Measurement of IT Capital Stock and It's Impact : A Case Study of Japan for Further International Comparisons

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Measurement of IT Capital Stock and It's Impact*

— A Case Study of Japan for Further International Comparisons —

Akihiko Shinozaki

Abstract

In this paper, using an input–output table (I–O table) and other related macroeconomic statistics that are commonly available around the world, we present a method for creating time series data of investment in information technology (IT), and consequently, the IT capital stock. These IT-related data can support international comparisons of the economic impact of IT based on relevant macroeconomic statistics. We take Japan as a case to explain the actual procedures of handling statistics to create IT investment and capital stock data. Furthermore, we present applied research with growth accounting analysis that can be conducted using the Japanese economic data we collected. The results demonstrate the importance of the IT capital stock data in capturing the influence of technology on economic development in the midst of transformation from the Industrial Age to the Information Age.

1. Introduction

As Chandler (2000) states, economies transformed "from the Industrial into the Information Age in the last decades of the twentieth century." Accordingly, it becomes important for economists to measure the impact of information technology (IT) on economic growth and development. Taking, for example, the Japanese economy, which was designated as "number one" in its matured stage of the Industrial Age in the 1980s[1], it is clear that it has experienced "lost decades" since the 1990s. This sharp contrast is apparent in such macroeconomic statistics as investment in IT and deepening of the IT capital stock.

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1) *Japan as Number One*, the title of a book written by Harvard University professor Ezra Vogel, became well known in those days.

The rising tide of the Information Age is supporting not only developed countries but also emerging economies such as ASEAN and BRIC countries, even though the driving forces of the economic development in those countries appear to be their respective manufacturing sectors. From the standpoint of empirical studies, it is of great importance in those economies to measure and compare the influence of IT based on relevant macroeconomic data.

It is readily apparent that an important statistic for examining any economic impact of the technology is IT capital stock: it is used for typical macroeconomic analysis of growth accounting and estimation of a production function model. Unfortunately, statistics related to IT capital stock are unavailable for several countries. To address its requirements and limitations, we first explain how to create IT investment data, a foundation for building IT capital stock, using an input–output table that most countries prepare, even though they provide no official statistics related to IT capital stock. In fact, Japan prepares no such statistics either. We then demonstrate how these data are valuable to analyze recent economic development, taking Japan as an example for which the engine of economic growth was lost in the midst of the transition to the Information Age. A case study of Japan aptly illustrates the importance of the IT capital stock data to examine the impact of IT on today's economic development.

2. Methodology of data building

2.1. Basic framework of data building

In the first part of this paper, we present the methodology and procedures for accumulating statistics related to IT investment and the IT capital stock. An outline of the actual process is the following.

[Overall process for obtaining IT investment and capital stock data]

(1) Define IT investment and measure benchmarks using the I–O table

(2) Calculate annual time series data

– Nominal time series data using supplemental statistics

– Real-term time series data using price indices

(3) Calculate the IT capital stock

First, the item codes of hardware and software products related to IT are defined and measured based on the input–output table. Unfortunately, although more frequent time series data (e.g. annual datasets) are necessary for relevant empirical studies, the input–output table is published only once every five years in Japan. Secondly, annual time series data are calculated using the growth rate of domestic demand for each product defined above, with such supplemental statistics as industrial production and international trade. This process can be divided into two steps: calculating nominal time series data, and then converting real-term data based on the deflator of each product as measured by price indices. Thirdly, IT capital stock data are calculated with real-term annual IT investment data, the depreciation rate of each IT asset, and estimated figures of initial endowments.

Using these steps of data building—definition and benchmark measurement, calculation of flow-based time series data, and creation of capital stock—valuable IT-related macro statistics will become available. We discuss each process more precisely in the following subsections.

2.2. Benchmarks based on the input–output table

2.2.1. Definition

The first step of data building is to define IT investment. For the definition, product codes or industry codes in the I–O table are useful and relevant. In the case of Japan, a fixed-capital matrix is available in the official input–output table. The fixed capital matrix provides all relevant domestic fixed-capital formation data in the benchmark year, listed according to the industry sector for which capital goods of each type are shown as in Fig. 1.

In light of international comparisons and precedent studies[2], we use the product code in the fixed-capital matrix for definition. We choose the following 11 items as components of IT investment. They are personal computers (3331011), computers except personal computers (3331021), computers peripheral equipment

Figure 1 Configuration of fixed-capital matrix.

item codes	capital goods (industry codes / industries)	010000 agriculture	- -	160000 automobile industry	- -	260000 communications and broadcasting	- -	private sector total
:	:							
3111011	photocopy							
3111099	other office equipment							
:	:							
3331011	personal computers							
3331021	computers except personal computers							
3331031	computers peripheral equipment							
:	:							
3321011	wired telecommunications equipment							
3321021	cellular phones							
3321031	other wireless telecommunications equipment							
3321099	other telecommunications equipment							
:	:							
4132031	construction of telecommunications facilities							
:	:							
7331011	software							
:	:							
total amount of capital formation								

Source: Ministry of Internal Affairs and Communications, *2005 Input–Output Tables*.

2) In the United States, IT investment is defined as "Information processing equipment and software", classified into three categories, "computers and peripheral equipment," "software," and "other." The "other" includes "communications equipment," "photocopy and related equipment," "office and accounting equipment," "medical equipment and instruments," and "nonmedical instruments."

Figure **2**　Classification of categories.

millions of yen in 2005

classification of categories			item codes	capital goods	purchaser's price (a)	producer's price (a)	(b)/(a)
hardware	computer related	computers and peripherals	3331011	personal computers	1,354,633	1,036,491	0.7651
			3331021	computers except personal computers	1,079,775	852,830	0.7898
			3331031	computers peripheral equipment	1,388,459	1,126,531	0.8114
	telecom related	telecommunications equipment and peripherals	3321011	wired telecommunications equipment	1,077,001	693,128	0.6436
			3321021	cellular phones	59,334	32,980	0.5558
			3321031	other wireless telecommunications equipment	686,986	575,684	0.8380
			3321099	other telecommunications equipment	314,892	265,255	0.8424
		construction of telecommunication	4132031	construction of telecommunications facilities	311,873	311,873	1.0000
	office related	office equipment and peripherals	3111011	photocopy	434,248	316,358	0.7285
			3111099	other office equipment	836,983	593,846	0.7095
software	software	software	7331011	software	7,277,117	7,267,071	0.9986
total IT investment					14,821,301	13,072,047	0.8820

