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研究ノート

Japan's IT puzzle: Neither a Solow paradox nor a new economy *

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Abstract

The purpose of this paper is to examine the impact of information technology (IT) on the Japanese economy. For this purpose, we conduct growth accounting analysis over the last 30 years, reviewing the contribution of information technology to the economic growth. This analysis yields two observations. First, Japan experienced a massive IT investment boom in the late 1980s and resultant productivity surge in both aggregate labor productivity and total factor productivity (TFP). Second, the investment boom, however, ended abruptly in the early 1990s when new types of open-network technology surged throughout the world. Since then the information technology has never contributed the changes of productivity growth. Therefore, it can be concluded that we see neither a "Solow paradox" nor a "new economy" in Japan.

1. Introduction

The major result from recent empirical studies related to the impact of information technology on economic growth has been that information technology has surely contributed to the surge in productivity in the United States and its consequent economic growth since the mid-1990s(1). A driving force of that drastic change has been massive investment in information technology since the early 1990s in the U.S. Eventually, it comes out as a consensus that a "new economy" has emerged while the "Solow paradox," as derived from Solow's famous quip, "You can see the computer age everywhere but in the productivity statistics(2)," has disappeared in the United States.

Japan, in contrast, experienced its "lost decade" in the 1990s, when business investment was sluggish and the economy grew at only 1.3 percent annually. The matter in question in this contrast between Japan and the U.S. is whether Japan's investment in information technology has contributed to its economic

growth over the last few decades. To address this question, we first measure Japan's economic growth and the contribution of information technology based on Solow's growth accounting method. Subsequently, we overview the periodic changes of Japan's productivity and IT investment to analyze whether the "new economy" as well as the "Solow paradox" has been true for Japan.

2. Analytical framework

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

Equation (1) presents the basic concept of growth accounting method with capital assets divided into IT and non-IT assets, where IT assets include not only computer hardware but also software and network infrastructure. One of the reasons for this is that intangible assets have been gaining importance. Another is that recent remarkable innovations have involved the convergence of computers and telecommunications equipment, as in:

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

where α, β, and γ respectively represent income shares of inputs such that $\alpha+\beta+\gamma=1$. Furthermore, Q is the private output, T is the TFP, K_o represents non-IT capital assets, K_i denotes IT capital assets, hr represents the work hours per employee, and L is the number of employees. Consequently, eq. (1) can be transformed to

$$(2)\ \dot{Q}-\dot{hrL}=\dot{T}+\alpha(\dot{K}_o-\dot{hrL})+\beta(\dot{K}_i-\dot{hrL}),$$

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

The basic equation shown above must be adjusted for the business cycle effect. Productivity is well known to be so pro-cyclical that the structural trend of productivity must be distinguished from business-cycle-related changes of productivity. The utilization rate of capital assets is used as a proxy of business cycle effects in this paper to remove the influence of the business cycle from labor productivity. Therefore, eq. (1) can be modified to

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

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

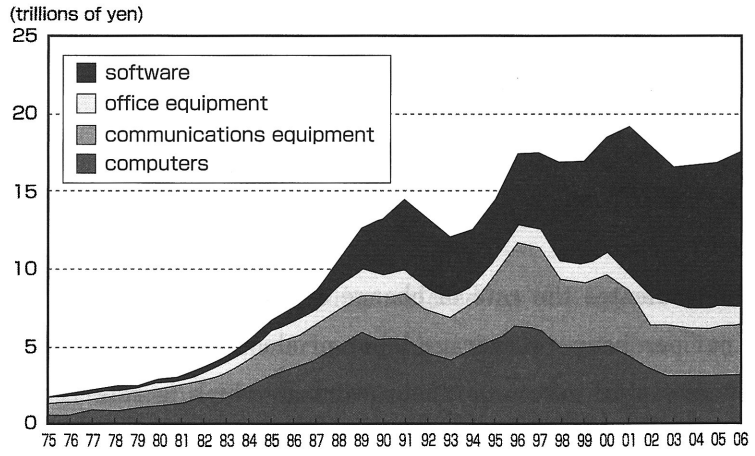
(4) $\dot{Q}-\dot{hrL}=T+\alpha(\dot{K}_o-\dot{hrL})+\beta(\dot{K}_i-\dot{hrL})+(\alpha+\beta)\dot{p}$.

