.3	16.7	4.6
(Related to machinery)	1986-90	11.0	1.7	0.6	0.2	0.1	-0.3	5.1	-1.3	0.7	15.8	10.4
	1990-94	0.5	-1.3	0.6	-2.2	-1.3	0.3	7.0	2.2	0.1	14.8	1.0
	1994-97	12.8	-3.4	0.6	0.6	0.4	-1.5	5.1	-7.8	1.9	12.3	23.5
Non-manufacturing	1982-86	2.2	-1.1	0.7	-0.2	-0.1	0.2	9.0	1.7	0.1	12.7	1.8
	1986-90	5.7	7.0	0.6	-0.7	-0.5	0.5	2.1	1.1	-0.2	12.1	-2.0
	1990-94	-1.4	0.3	0.6	-1.7	-1.1	0.5	3.4	1.7	-0.2	14.6	-2.3
	1994-97	0.9	-0.1	0.7	-0.2	-0.1	0.3	2.9	0.9	0.0	18.2	0.2
Industries covered	1982-86	2.6	-0.9	0.6	-0.1	-0.1	0.2	6.7	1.4	0.2	13.6	2.2
	1986-90	6.2	1.2	0.6	-0.5	-0.3	0.0	2.4	-0.1	0.4	13.1	5.4
	1990-94	-0.7	-0.4	0.6	-1.8	-1.1	0.4	3.9	1.7	-0.1	14.3	-1.0
	1994-97	3.7	-0.8	0.6	0.0	0.0	0.1	3.4	0.3	0.3	16.2	4.1

Table 6. Contribution of Each Input Factor to Value-added Productivity (based on Annual Report, Summary)

		$G(Q/L_n)$ (%)	A (%)	α	$G(L/L_n)$ (%)	$\alpha G(L/L_n)$ (%)	β	$G(K_o/L_n)$ (%)	$\beta G(K_o/L_n)$ (%)	γ	$G(K_I/L_n)$ (%)	$\gamma G(K_I/L_n)$ (%)
Manufacturing	1982-86	0.0	-2.1	0.6	0.1	0.0	0.4	4.7	2.0	0.0	13.4	0.1
(Related to	1986-90	4.2	0.6	0.6	-1.0	-0.6	0.0	5.1	0.1	0.3	12.4	4.2
consumption)	1990-94	1.5	0.4	0.7	-1.8	-1.2	0.2	4.1	0.9	0.1	16.5	1.5
	1994-97	3.9	0.0	0.8	0.3	0.3	0.0	4.2	-0.1	0.2	15.9	3.7
Manufacturing	1982-86	1.9	-1.9	0.5	0.2	0.1	0.4	5.1	1.9	0.1	13.3	1.8
(Related to raw	1986-90	8.6	1.1	0.5	-0.1	0.0	0.0	5.5	0.0	0.5	14.4	7.6
materials)	1990-94	0.6	-0.3	0.5	-1.8	-0.9	0.5	3.2	1.5	0.0	12.2	0.3
	1994-97	6.4	-0.9	0.5	0.3	0.2	0.0	6.7	-0.2	0.5	14.6	7.3
Manufacturing	1982-86	4.3	-1.0	0.6	0.0	0.0	0.1	5.3	0.6	0.3	16.7	4.8
(Related to machinery)	1986-90	11.0	1.8	0.6	0.2	0.1	-0.3	7.4	-2.5	0.7	15.8	11.5
	1990-94	0.6	-1.0	0.7	-2.2	-1.4	0.2	5.2	1.2	0.1	14.8	1.8
	1994-97	12.3	-7.8	0.7	0.6	0.5	-2.3	5.9	-13.7	2.6	12.8	33.4
Non-manufacturing	1982-86	4.5	-0.2	0.6	-0.4	-0.2	0.0	1.6	0.0	0.4	12.7	5.0
	1986-90	3.3	-3.4	0.6	-0.4	-0.2	-0.3	6.0	-1.9	0.7	12.1	8.8
	1990-94	0.0	-1.2	0.6	-1.5	-0.9	0.4	5.2	1.9	0.0	14.6	0.3
	1994-97	2.5	-2.1	0.7	0.1	0.0	0.1	0.2	0.0	0.2	19.3	4.5
Industries covered	1982-86	3.9	-0.2	0.6	-0.2	-0.1	0.1	4.0	0.6	0.3	13.6	3.6
	1986-90	6.7	-0.4	0.6	-0.4	-0.2	-0.2	5.8	-1.4	0.7	13.1	8.7
	1990-94	0.4	-0.9	0.6	-1.8	-1.1	0.3	4.6	1.5	0.1	14.3	0.8
	1994-97	6.9	-2.2	0.7	0.2	0.1	-0.2	3.6	-0.8	0.6	17.1	9.7

3. Analysis of Information- and communication- capital stock by DEA (Data Envelopment Analysis)

DEA is the non-parametric mathematical programming approach to estimate efficiency frontier. In this section, the efficiency value and the excess stock of Information- and communication-capital stock for each industry measured by DEA are examined.