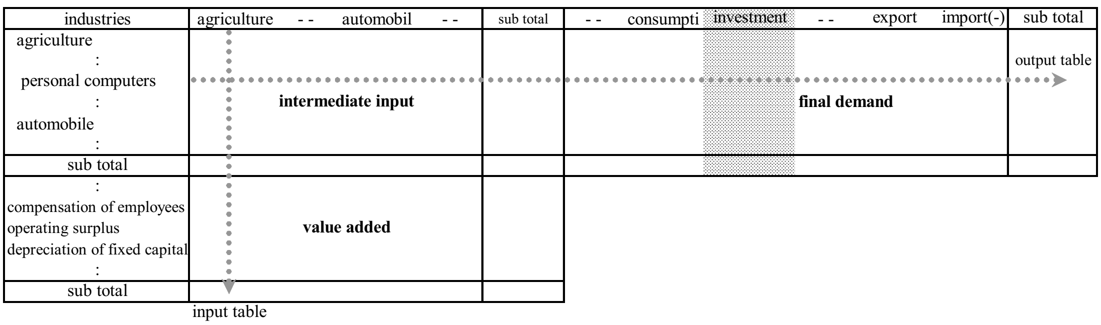
(3331031), wired telecommunications equipment (3321011), cellular telephones (3321021), wireless telecommunications equipment except cellular telephones (3321031), other telecommunications equipment (3321099), photocopiers (3111011), other office equipment (3111099), construction of telecommunications facilities (4132031), and software products (7331011).

As described in the next subsection, we then categorize the 11 products above into five items because of the limited nature of available statistics for creating annual time series data. They are (1) computers and peripherals (3331011, 3331021, 3331031), (2) telecommunications equipment and peripherals (3321011, 3321021, 3321031, 3321099), (3) construction of telecommunications facilities (4132031), (4) office equipment and peripherals (3111011, 3111099), and (5) software products (7331011).

2.2.2 Benchmark measurement

Annual figures calculated once every five years are measured as benchmark components of IT investment through evaluation of the amount of defined products in the private sector's fixed-capital matrix. In case a fixed-capital matrix is unavailable, the benchmark can be measured using an "output table" in the I–O table, rather than an "input table." The output table describes where and how each product is demanded and used. Taking computer peripheral equipment, for example, some are purchased and used as an intermediate input

Figure **3**　Configuration of input–output table.



by a wide range of industries while others are consumed or invested by households or firms as final demand (Fig. 3). Figures in the final demand of investment in defined products are measured as benchmarks of IT investment. Using these procedures, we can create benchmarks of IT investment for every five years[3].

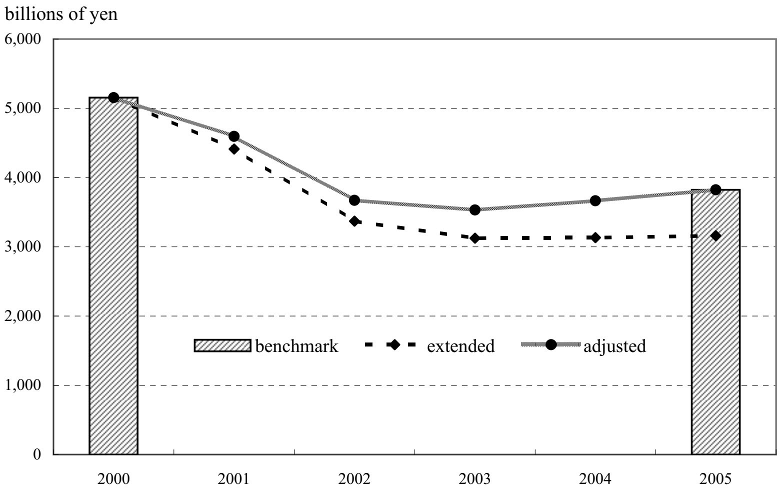
2.3. Time series data of IT investment

The next step is to bridge over five-year benchmarks annually. One of the greatest difficulties with this process is a shortage of precise annual data. In other words, missing or imperfect data become apparent, especially tracking back before the 1990s. To address the limitation of available statistics for creating annual time series data, 11 product categories used in the input–output table are integrated into five item components, as described in the previous subsection, which are then calculated annually using supplemental statistics.

The process to bridge over five-year benchmarks for obtaining annual data is divisible into two steps, they are (1) calculating nominal time series data and (2) converting real-term data. For nominal data, we adopt the annual rate of change of domestic demand on each category. The amounts of domestic demand are formulated by subtracting the value of exports from those of domestic production and adding the value of imports using supplemental statistics related to industrial production and international trade.

It is noteworthy that some discrepancy might occur in this process for the benchmark year because the

Figure **4** Benchmarks, simply extended, and adjusted data (computers and peripherals).



Source: Figure 5-1 and Ministry of Internal Affairs and Communications, *2005 Input–Output Tables*.

3) In case the value of each IT related item is measured in terms of producer's price that excludes delivery cost, brokers' commissions, and installation cost, it is required to convert the value into purchaser's price that includes those costs to avoid underestimation of IT investment. See Figure 2.

values accumulated annual change of domestic demand and values of benchmarks in the I–O table are not identical. For example, for the process of bridging over benchmarks between 2000 and 2005, the figures simply extended to 2005 by accumulating the annual rate of change of domestic demand from 2000 differ from the figures in the 2005 input–output table (Figure 4).

To adjust such discrepancies, we use the "linking coefficient", which corrects the gaps annually and smoothly. The formula of the "linking coefficient" is

$$IO05 = IO00\ (1 + DC0005 + ADJ),$$

where *IO*05 represents benchmark figure from the 2005 input–output table, *IO*00 represents benchmark figure from 2000 input–output table, *DC*0005 represents the accumulated rate of change of domestic demand during 2000–2005, and *ADJ* represents the adjustment factor. Then, this formula can be transformed as

$$io0005 = dc0005 + adj\ ,$$

where *io*0005 represents the annual rate of change of the I–O table benchmark figure during 2000–2005, *dc*0005 represents the annual rate of change of domestic demand, and *adj* represents the annual rate of change of adjustment factor, i.e. the "linking coefficient."

Accordingly, the annual rate of change with no discrepancy is obtained from the annual rate of change of domestic demand and "linking coefficient (*adj*)." This procedure is conducted for each item for the years between benchmarks. Linking these rates of change in succession produced the nominal IT investment value annually for each item of the five categories. We can convert these nominal time series data into real-term annual data using price indices as deflators. The steps up to this point tabulate the nominal and real values of IT investment annually (Fig. 5).

2.4. Time series data of IT capital stock

It is a time series of capital stock data that we need for empirical studies to analyze the impact of IT on economic growth and development. Using investment flow data, depreciation rate, and initial endowment of the assets, we can measure the time series amount of IT capital stock according to the following formula.

$$K_t = I_t + (1 - \delta)\ K_{t-1}$$

In that equation, K stands for the capital stock, I represents the investment flow, δ denotes the depreciation rate, and t signifies the year or time series. Given that the annual growth rate of investment (g) and depreciation rate are constant for the years before t, the following formula is obtained[4).

$$K_{t-1} = I_t / (g + \delta)$$

Therefore, on the assumption that first several years' growth rate and depreciation rate are maintained until the initial benchmark year, the initial IT capital stock endowment can be measured. Here, the missing figure for calculating the time series IT capital stock is the depreciation rate, which is obtainable from

4) This formula is commonly adopted for creating capital stock from investment flows.

Figure 5-1 IT investment data (nominal).

(billions of current yen)

year	(1)	(2)	(3)	(4)	sub total	(5)	total
75	663	292	469	313	1,737	46	1,783
76	715	315	499	343	1,872	51	1,923
77	811	335	531	385	2,062	84	2,146
78	927	349	565	474	2,316	97	2,412
79	1,143	353	602	424	2,521	140	2,661
80	1,264	375	641	423	2,702	167	2,869
81	1,423	477	653	318	2,870	247	3,117
82	1,647	593	665	385	3,289	326	3,615
83	1,736	787	677	644	3,844	395	4,240
84	2,426	1,042	690	739	4,898	556	5,453
85	3,173	1,271	703	888	6,036	714	6,749
86	3,656	1,347	640	1,006	6,650	990	7,640
87	4,056	1,562	583	1,149	7,350	1,198	8,548
88	4,766	1,731	531	1,570	8,598	1,951	10,549
89	5,480	1,822	484	1,728	9,513	2,725	12,238
90	5,452	2,233	440	1,487	9,613	3,751	13,363
91	5,576	2,376	492	1,563	10,008	4,665	14,673
92	4,618	2,119	537	1,423	8,697	4,660	13,356
93	4,040	2,243	604	1,275	8,163	4,136	12,299
94	4,789	2,434	621	1,186	9,030	3,781	12,811
95	5,514	3,169	781	1,156	10,620	4,010	14,630
96	6,345	4,403	1,065	1,159	12,973	4,620	17,593
97	6,146	4,028	1,151	1,262	12,588	5,064	17,652
98	4,988	3,125	1,213	1,150	10,476	5,413	15,889
99	4,847	2,961	1,255	1,214	10,277	5,739	16,016
00	5,154	3,074	1,445	1,402	11,075	6,015	17,090
01	4,594	3,111	795	1,073	9,573	6,755	16,327
02	3,671	2,128	502	1,759	8,060	6,969	15,028
03	3,532	2,387	415	1,298	7,632	6,929	14,562
04	3,665	2,075	340	1,275	7,356	7,208	14,563
05	3,823	2,138	312	1,271	7,544	7,277	14,821
06	3,792	2,258	323	1,168	7,540	7,464	15,004
07	3,284	2,298	307	1,099	6,988	7,817	14,805
08	3,212	2,119	318	781	6,430	7,887	14,317
09	2,441	1,682	304	553	4,979	7,366	12,345

(1) computers and peripherals
(2) telecommunications equipment and peripherals
(3) construction of telecommunications facilities
(4) office equipment and peripherals
(5) software

Fraumeni (1997) for hardware. Although the figures presented by Fraumeni (1997) are derived from IT investment in the United States, it is reasonable to assume that the depreciation rates of IT-related products are almost identical around the world because the nature of the technology: it diffuses rapidly and globally. As for the depreciation rate of software, we assume 20%, or 5 years' duration, in light of precedent studies.

These procedures enable us to tabulate time series data related to IT investment and capital stock. Using these essential statistics the economist can carry out such empirical studies as growth accounting analysis and estimation of production function models, examining the impact of the IT to the macroeconomic performances

Figure **5-2** IT investment data (real).

(billions of 2005 constant yen)

year	(1)	(2)	(3)	(4)	sub total	(5)	total
75	70	123	807	63	1,062	73	1,135
76	76	134	802	89	1,101	74	1,176
77	90	141	797	111	1,138	114	1,252
78	112	147	792	151	1,202	125	1,327
79	145	149	787	141	1,222	175	1,397
80	161	156	782	149	1,248	194	1,443
81	190	196	793	121	1,301	274	1,575
82	236	243	805	164	1,449	351	1,801
83	267	324	816	301	1,709	417	2,126
84	395	427	828	371	2,021	571	2,592
85	581	531	840	468	2,420	720	3,140
86	820	631	746	579	2,776	999	3,776
87	1,086	801	662	748	3,297	1,212	4,509
88	1,344	936	588	1,124	3,991	1,955	5,946
89	1,542	990	522	1,252	4,306	2,603	6,909
90	1,576	1,235	463	1,081	4,354	3,442	7,796
91	1,683	1,350	503	1,165	4,701	4,130	8,831
92	1,455	1,212	540	1,084	4,291	4,100	8,391
93	1,322	1,290	605	999	4,216	3,708	7,924
94	1,679	1,423	622	953	4,676	3,561	8,237
95	2,115	1,895	781	955	5,746	3,906	9,652
96	2,582	2,705	1,072	964	7,322	4,511	11,833
97	2,548	2,500	1,148	1,061	7,256	4,782	12,038
98	2,157	1,990	1,241	994	6,382	4,986	11,368
99	2,158	2,054	1,304	1,113	6,630	5,251	11,880
00	2,481	2,262	1,494	1,307	7,545	5,490	13,034
01	2,487	2,430	837	1,011	6,765	6,298	13,063
02	2,397	1,801	535	1,660	6,393	6,621	13,014
03	2,769	2,178	439	1,252	6,638	6,854	13,492
04	3,250	2,002	352	1,243	6,846	7,161	14,008
05	3,823	2,138	312	1,271	7,544	7,277	14,821
06	3,989	2,346	299	1,226	7,861	7,369	15,230
07	3,785	2,631	278	1,181	7,875	7,642	15,517
08	4,072	2,545	292	845	7,753	7,611	15,364
09	3,514	2,097	288	628	6,526	7,323	13,850

(1) computers and peripherals
(2) telecommunications equipment and peripherals
(3) construction of telecommunications facilities
(4) office equipment and peripherals
(5) software

Figure **6** Depreciation of IT capital stock.