3.1 CCR (Charnes-Cooper-Rhodes) Model

In DEA, each item to be analyzed is called DMU (Decision Making Unit). In DEA, an appropriate weight to input and output for a particular DMU is calculated, and then the efficiency is indicated with the value of output/input (D Efficiency Value). Weights are calculated to maximize D Efficiency Value of the particular DMU under the certain constraints. In this paper, CCR Model, the most standard model of DEA, is adopted. The premise of CCR Model is that its economy of scale is constant. When formulated with the number of DMU as *n*, the numbers of input factors and output factors as *m* and *s* respectively, CCR Model becomes a fractional programming problem. In DEA, this

fractional programming problem is normally converted into a linear programming problem, and then its dual function is solved. This dual problem can be written as follows with θ_0 as real number, λ as variable, *X* and *Y* as matrix for input and output factors respectively for all DMU, x_0 y_0 as input and output vectors for each DMU_0 (DMU for which the efficiency value is to be determined):

$$\begin{aligned} \min \quad & \theta_o \\ st. \quad & \theta_o \mathbf{x}_o - \mathbf{X}\lambda \geq \mathbf{0} \\ & \mathbf{y}_o - \mathbf{Y}\lambda \leq \mathbf{0} \\ & \lambda \geq \mathbf{0} \end{aligned} \qquad (11)$$

In general, it is solved as below, taking the existence of possible slack into consideration:

$$\begin{aligned} \max \quad & w = \mathbf{es}_x + \mathbf{es}_y \\ st. \quad & \mathbf{s}_x = \theta^* \mathbf{x}_o - \mathbf{X}\lambda \\ & \mathbf{s}_y = \mathbf{Y}\lambda - \mathbf{y}_o \\ & \lambda \geq \mathbf{0}, \mathbf{s}_x \geq \mathbf{0}, \mathbf{s}_y \geq \mathbf{0} \end{aligned} \qquad (12)$$

where *e* means a row vector, all of which components are 1, *sx* and *sy* are input and output slacks respectively. Slacks is described in detail later.

3.2 Input Factors and Output Factor

Since DEA is the methodology to measure the efficiency with output against input, the selection of these factors are very significant. In this paper, *Lt*, Annual Working Hours per person, to represent Labor, and *KI*, Amount of Information- and communication- capital stock per person, and *Ko*, Amount of Capital Stock Other Than Information- and communication- capital stock per person, both to represent Capital, are used as input factors. And *Q*, amount of Value-added per person, is used as output factor.

3.3 Time-series Analysis for Each Industry

In this section, each industry is analyzed in time series for 1982- 97. Three kinds of data calculated from SNA, the Financial Statements Statistics of Corporations by Industry, and the annual reports respectively are applied to *Q* (Amount of Value-added per person) used in the analysis, so as to eliminate the errors and peculiarities of each data source and to make possible the more detached examination of the results, as in the case of the Analysis by Growth Accounting.

The results are shown in Tables 7~9. The colored cells show the years when the pertinent industries are considered efficient (in other words, D Efficiency Value =1). In 1982, as many industries as 14 in SNA-based data and 12 in the Financial Statements Statistics of Corporations by Industry and the annual reports data, were considered efficient. Then, toward the strong yen recession in 1986, the number of inefficient industries increased, but in 1988 and 1989, in the midst of the bubble economy, the number of efficient industries increased again, indicating that each input factor was made the best use of and effectively produced the values-added. Then, 1990 marked the change into the rapid decrease of the industries considered efficient, due to the impact of the collapse of the bubble economy, and in 1993, the number of industries considered efficient reached the lowest of 1 in SNA-based and the Financial Statements Statistics of Corporations -based analyses, and 0 in the annual report-based analysis. Since 1995, the number of industries considered efficient turned to increase, and in 1997, it reached ten by SNA-based analysis, six by the Financial Statements Statistics of Corporations -based analysis and ten by the annual report-based analysis, with Electric Machinery, Precision Machinery, and Chemical Products as their core, though the rest varies by data sources. This suggests the improvement in business in many industries owing to the progress of corporate restructuring and the temporal improvement of macro economy during 1996~1997.

Table 7. Time-series Change in D Efficiency Values for Each Industry (based on SNA)