	Hardware			Software
	Computer related	Telecom related	Office related	
Depreciation Rate	0.31190	0.11000	0.18000	0.20000
Duration (year)	3.2	9.1	5.6	5.0

Source: Fraumeni (1997)., Japan Center for Economic Research (2000)

Figure 7 IT capital stock data.

billions of 2005 constant yen

year	Net IT capital stock					
	total (a)=(b)+(c)	hardware capital stock (b)	of which computer related	of which telecom related	of which office related	software capital stock (c)
75	8,911	8,698	168	8,328	202	214
76	9,039	8,794	192	8,348	255	245
77	9,219	8,909	222	8,367	320	310
78	9,436	9,063	265	8,386	413	373
79	9,680	9,206	328	8,399	479	473
80	9,915	9,342	386	8,414	542	573
81	10,232	9,500	456	8,478	566	732
82	10,709	9,772	550	8,594	628	937
83	11,418	10,251	646	8,788	817	1,167
84	12,462	10,957	840	9,077	1,041	1,505
85	13,853	11,929	1,158	9,449	1,322	1,924
86	15,606	13,067	1,618	9,786	1,663	2,539
87	17,727	14,483	2,200	10,172	2,112	3,243
88	20,839	16,290	2,857	10,576	2,856	4,549
89	24,269	18,027	3,509	10,925	3,594	6,242
90	27,874	19,438	3,990	11,420	4,028	8,436
91	31,793	20,914	4,429	12,018	4,467	10,879
92	34,500	21,698	4,502	12,448	4,747	12,803
93	36,236	22,286	4,420	12,974	4,891	13,950
94	37,997	23,275	4,720	13,592	4,963	14,721
95	40,844	25,160	5,363	14,772	5,025	15,683
96	45,338	28,280	6,273	16,923	5,085	17,058
97	49,232	30,803	6,864	18,710	5,230	18,428
98	51,774	32,045	6,880	19,883	5,282	19,729
99	54,425	33,391	6,892	21,055	5,444	21,034
00	57,807	35,490	7,224	22,495	5,772	22,317
01	60,640	36,488	7,457	23,287	5,744	24,152
02	62,902	36,960	7,528	23,062	6,370	25,942
03	65,174	37,567	7,949	23,142	6,475	27,607
04	67,470	38,223	8,720	22,950	6,553	29,247
05	70,018	39,343	9,823	22,876	6,644	30,675
06	72,337	40,428	10,748	23,005	6,675	31,909
07	74,388	41,219	11,181	23,383	6,655	33,169
08	75,861	41,715	11,765	23,648	6,302	34,146
09	75,476	40,836	11,610	23,431	5,795	34,640

in the Information Age.

3. Case of empirical study using IT capital stock data

In the second part of this paper, we demonstrate how the IT-related data we created are useful and valuable to analyze recent economic growth and development. For this purpose, we take Japan as an example because the case of the Japanese economy aptly illustrates the importance of the IT related data for capturing the impact of technology on recent macroeconomic performance.

Indeed, the analysis of the Japanese economy yielded two observations. First, Japan experienced a massive IT investment boom up to the late 1980s and a resultant productivity surge in both aggregate labor productivity and total factor productivity (TFP). Second, the economy has experienced a deep slump since the investment boom ended in the 1990s, when open-network technology of new types surged throughout the world.

3.1. Overview of IT investment and capital stock

Before undertaking a typical macroeconomic analysis of growth accounting, it is useful to observe the level, configuration, and changes in Japan's IT investment. As Fig. 5 depicts, nominal IT investment amounted to 12 trillion yen (132 billion US dollars) in 2009, which accounted for 2.6 percent of the nominal Gross Domestic Product (GDP), and 19.3 percent of total nonresidential fixed investment. The amount of investment in software technology, approximately 7.4 trillion yen (79 billion dollars), surpassed investment in hardware, which amounted to 5.0 trillion yen (53 billion US dollars). However, the amount of investment in hardware including computers, communications, and office equipment was twice what had been invested in software up until the late 1990s. Regarding computer investment, it was for a time the largest component of IT investment, but it is now merely 2.4 trillion yen (26 billion US dollars), slightly less than the current figure of 2.5 trillion yen (27 billion US dollars) investment in communications and office equipment.

Several characteristics are readily apparent from Fig. 8. The first is the long-run investment boom that took place until the late 1980s. Second is the cyclical fluctuation in technology investment since 1990s. The third is the downward investment trend in the 2000s despite the fact that software investment showed steady expansion except for the last two years of the decade when the global financial crisis depressed the economy.

It is much more instructive to conduct an international comparison between Japan and the United States for resource allocation to IT and the consequent macroeconomic economic performance. The upper chart of Fig. 9 shows the private sector's IT investment ratio to the total nonresidential fixed investment for both economies. The ratio represents the degree to which firms allocate their resources to IT assets in the long run. No significant difference arose between the economies until the early 1990s. However, a clear contrast has been apparent since the mid-1990s; that is, stagnation in Japan and aggressive behavior in the U.S. in relation to firms' resource allocation to information technology. The Japanese economy has apparently failed in the rising tide of Information Age, although the United States has had a long and smooth journey and has reaped the benefits of the Internet Revolution over the last two decades.

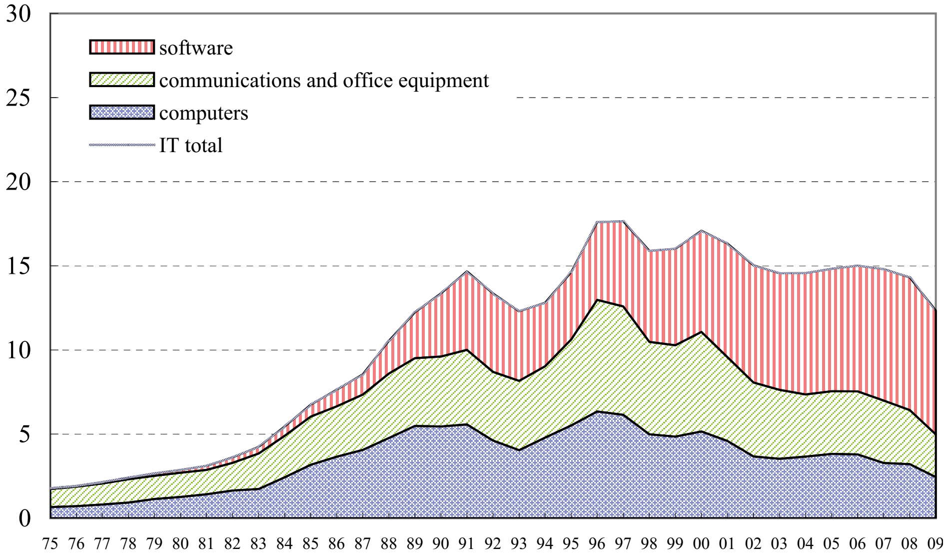
In Japan's private sector, banking industry leaders were especially enthusiastic about enhancing online transaction systems in the late 1980s when deregulation was beginning in the telecommunications market. The IT investment boom, however, halted in the 1990s when open-network technology of new types surged throughout the world, resulting in a downsizing from mainframe computers and increased personal computer use with its wide internet reach. By that time, Japan's investment in IT showed repeated cyclical fluctuations and a downward trend, as has the macroeconomic performance that marked the decades.

Such a major shift in investment trends–from the boom in the 1980s to a deep slump since the 1990s–affected the accumulation of IT assets. The Japanese economy seems to have lost its growth engine since

Figure **8** IT investment in Japan and the U.S.

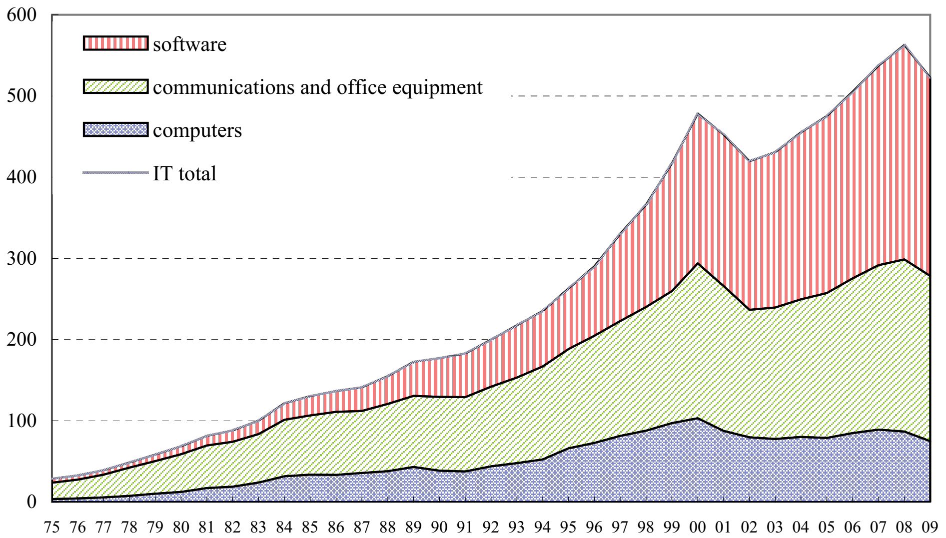
1) Japan

(trillions of yen)



2) United States

(billions of dollars)

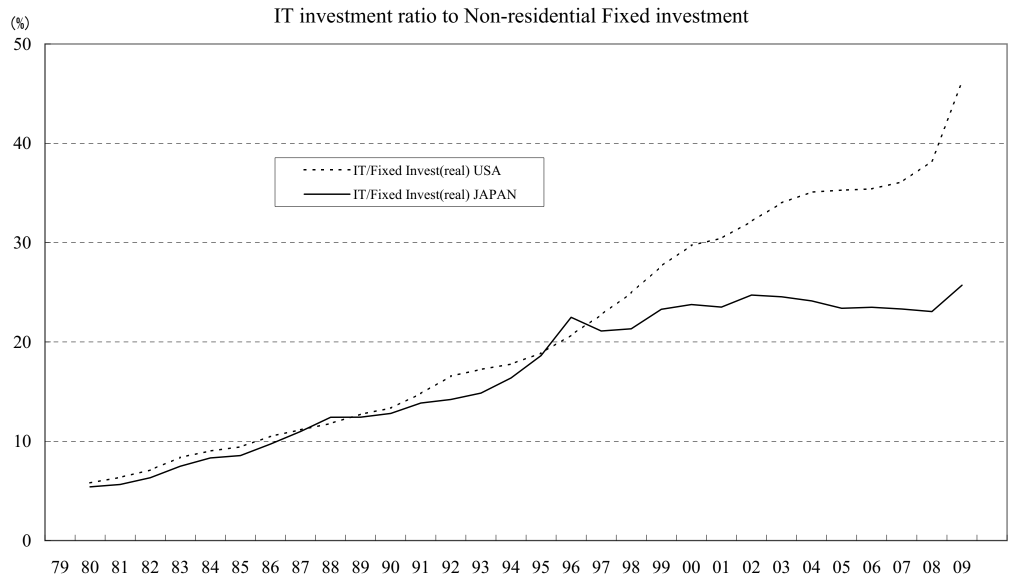


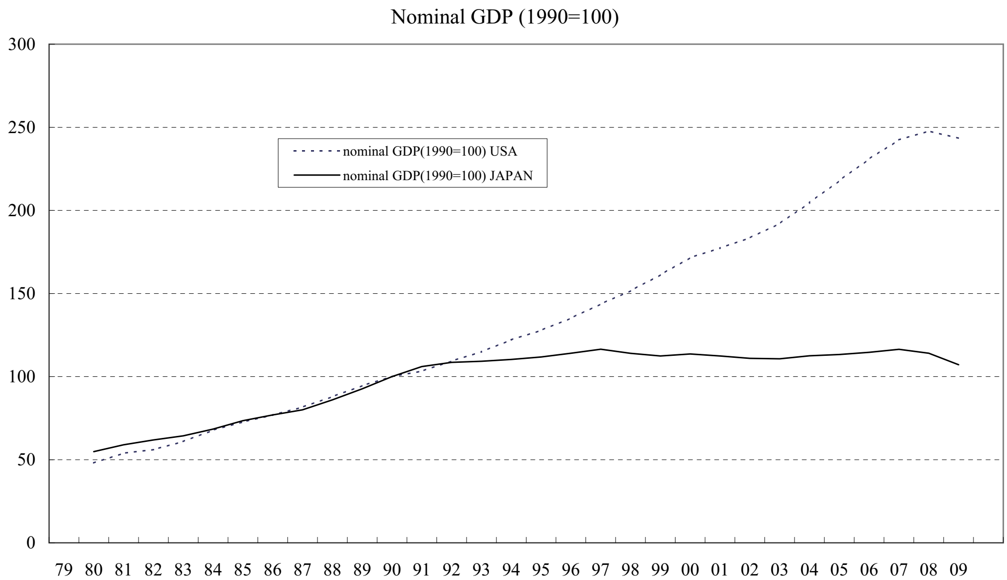
then. To examine this shift empirically, we must verify the contribution of IT to macroeconomic performance. Growth accounting analysis is an appropriate and simple approach.

3.2. Background of the argument on productivity and IT

A controversy related to the potential growth rate of the Japanese economy has arisen. The majority view

Figure 9　Resource allocation for IT and economic growth.





claims that the economy can grow at merely one percent or less annually[5], although some analysts argue that it is feasible to raise the growth rate to higher than two percent annually[6]. In this argument, the major difference between pessimism and optimism derives, apparently, from whether the Japanese economy can reap the benefits of globalization and innovation in information technology.