	fiscal year															
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Food	1	1	0.96	0.96	0.91	0.87	0.88	0.78	0.80	0.85	0.88	0.81	0.80	0.79	0.77	0.76
Textile	1	1	0.92	0.95	0.93	0.96	0.86	0.78	0.84	0.84	0.93	0.95	0.89	0.86	0.75	0.79
Pulp and paper	1	1	0.99	0.93	0.89	0.92	1	1	1	0.97	1	0.99	0.95	0.99	0.98	1
Chemical	1	1	1	1	1	0.99	0.99	1	0.99	0.98	1	0.99	1	0.98	1	1
Oil & Gas	1	0.98	1	0.96	0.85	1	0.78	0.75	0.76	0.91	0.97	0.86	0.84	0.75	0.89	1
Non metallic	1	1	1	1	0.94	0.95	0.99	0.94	0.94	0.90	0.99	0.93	0.99	1	1	0.95
Iron & steel	1	0.95	1	1	0.94	0.97	1	0.98	0.99	0.98	1	0.98	1	0.99	1	1
General machinery	1	0.98	0.98	1	0.93	0.90	0.99	0.98	1	1	0.99	0.91	0.90	0.94	0.97	0.94
Electrical machinery	0.96	0.98	1	1	0.97	0.94	0.98	1	0.99	0.99	0.88	0.83	0.87	0.91	1	1
Transportation equipment	1	0.99	1	0.99	0.99	1	0.98	1	1	1	1	1	0.99	1	0.99	0.94
Precision instrument	1	0.99	0.98	1	0.92	0.89	0.95	1	0.99	1	0.98	0.89	0.86	0.90	0.95	1
Construction	1	0.92	0.89	0.93	0.91	0.98	1	0.94	0.95	0.92	0.95	0.90	0.85	0.80	0.75	0.69
Trade	1	1	0.97	1	0.96	0.98	1	0.95	0.99	0.99	1	0.97	0.98	0.97	0.96	1
Finance and insurance	0.95	0.99	1	0.99	1	1	1	1	1	0.97	0.90	0.92	0.95	0.94	0.95	1
Transportation and communication	1	1	1	1	0.99	0.94	0.99	0.98	1	0.96	0.95	0.93	0.93	0.95	0.99	1
Electricity,gas,and water supply	1	1	1	0.97	0.92	0.92	0.99	0.95	0.98	1	0.97	0.95	0.94	0.96	1	1
Total	1	1	1	1	0.98	0.98	1	0.99	1	0.99	1	0.98	0.98	0.99	1	1
Manufacturing （consumption）	1	1	0.93	0.95	0.91	0.90	0.87	0.80	0.84	0.89	0.94	0.91	0.89	0.91	0.87	0.88
Manufacturing （material）	1	0.97	1	1	0.96	0.98	1	1	1	0.99	1	0.98	1.00	0.98	1	1
Manufacturing （machinery）	1	0.99	1	1	0.97	0.94	0.98	1	1	1	0.96	0.91	0.93	0.95	1	1
Non Manufacturing	1	1	1	1	0.98	0.98	1	0.97	1	0.98	1	0.98	0.98	0.96	0.96	0.97

Table 8. Time-series Change in D Efficiency Values for Each Industry (based on Financial Statements Statistics of Corporations by Industry)

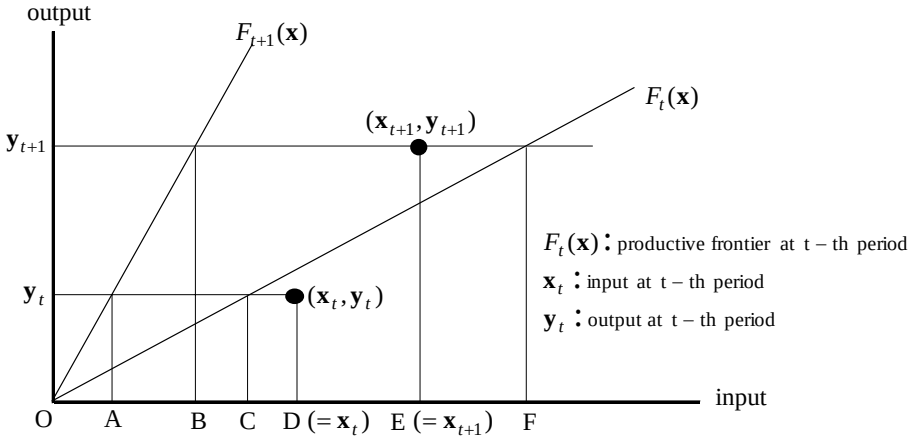
	fiscal year															
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Food	1	1	0.93	0.97	0.91	0.89	0.93	0.93	0.97	1	1	0.95	0.99	0.95	1	0.94
Textile	0.93	1	0.98	1	0.98	0.95	0.97	1	1	0.89	0.99	0.92	1	1	0.98	0.96
Pulp and paper	1	0.97	1	0.96	0.87	0.90	0.95	0.94	1	0.91	0.96	0.92	0.91	0.92	1	0.99
Chemical	0.99	1	1	1	0.92	0.95	1	1	1	0.99	1	1	0.99	0.97	1	1
Oil & Gas	1	0.67	0.71	0.45	0.42	0.56	0.59	0.53	0.56	0.55	0.59	0.57	0.54	0.50	0.52	0.44
Non metalic	0.98	1	1	1	0.87	0.99	0.99	1	0.95	0.93	0.95	0.94	0.99	0.94	0.95	1
Iron & steel	1	1	1	0.96	0.90	0.95	0.98	1	1	1	0.94	0.89	0.98	0.97	0.98	1
General machinery	1	0.95	0.96	0.98	0.95	0.91	0.98	0.97	1	1	0.93	0.88	0.87	0.88	0.96	0.98
Electrical machinery	1	0.97	1	0.98	0.85	0.89	0.90	1	0.99	0.91	0.80	0.74	0.80	0.84	0.98	1
Transportation equipment	1	1	0.96	1	1.00	0.93	0.96	0.99	1	0.99	0.99	0.93	0.91	0.94	1	0.96
Precision instrument	1	1	1	0.98	0.83	0.88	0.92	0.94	1	0.98	0.89	0.86	0.88	0.92	0.99	1
Construction	1	0.93	0.91	0.88	0.88	0.88	0.96	1	0.99	1	1	0.97	0.93	0.92	0.96	0.91
Trade	1	0.98	0.96	0.95	0.96	0.99	1	1	1	0.97	1	0.97	1	1	0.98	0.99
Finance and insurance																
Transportation and communication	1	1	0.99	1	0.94	0.89	0.94	1	1	1	0.98	0.96	0.93	0.99	1	0.97
Electricity,gas,and water supply	1	1	0.96	1	0.99	0.91	0.95	0.97	1	1	0.97	0.95	0.96	0.97	0.99	1
Total	1	0.99	0.97	0.98	0.95	0.94	0.97	1	1	0.99	1	0.97	0.99	0.98	1	1
Manufacturing （consumption）	1	1	0.94	1	0.96	0.94	0.96	0.98	1	0.96	1	0.96	1	0.99	1	0.96
Manufacturing （material）	1	0.99	1	0.96	0.89	0.95	0.98	1	1	0.98	0.96	0.94	0.97	0.95	0.99	1
Manufacturing （machinery）	1	0.97	0.96	0.99	0.92	0.90	0.93	0.99	1	0.96	0.89	0.84	0.85	0.90	0.99	1
Non Manufacturing	1	0.98	0.95	0.96	0.95	0.95	0.98	1	1	0.99	1	0.98	0.99	1	1	0.99