As described herein, we specifically examined the magnitude of the effects of IT on Japanese economic growth because recent empirical studies have revealed that IT contributed definitely to the surge in productivity in the United States and its consequent economic growth since the mid-1990s[7]. In the U.S., a driving force of this drastic change has been massive investment in IT since the early 1990s. Eventually, the consensus formed that a "new economy" emerged, as the "Solow paradox"[8] evaporated in the United States.

Japan, in contrast, has experienced "lost decades" since the 1990s, when business investment was sluggish and the economy grew at only 0.9 percent annually. The matter in question in the contrast between Japan and the U.S. is whether Japan's investment in IT contributed to its economic growth over the last few decades and what will happen over the next few decades. To address this question, we conducted a growth accounting analysis of the previous 35 years, reviewing Japan's economic growth and the contribution of IT to that growth. We then examined the periodic changes in Japan's productivity and IT investment to assess whether the "new economy" as well as the "paradox" hold true for Japan.

3.3. Analytical framework of growth accounting

For the analyses presented in this subsection, we used a growth accounting method pioneered by Solow (1957). This method is based on the framework of a neoclassical production function used to estimate the contributions to output per hour derived from increases in capital assets per hours worked and total factor productivity (TFP), where TFP is estimated as a residual of technological or organizational improvements that increase output for a given amount of input.

Equation (1) presents the fundamental concept of the growth accounting method, capital assets divided into IT and non-IT assets, where IT assets include not only computer hardware but also software and network infrastructure. One reason for this is that intangible assets have become more important. Another is that recent extraordinary innovations have resulted from the convergence of computers and telecommunications equipment, as in

(1) $Q = TK_o^{\alpha}K_i^{\beta}L^{\gamma}$,

5) See, for example, Japan Center for Economic Research (2010).
6) See, for example, Adams, et al. (2007) and Shinozaki (2009a, b).
7) For detailed arguments, see Jorgenson, et al. (2008), Oliner, et al. (2007).
8) The "paradox" derived from Solow's famous quip, "You can see the computer age everywhere but in the productivity statistics (Solow [1987])." Until the early 1990s, most empirical studies of the U.S. economy revealed no evidence of a positive correlation; some found a negative correlation, between IT and productivity (U.S. Department of Labor [1994]). Therefore, it is likely that the "Solow paradox" pertained there.

where α, β, and γ respectively represent income shares of inputs such that $\alpha + \beta + \gamma = 1$. Furthermore, Q signifies the private output, T stands for TFP, K_o represents non-IT capital assets, K_i denotes IT capital assets, and L denotes labor input representing work hours of total employees. Consequently, eqn. (1) can be transformed to

$$(2)\quad \dot{Q}-\dot{L} = \dot{T} + \alpha(\dot{K_o}-\dot{L}) + \beta(\dot{K_i}-\dot{L}),$$

where a dot over a variable denotes the rate of change expressed as a log difference. In eqn. (2), $\dot{Q}-\dot{L}$ represents changes in output per hour, or the average labor productivity, $\dot{T}$ stands for changes in TFP, and $\dot{K}-\dot{L}$ represents changes in capital assets per hours worked, labeled capital deepening. The capital-deepening component is further divided into the contribution from IT assets and other non-IT assets in eqn. (2).

The basic equation presented above must be adjusted for the following two factors. The first is the business cycle effect. Productivity is known to be so pro-cyclical that the structural trend of productivity must be distinguished from business-cycle-related changes to productivity. For this discussion, the utilization rate of capital assets was used as a proxy of business cycle effects to remove the influence of the business cycle from labor productivity. The second adjustment we made was to consider labor quality. An important trend that drives economic development is knowledge. In a knowledge-based economy, economic prosperity depends deeply on labor quality as well as capital stock and technology. We employed education records as a proxy of labor quality for these analyses. Therefore, eqn. (1) can be modified so that

$$(3)\quad Q = T(pK_o)^{\alpha}(pK_i)^{\beta}(eduL)^{\gamma},$$

whereby p is the utilization rate of capital assets, assuming that the utilization rate is homogeneous in each asset, and where edu signifies the education records of employees as a proxy of labor quality. Consequently, eqn. (3) can be transformed into the expression shown below.

$$(4)\quad \dot{Q}-\dot{L} = \dot{T} + \alpha(\dot{K_o}-\dot{L}) + \beta(\dot{K_i}-\dot{L}) + (\alpha+\beta)\dot{p} + \gamma \dot{edu}$$

Using that equation, we can measure the contributions to changes in labor productivity, or output per hour, through decomposition into four factors: changes in TFP ($\dot{T}$), non-IT capital assets per hours worked (capital deepening of non-IT: $\dot{K_o}-\dot{L}$), IT capital assets per hours worked (capital deepening of IT: $\dot{K_i}-\dot{L}$), the utilization rate of capital assets ($\dot{p}$) as a proxy of the business cycle effect, and the education records of employees ($\dot{edu}$) as a proxy of labor quality.

3.4. Results of growth accounting analysis

3.4.1. Japan's past economic performance

Based on the formula and dataset[9], we analyzed the long-run economic performance of Japan and the contribution of information technology. Figure 10 presents results of the measurements of economic growth,

9) In the case of Japan, available capital stock data are gross-based rather than net-based. Therefore, we built a gross-based IT capital stock by converting the depreciation rate to retirement rate.

Figure 10 Economic growth, labor productivity, TFP, and the contribution of IT.

	76-80	81-85	86-90	91-95	96-00	01-05	06-09	changes from previous five years					
	a	b	c	d	e	f	g	b-a	c-b	d-c	e-d	f-e	g-f
Private output	4.8	3.3	5.0	1.3	0.8	1.5	-0.7	-1.5	1.7	-3.7	-0.5	0.8	-2.2
Hours worked	1.4	0.9	1.3	-0.2	-0.5	-0.6	-0.0	-0.5	0.4	-1.5	-0.3	-0.1	0.6
Output per hour	3.4	2.4	3.7	1.5	1.3	2.1	-0.7	-1.1	1.3	-2.1	-0.2	0.8	-2.8
Business cycle effect	1.2	-0.0	0.3	-0.8	0.1	0.2	-1.6	-1.2	0.3	-1.1	0.9	0.2	-1.9
Fundamental trend	2.2	2.4	3.4	2.4	1.2	1.9	1.0	0.2	1.0	-1.0	-1.1	0.7	-0.9
Capital deepening	1.7	1.5	1.7	1.5	1.0	0.7	0.5	-0.2	0.2	-0.2	-0.6	-0.3	-0.2
of non IT-assets	1.7	1.4	1.4	1.3	0.7	0.4	0.3	-0.3	0.0	-0.1	-0.6	-0.3	-0.1
of IT assets	0.0	0.1	0.3	0.3	0.3	0.2	0.1	0.1	0.2	-0.1	0.0	-0.0	-0.1
Labor quality	0.3	0.4	0.3	0.3	0.4	0.3	0.2	0.1	-0.1	-0.0	0.1	-0.0	-0.2
Total factor productivity	0.3	0.5	1.3	0.5	-0.1	0.9	0.4	0.3	0.8	-0.8	-0.6	1.0	-0.6
[Income shares (percentage)]													
share Ko (α)	32.1	30.5	30.7	26.6	23.4	23.3	23.3	-1.5	0.2	-4.1	-3.3	-0.1	0.1
share Ki (β)	2.0	1.8	2.5	2.9	3.5	4.5	4.9	-0.2	0.7	0.4	0.6	0.9	0.4
share L (γ)	66.0	67.7	66.8	70.5	73.1	72.3	71.8	1.7	-0.9	3.7	2.7	-0.8	-0.5
[Annual growth rate of inputs]													
dKo	6.6	5.5	5.9	4.5	2.4	1.3	1.4	-1.2	0.5	-1.4	-2.1	-1.1	0.1
dKi	3.9	7.0	13.8	8.7	7.6	4.8	3.0	3.1	6.8	-5.1	-1.1	-2.8	-1.8
dedu	0.4	0.6	0.5	0.4	0.5	0.4	0.2	0.2	-0.1	-0.1	0.1	-0.1	-0.2

Source: Author's calculation.

Note: Figures might not sum precisely because of rounding.

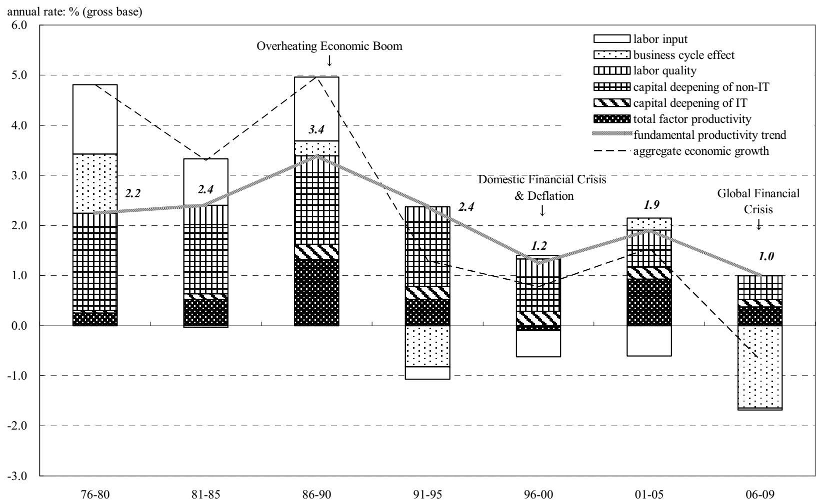
with labor productivity shown as hourly output since the second half of the 1970s. The first line in the table traces the growth rate of the entire economy; the third line shows the productivity growth rate as a formula of the first line (growth rate of output) minus the second line (growth rate of labor input). The fourth and fifth lines show this productivity growth rate with the business cycle effect and fundamental trend.

Japanese macroeconomic performance has changed drastically over the last three decades. The figures in the first line portray the transformation accurately. The economy apparently enjoyed a powerful boom in the late 1980s and plunged into a deep slump in the 1990s. The economy grew at a healthy 3.3 percent annually in the early 1980s and a vigorous 5.0 percent annually in the late 1980s. That growth was accompanied by a rapid advance in labor productivity. Output per hour rose at an annual rate of 2.4 percent in the early 1980s and a robust 3.7 percent in the late 1980s. This improvement was not driven by a cyclical effect in those days, but rather by a fundamental trend in productivity improvement. More precisely, it was driven by the surge in TFP and the capital deepening of IT assets.

In the 1990s, however, the economy plummeted into a deep slump, especially in the second half of the decade. The economy grew at a mere 1.0 (1.3 in the first half, 0.8 in the second half) percent annually with sluggish productivity improvement during the 1990s. The growth rate of the economy was less than a quarter the rate of the late 1970s or late 1980s, and less than one-third the rate of the early 1980s. This sluggishness is also apparent in productivity figures. The fundamental trend of output per hour rose 2.4 percent annually in the early 1990s and at the even worse pace of 1.2 percent in the late 1990s. Productivity growth in the latter 1990s fell sharply by more than two percentage points from the late 1980s. In fact, TFP also fell by about 1.5 percentage points to negative 0.1. These figures well represent the stagnant economic condition that is often designated as the "lost decade" of the Japanese economy.

Nevertheless, the economy eventually seemed to show some signs of recovery in the early 2000s when,

Figure 11 Long-run economic performances.



led by the Koizumi Administration, Japan underwent several important reforms (Fig. 11). The aggregate growth rate of the economy was 1.5 percent in the first half of the 2000s, mainly because of the decreasing trend in labor input, a reflection of the private sector efforts at downsizing and restructuring. Regarding the fundamental productivity trend, productivity apparently bailed the country out of its deepest slump in the late 1990s. The productivity trend has recovered 0.7 percentage points from 1.2 percent to 1.9 percent since 2001, mainly because of the resurgence of TFP. The annual growth rate of TFP, which fell to negative 0.1 percent in the late 1990s, has improved one percentage point to 1.0 and compensates somewhat for the weak contribution of capital deepening. The resurgence of TFP reflects the recovery signs of aggregate efficiency in the Japanese economy.

Unfortunately, these recovery signs disappeared in the late 2000s, mainly because of the global financial crisis and partly because of political turmoil in the Post-Koizumi period. The economy shrank at 0.7 percent annually with sluggish productivity improvement during 2006-2009. The fundamental trend of output per hour rose merely 1.0 percent annually in the late 2000s, at an even worse pace than 1.2 percent in the late 1990s. Productivity growth in the latter 2000s fell again by 0.9 percentage points from the level of the early 2000s. Accordingly, TFP also fell by 0.5 percentage points.