Table 9. Time-series Change in D Efficiency Values for Each Industry (based on Annual Reports)

	fiscal year															
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Food	1	0.99	0.99	0.85	0.83	0.80	0.84	0.89	0.95	0.98	0.99	0.98	1	0.99	1	1
Textile	0.98	1	1	1	0.93	0.99	0.97	0.95	1	0.96	0.94	0.91	0.95	0.99	1	1
Pulp and paper	1	1	1	0.95	0.93	0.94	1	1	0.99	0.91	0.89	0.81	0.87	1	0.92	0.98
Chemical	1	0.99	1	1	0.96	0.97	1	0.99	1	0.98	1	0.98	1	0.96	1	1
Oil & Gas	1	0.73	0.73	0.53	0.47	0.64	0.64	0.62	0.65	0.60	0.65	0.64	0.58	0.46	0.55	0.53
Non metallic	0.98	1	1	1	0.91	0.96	1	1	0.99	0.97	0.92	0.88	0.91	0.94	1	1
Iron & steel	1	0.97	1	0.91	0.78	0.93	0.99	1	1	0.94	0.86	0.80	0.91	0.94	0.97	1
General machinery	1	1	0.99	0.95	0.85	0.84	0.96	1	0.99	0.91	0.83	0.83	0.91	0.98	0.99	1
Electrical machinery	1	1	1	0.94	0.83	0.86	0.96	1	0.98	0.92	0.83	0.81	0.90	1	1	1
Transportation equipment	0.99	0.98	0.93	1	0.90	0.86	0.93	1	1	0.99	0.90	0.80	0.78	0.76	0.93	1
Precision instrument	1	1	1	0.94	0.88	0.97	0.99	0.99	1	0.95	0.88	0.88	0.88	0.97	1	0.99
Construction	1	1	0.93	0.87	0.89	0.95	0.94	1	1	1	1	0.98	0.93	0.87	0.90	0.88
Trade	1	0.99	1	0.99	0.94	0.96	1	1	1	1	0.95	0.91	0.92	0.93	0.98	0.97
Finance and insurance																
Transportation and communication	1	0.94	1	1	0.99	0.98	0.95	1	0.99	1	1	0.99	0.96	0.99	0.99	1
Electricity,gas,and water supply	1	1	0.96	1	1	0.93	0.92	0.91	0.92	0.93	0.92	0.93	0.97	0.93	0.94	1
Total	1	1	1	0.98	0.94	0.94	0.98	1	1	0.99	0.94	0.91	0.93	0.94	0.98	1
Manufacturing （consumption）	1	1	1	0.94	0.90	0.91	0.92	0.95	1	0.99	0.98	0.97	0.99	1	1	1
Manufacturing （material）	1	0.97	1	0.95	0.87	0.95	1	1	1	0.96	0.93	0.90	0.95	0.95	0.99	1
Manufacturing （machinery）	1	1	1	0.97	0.87	0.87	0.96	1	0.99	0.95	0.86	0.80	0.84	0.88	0.97	1
Non Manufacturing	1	1	1	0.98	0.99	0.97	0.98	1	1	1	0.98	0.97	0.97	0.97	0.98	1

Table 10 shows the change in Malmquist Productivity Index for Process Manufacturing, which are General Machinery, Electric Machinery, Transport Machinery, and Precision Machinery, using DEA. By using Malmquist Productivity Index, the time-series changes in four industries in Process Manufacturing area can be divided into the effect of the shift in Production Frontier and that of the change in Technological Efficiency.

Fig.2 Productivity Index



$$\text{Malmquist productivity indexes} = \left(\frac{OB/OE}{OC/OD}\right) \cdot \left\{\left(\frac{OF/OE}{OB/OE}\right) \cdot \left(\frac{OC/OD}{OA/OD}\right)\right\}^{\frac{1}{2}}$$

As shown in Table 10, Productivity decreased in the first half of the 1990s compared to the latter half of the 1980s, but in the middle of the 1990s, the slight improvement was seen. It is perceived that the cause for the decrease of productivity was the technical change, the shift in Production Frontier in other words, until 1993, and then the efficiency change, which is the decrease in Technological Efficiency, after 1994.