3.4.2. Failure in the Information Age

In the discussion presented in this subsection, we specifically address the contribution of IT to productivity improvement and the resultant economic growth. As Fig. 10 shows, capital deepening, which reflects business investment, largely accounts for the labor productivity improvement in each period. For example, the growth rate of productivity trends during 1976-1980, 1981-1985, 1986-1990, 1991-1995, 1996-

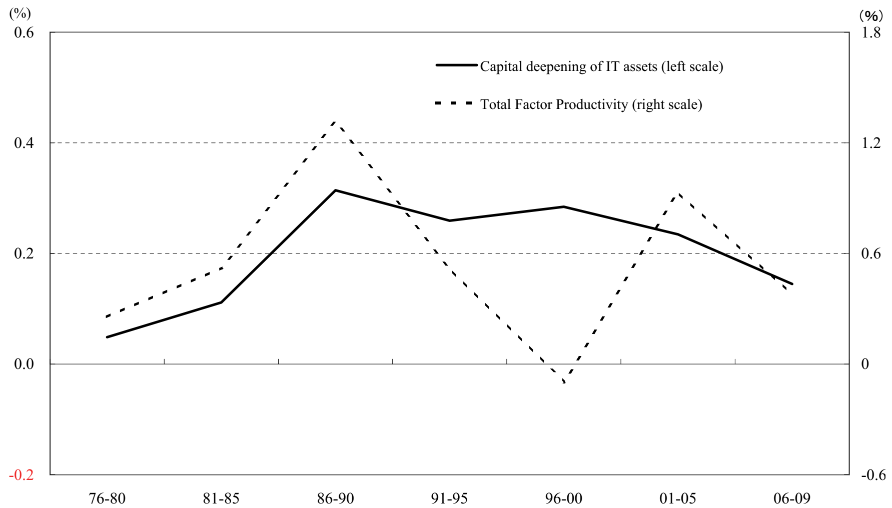
2000, 2001-2005, and 2006-2009 were, respectively, 2.2, 2.4, 3.4, 2.4, 1.2, 1.9, and 1.0 percent (see the fifth line of the table), of which capital deepening contributed 1.7, 1.5, 1.7, 1.5, 1.0, 0.7, and 0.5 percentage points, respectively (see the sixth line of the table).

Although the overall contribution of capital deepening seems to have changed little until the early 1990s, its composition has shifted substantially. The capital deepening of IT assets gained in influence, from 0.0 in the late 1970s to 0.3 in the late 1980s and has remained almost unchanged until late 1990s. However, the contribution of IT capital deepening has declined to 0.1 since the 2000s (see the eighth line of the table), although non-IT assets have constantly lost influence from 1.7 in the late 1970s to 0.3 in the late 2000s (see the seventh line of the table). The surge of IT capital deepened in the late 1980s, reflecting the increased importance of IT (see the increase of income share in the addendum) and the faster growth of IT assets (see the growth rate of input in the addendum). In the first half of the 1990s, however, the growth rate of IT capital slowed; it has continued to slow during the 2000s.

The substantial matter at issue is concentrated in the figures of periodic changes in IT assets in terms of their contribution to productivity improvement and resultant economic growth. The last six columns of Fig. 10 present important data. Acceleration of TFP (see the tenth line) and the contribution of IT assets (see the eighth line) are described as periodic changes in each of the five-year periods. The remarkable fact is that the changes in TFP and contribution of IT capital assets ran in the same direction and not in opposite directions until the mid-1990s (Fig. 12).

This characteristic differs greatly from the growth rate of TFP and the contribution of IT assets, which ran in opposite directions in the U.S. until the mid-1990s (Fig. 13). In the United States, therefore, "econo-

Figure **12** Japan's TFP growth and IT capital deepening.



Source: Author's calculation. See Fig. 10.

Figure **13** Acceleration of the U.S. economy and the contribution of IT assets.

	1959–73 (a)	1973–95 (b)	1995–2006 (c)	95–2000 (d)	difference (b)–(a)	(c)–(b)	(d)–(b)
Output per hour	2.8	1.5	2.6	2.7	-1.3	1.1	1.2
Capital deepening	1.4	0.9	1.4	1.5	-0.5	0.5	0.6
of IT assets	0.2	0.4	0.8	1.0	0.2	0.4	0.6
Labor quality	0.3	0.3	0.3	0.2	0.0	0.0	-0.1
Total factor productivity	1.1	0.4	1.0	1.0	-0.7	0.6	0.6

Source: Jorgenson et al. (2008).

Note: Figures might not sum precisely because of rounding.

mists were puzzled as to why productivity growth was so slow despite the widespread use of information technology.” [10]It was, demonstrably, a “Solow paradox.”

The Japanese economy is a case in contrast. For example, during 1981–1985, TFP increased 0.3 percentage points from the preceding five-year period with IT capital assets contributing 0.1 percentage points. The 0.8-percentage-point TFP acceleration achieved with IT capital assets contributed 0.2 percent points during 1986-1990, along with a 0.8-percentage-point TFP deceleration with a negative 0.1-percentage-point IT capital deepening during 1991–1995. Accordingly, changes in TFP were positive when capital deepening of IT assets contributed positively, whereas change in TFP was negative when IT capital deepening contributed negatively. In other words, no “paradox” existed in the Japanese economy before the mid-1990s.

Conversely, no manner of clear correlation has been shown between TFP and the contribution of IT assets since the second half of the 1990s[11]. For example, during 1996–2000, TFP decreased 0.6 percentage points from the prior five-year period with an unchanged IT capital assets contribution. During 2001–2005, the TFP growth rate increased by 1.0 percentage points with a slightly negative (-0.0 percent point) contribution of IT capital assets. Therefore, it seems likely that more marked changes in TFP, from 0.5 to -0.1 to 0.9, were never affected by the capital deepening of IT assets, which remained almost unchanged during those periods.

It follows that no “paradox” existed before the mid-1990s, and that no “new economy” arose after the mid-1990s in Japan, either. The former observation (no “paradox”) represents a successful investment in “legacy” information system in the 1980s, but the latter observation (no “new economy”) represents unsuccessful investment in open-network technologies related to the internet since the 1990s. In light of the description presented above, it seems reasonable to conclude that Japan missed the chance to take advantage of innovation in information technology and that it failed to transform its economy from one of the Industrial Age into one that can compete in the Information Age.

10) Baily (2002), p. 4.
11) The scope of our precise examination is limited to the period preceding the mid-2000s because every economic indicator was affected irregularly by the unusual global financial crisis that occurred in the late 2000s.

4. Conclusion

As described in this paper, we first reported how to create time series data of investment in information technology, or IT, and the consequent IT capital stock, using an input–output table (I–O table) and other related macroeconomic statistics. We presented the Japanese economy as a case to explain the actual procedures for tabulating statistics of IT investment and capital stock. As demonstrated in the second part of this paper, applied research such as growth accounting analysis can be conducted using IT capital stock data. The case study of the Japanese economy presented herein aptly demonstrates the importance of the IT capital stock data to capture the influence of the technology on the macroeconomic performances in the midst of transformation from the Industrial Age into the Information Age. World-wide collaboration for data building and collection is necessary because IT investment and capital stock data enable economists to conduct international comparisons related to the economic impact of IT based on relevant macroeconomic statistics.

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