Table 10. Change in Productivity Index

	data source								
	SNA						Annual Report		
	efficiency change	Technical change	Malmquist indexes	efficiency change	Technical change	Malmquist indexes	efficiency change	Technical change	Malmquist indexes
1982～83	1.031	0.968	0.998	0.980	1.016	0.995	1.040	0.930	0.967
1983～84	0.992	1.007	0.999	1.046	0.983	1.028	1.031	0.908	0.936
1984～85	0.982	1.026	1.008	1.029	0.988	1.016	1.046	0.881	0.922
1985～86	1.001	0.913	0.914	1.018	0.883	0.899	0.995	0.866	0.862
1986～87	0.990	0.965	0.955	1.000	0.979	0.979	1.033	0.991	1.024
1987～88	0.967	1.087	1.051	0.996	1.053	1.048	1.001	1.124	1.125
1988～89	1.014	1.000	1.014	0.985	1.056	1.040	1.016	1.059	1.076
1989～90	0.979	1.020	0.998	0.995	1.026	1.021	1.049	0.950	0.997
1990～91	0.993	0.996	0.989	1.001	0.926	0.927	1.011	0.907	0.917
1991～92	1.006	0.924	0.930	0.992	0.876	0.869	0.956	0.917	0.877
1992～93	1.025	0.913	0.936	1.015	0.869	0.882	1.014	0.950	0.963
1993～94	0.978	1.014	0.992	0.930	1.038	0.966	1.002	1.060	1.062
1994～95	0.973	1.002	0.975	0.922	1.013	0.934	0.971	1.077	1.046
1995～96	0.931	1.054	0.981	0.852	1.187	1.011	0.815	1.241	1.012
1996～97	0.938	1.049	0.984	0.935	1.073	1.003	0.935	1.081	1.011

3.4 Analysis of Slack and Substitution Rate

Table 10 suggests the cause for the decrease of productivity to be the decrease in Technological Efficiency. In order to see specifically which input factor is relatively excessive, the slack for each input factor can be used as reference. Figure 3 shows the image of slack with 2 input and 1 output factors. In DEA, Efficiency Value θ means that if output amount is kept constant and input factors are uniformly reduced by θ times, the corresponding DMU is efficient (θ =1). In Figure 3, θ value of DMU A is OP/OA, and A becomes efficient (θ =1) by reducing Input 1 and Input 2 by θ times each and by moving to Point P. Meanwhile, θ value of DMU A' is OP'/OA', and by reducing Input 1 and Input 2 by θ times as in the case of A, A' moves to P' and its θ becomes 1. However, in this case, Input 2 for DMU B is less than P', so the reduction of P'B from Input 2 is

necessary for A' to be really efficient. This P'B, the amount to be reduced, is called Slack. Slack is not the kind of value to be reduced in the same ratio as in the other factors, so it is considered to imply "excess" more strongly than the reduced amount indicated by Efficiency Value θ .

In this section, the change of Slack is examined for General Machinery, Electric Machinery, and Transport Machinery in Process Manufacturing area (Table 11~13, Fig.4~5) for which the Change in Productivity Index (Table 10) shows the decrease of Technological Efficiency since 1994. In addition, it is examined for Finance/Insurance (Table 14, Fig.6), too, where, unlike Manufacturing and the other equipment industries, the substitution rate is small between Labor and Capital Stock Other Than Information- and Communication- Capital Stock, and the scale of IT Investment is considered large. *Q* is analyzed separately with the data calculated from the different data sources: SNA, the Financial Statements Statistics of Corporations by Industry, and the annual reports. However, Finance/Insurance is not analyzed with the latter two data sources. Tables 11~13 and Fig.4~5 indicate that in Manufacturing area, Slack existed mostly in Other Capitals, and then in Information- and Communication- Capital Stock, after 1994 for which period the decrease in Technological Efficiency was the cause of productivity decrease. Meanwhile, in Finance/Insurance, Table 14 indicates that Slack existed in Labor Input during 1982-1985, after which period it disappeared. And since 1991, Slack was seen increasing in Other Capital and Information- and Communication- Capital Stock, especially in the latter. It is inferred from these results that, given the four-year redemption of Information- and Communication- Capital Stock adopted in this analysis, the investment during the bubble economy weighed heavily on the business as the excessive equipment after its collapse, and especially Other Capital, whose redemption period is longer than Information- and Communication- Capital Stock, contributed to the decrease of Technological Efficiency since 1994. Meanwhile, in Finance/Insurance in which Other Capital Investment is much less compared to IT Investment, Labor was relatively excessive before 1985, and IT Investment was aggressively pursued in order to replace Labor, resulting in the excess of Information- and Communication- Capital Stock which was not well utilized after 1991, with such an additional factor as the curtailment of business scale, forced by the environmental change as the collapse of the bubble economy.

Fig. 3 Image of Slack

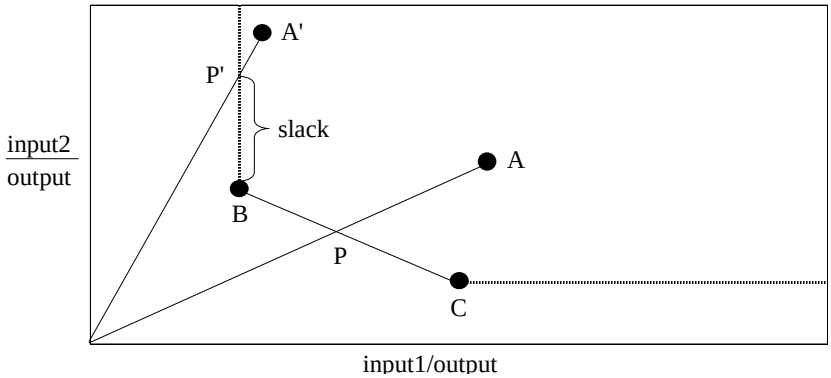


Table 11. Change of Slack (based on SNA)

	General machinery				Electrical machinery				Transportation equipment				Precision instrument			
		slack				slack				slack				slack		
	D	K_O	K_I	L	D	K_O	K_I	L	D	K_O	K_I	L	D	K_O	K_I	L
1982	1	0	0	0	0.96	1.17	0	0.42	1	0	0	0	1	0	0	0
1983	0.98	0.21	0	0	0.98	0.65	0	0.23	0.99	0	0.01	0	0.99	0	0.02	0
1984	0.98	0	0	0.11	1	0	0	0	1	0	0	0	0.98	0.08	0	0
1985	1	0	0	0	1	0	0	0	0.99	0	0	0	1	0	0	0
1986	0.93	0.13	0	0	0.97	0.13	0	0	0.99	0.44	0	0	0.92	0	0.02	0
1987	0.90	0	0.02	0	0.94	0	0	0.12	1	0	0	0	0.89	0.18	0	0
1988	0.99	0.30	0	0	0.98	0	0	0.06	0.98	0	0	0	0.95	0	0	0
1989	0.98	0	0.03	0	1	0	0	0	1	0	0	0	1	0	0	0
1990	1	0	0	0	0.99	0	0	0	1	0	0	0	0.99	0.02	0	0
1991	1	0	0	0	0.99	0.37	0	0	1	0	0	0	1	0	0	0
1992	0.99	2.63	0.18	0	0.88	0.48	0	0	1	0	0	0	0.98	0.84	0	0
1993	0.91	4.18	0.30	0	0.83	0.33	0	0	1	0	0	0	0.89	0.20	0	0
1994	0.90	5.00	0.36	0	0.87	0.40	0	0	0.99	0.70	0	0	0.86	0.60	0	0
1995	0.94	5.32	0.65	0	0.91	0	0.03	0.16	1	0	0	0	0.90	0	0.04	0
1996	0.97	6.48	1.03	0	1	0	0	0	0.99	1.96	0.14	0	0.95	0	0.09	0
1997	0.94	6.85	1.04	0	1	0	0	0	0.94	3.70	0.15	0	1	0	0	0

Table 12. Change of Slack (based on Financial Statements Statistics of Corporations by Industry)

	General machinery				Electrical machinery				Transportation equipment				Precision instrument			
		slack				slack				slack				slack		
	D	K^O	K^I	L	D	K^O	K^I	L	D	K^O	K^I	L	D	K^O	K^I	L
1982	1.00	0.00	0.00	0.00	1.00	0	0	0	1	0	0	0	1	0	0	0
1983	0.95	0.50	0	0	0.98	0	0	0.02	1	0	0	0	1	0	0	0
1984	0.96	0.32	0	0	0.99	0	0	0.04	0.96	0.49	0	0	1	0	0	0
1985	0.98	1.19	0	0	0.98	0.10	0	0	1	0	0	0	0.97	0.04	0	0
1986	0.96	1.22	0	0	0.86	0.25	0	0	1	1.18	0	0	0.84	0	0.01	0
1987	0.92	0.72	0	0	0.90	0	0	0.11	0.93	1.25	0	0	0.88	0.24	0	0
1988	0.98	1.15	0	0	0.90	0	0	0.05	0.95	0.50	0	0	0.93	0.05	0	0
1989	0.97	0.21	0	0	1	0	0	0	0.99	0	0.02	0	0.93	0.09	0	0
1990	1	0	0	0	1	0.22	0	0	1	0	0	0	1	0	0	0
1991	1	0	0	0	0.91	0.56	0	0	1	1.46	0	0	0.98	0.19	0	0
1992	0.93	2.49	0.17	0	0.81	0.58	0	0	1	2.12	0	0	0.89	0.90	0	0
1993	0.90	4.11	0.30	0	0.75	0.40	0	0	0.93	2.18	0	0	0.88	0.29	0	0
1994	0.89	4.92	0.36	0	0.80	0.46	0	0	0.92	1.85	0	0	0.89	0.70	0	0
1995	0.90	5.10	0.63	0	0.86	0	0.12	0.24	0.95	0	0.08	0	0.93	0	0.03	0
1996	0.98	6.52	1.04	0	0.97	0	0.11	0.11	1	0	0	0	0.99	0	0.09	0
1997	0.99	7.21	1.09	0	1	0	0	0	0.97	1.90	0.02	0	1	0	0	0

Table.13 Change of Slack (based on Annual Reports)

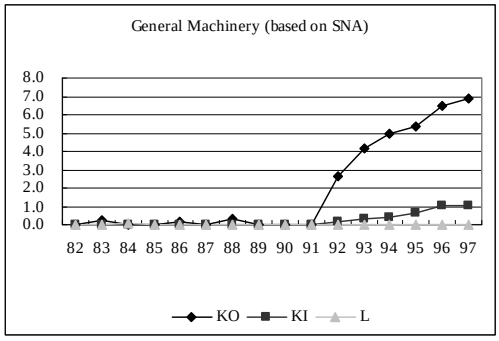
	General machinery				Electrical machinery				Transportation equipment				Precision instrument			
		slack				slack				slack				slack		
	D	K^O	K^I	L	D	K^O	K^I	L	D	K^O	K^I	L	D	K^O	K^I	L
1982	1	0	0	0	1	0	0	0	0.99	3.74	0	0.67	1	0	0	0
1983	1	0	0	0	0.99	0	0	0	0.98	2.37	0	0.50	1	0	0	0
1984	0.99	0	0	0	1	0	0	0	0.93	1.63	0	0.24	1	0	0	0
1985	0.95	0.76	0	0	0.94	0.18	0	0	1	0	0	0	0.94	0.04	0	0
1986	0.85	0.76	0	0	0.83	0.29	0	0	0.90	1.14	0	0	0.89	0	0.02	0
1987	0.84	0.38	0	0	0.87	0	0.04	0	0.86	1.32	0	0	0.91	0.25	0	0
1988	0.95	0.84	0	0	0.95	0	0.02	0	0.93	0.77	0	0	0.94	0.06	0	0
1989	1	0	0	0	1	0	0	0	1	0	0	0	0.98	0.09	0	0
1990	0.997	0.43	0	0	0.98	0.22	0	0	1	0	0	0	1	0	0	0
1991	0.91	1.03	0	0	0.92	0.56	0	0	0.99	1.28	0	0	0.95	0.34	0	0
1992	0.83	1.97	0	0	0.83	0.60	0	0	0.91	1.52	0	0	0.88	1.23	0	0
1993	0.83	2.59	0	0	0.81	0.43	0	0	0.80	1.29	0	0	0.88	0.81	0	0
1994	0.91	3.23	0	0	0.88	0.51	0	0	0.79	0.79	0	0	0.88	1.33	0	0
1995	0.97	1.42	0	0	0.97	0	0.23	0	0.80	0	0.04	0.16	0.97	0.46	0	0
1996	0.98	0	0.04	0	1	0	0.16	0	0.95	0	0.08	0.09	1	0	0	0
1997	1	0	0	0	1	0	0	0	1	0	0	0	0.99	1.97	0.06	0

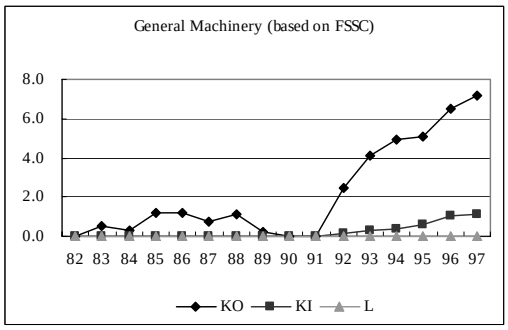
Table 14. Change of Slack for Finance/Insurance (based on SNA)

	Finance/Insurance			
		slack		
	D	K^o	K^I	L
1982	0.95	0.36	0.00	0.24
1983	0.99	0.27	0.00	0.09
1984	1.00	0.00	0.00	0.00
1985	0.99	0.00	0.00	0.09
1986	1.00	0.00	0.00	0.00
1987	1.00	0.00	0.00	0.00
1988	1.00	0.00	0.00	0.00
1989	1.00	0.00	0.00	0.00
1990	1.00	0.00	0.00	0.00
1991	0.97	0.08	0.00	0.00
1992	0.90	0.00	0.45	0.00
1993	0.92	0.23	0.00	0.00
1994	0.95	0.25	0.00	0.00
1995	0.94	0.00	2.05	0.00
1996	0.95	0.00	1.54	0.00
1997	1.00	0.00	0.00	0.00

Fig. 4　Change of Slack（General Machinery）

The upper left Figure is (Based on SNA). The upper right Figure is (Based on FSSC). And, the lower left Figure is (Based on Annual Reports).





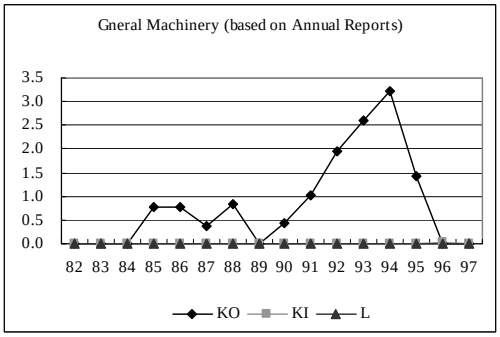
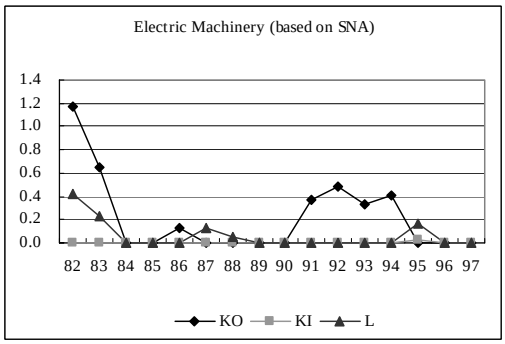
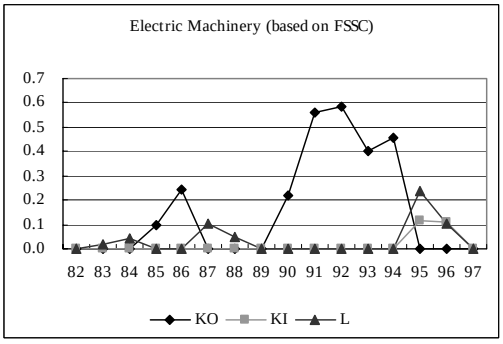


Fig. 5　Change of Slack（Electric Machinery）
The upper left Figure is (Based on SNA). The upper right Figure is (Based on FSSC). And, the lower left Figure is (Based on Annual Reports).





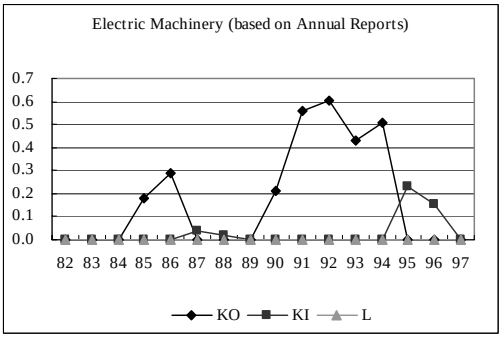
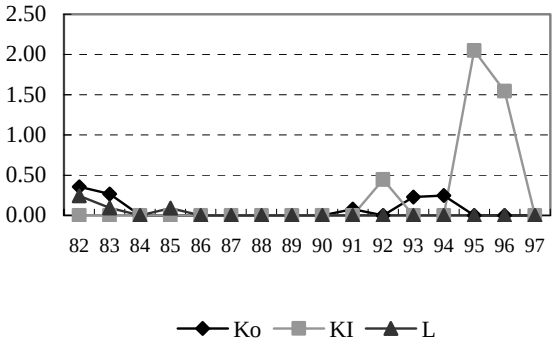


Fig. 6　Change of Slack（Finance/Insurance）
(Based on SNA)



4. Observations on Economic Impact of Introducing IT into Each Industry

The results of the analyses presented so far, namely Analysis on the Economic Impact of Information Equipment by Growth Accounting, Analysis of Information Equipment Stock by DEA (Data Envelopment Analysis), reveal that the economic impact of IT introduction at each industry level changed greatly before and after 1990 in Japan. In summary, the result of Analysis on the

Economic Impact of Information Equipment by Growth Accounting shows that the economic impact of Information Equipment had been positive in many industries in the latter half of the 1980s, then turned to the decline, even to the negative, in many industries in the first half of the 1990s. That of Analysis of Information Equipment Stock by DEA shows that the management efficiency in the first half of the 1990s dropped lower than the level of the late 1980s in Consumption-related Manufacturing and a part of Non-manufacturing area such as Wholesale/Retail, Transport/Communication and Construction, and Information Equipment became excessive in Finance/Insurance in the first half of the 1990s. Its causes may be the accumulation of excessive capital leading the worsening of management, due to the extravagant IT Investment and the over-enhancement of facilities carried out by many of the firms with ample funds raised by equity finance under the bubble economy, as well as the rapid deterioration of business environment by its collapse after 1990. Another factor may be the quality of IT in the late 1980s which was still in the developing stage and not applicable enough to the office works, sales, and other business operation in general. These results confirm that Japanese industry was in the state called Paradox of Productivity in the first half of 90s. The same results are confirmed by the two different methodologies presented in this paper, therefore they can be considered reliable since the errors specific to each method are somehow offset by other methods.

Many Japanese firms were obliged to take action to reduce IT Investment in the first half of the 1990s, in order to get rid of the excessive Information Stock. However, after 1995, IT Investment turned to expansion again owing to the diffusion of the Internet and PC. Analysis on the Economic Impact of Information Equipment by Growth Accounting shows the definite improvement of the economic impact of Information Equipment at each industry level, which increased and/or turned from negative to positive, after 1995. This improvement confirms that Paradox of Productivity disappeared in Japan in the latter half of 1990.

Three different data sources are employed to calculate *Q* (Value-added Production) for the Analysis by Growth Accounting and a part of DEA Analysis, namely SNA, Financial Statements Statistics of Corporations by Industry, and annual reports. The above-mentioned trends are observed in the results

with any of those data sources. So these results can be considered highly objective, with data errors and peculiarities eliminated.

The level of IT application and its technology level has improved a lot since the latter half of the 1990s, thanks to the gaining popularity of e-mails and web-sites at the business level, as well as the spread of business models and theories such as Strategic Information Systems (SIS), Supply Chain Management (SCM) and Customer Relationship Management (CRM) which make the high level use of Information Systems. Therefore, we plan to examine in the future the economic effect of IT in Japan at the industry level by proceeding with the measurement and analysis of the data after the latter half of the 1990s.

NOTES

(1) Brynjolfsson, E. “Firm-level Evidence of High Returns to Information Systems Spending” , Management Science, Vol.40, No. 4, pp. 541-558. 1996.

(2) The items used for calculating *Kin* include an item which is assumed to be the product of Information Equipment Stock and the profit rate. So *K* and *Kin* cannot be necessarily treated equally in the context of economics. But they are treated equally in this paper, because the accumulation of cost for 4 years is used to calculate *Kin,* which can be fairly close to the concept of stock.

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