Here, we can measure the contributions to changes in labor productivity, or output per hour, through decomposition into four factors: TFP ($\dot{T}$), non-IT capital assets per hour worked (capital deepening of non-IT: $\dot{K}_o-\dot{hrL}$), IT capital assets per hour worked (capital deepening of IT: $\dot{K}_i-\dot{hrL}$), and the utilization rate of capital assets ($\dot{p}$) as a proxy of the business cycle effect.

3. Dataset and overview of IT investment in Japan

All datasets described in this paper are taken from officially published statistics compiled by government ministries or research institutes: output data and overall capital input data from the Cabinet Office, labor input data from the Statistics Bureau of Ministry of Internal Affairs and Communications, utilization rates from the Ministry of Economy, Trade and Industry, and contributions of information technology assets from InfoCom Research, Inc.

Figure 1. Japan's nominal investment in IT



Source: InfoCom Research, Inc. (2007).

Before carrying out growth accounting analysis, it will be useful to review Japan's IT investment history. As Fig. 1 illustrates, the total investment in information technology amounts to 18 trillion yen (150 billion US dollars) in 2006, which accounts for 3.5 percent of the nominal Gross Domestic Product, (GDP), and 22.0 percent of total nonresidential fixed investment. The amount of investment in software

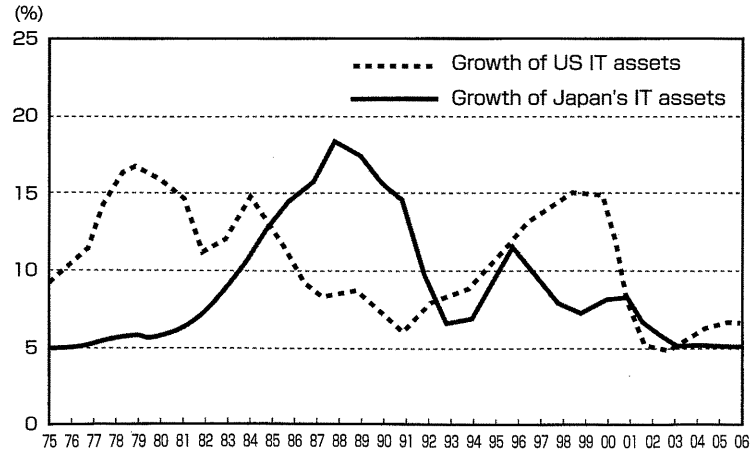
technology, approximate 9.9 trillion yen (83 billion dollars), is larger than that in hardware, which amounted to 7.7 trillion yen (64 billion US dollars). However, the amount of investment in hardware including computers, communications, and office equipment was greater than that in software until the late 1990s. As for computer investment, it was for a time the largest component of IT investment, but it is now just 3.1 trillion yen (25 billion US dollars), not more than the current figure of 3.3 trillion yen (28 billion US dollars) investment in communications equipment.

Several characteristics are readily apparent from Fig. 1. They are first, a long-run investment boom in the late 1980s. Secondly, decreased technology investment in the early 1990s and a cyclical fluctuation from the mid-1990s to the late 1990s. Thirdly, the end of the downward trend and a slight sign of recovery in hardware investment is apparent in the early 2000s. Finally, there has been notable expansion of software investment since the late 1990s. It must be emphasized that Japanese private business sectors aggressively invested in "legacy" types of technology based on mainframe computers and closed switched network system in the 1980s, but they were much less apt to invest in the new open-network technology in the 1990s.

In Japan, deregulation had just begun in the telecommunications market in 1985, while banking industry leaders were enthusiastic about enhancing online transaction systems based on "legacy" technology with little attention given to the "Solow paradox." Consequently, they successfully adopted "legacy" information systems while U.S. firms were confronting the productivity paradox.

The Japanese IT investment boom, however, ended abruptly in the early 1990s when new types of open-network technology surged throughout the world; they were downsizing from mainframe computers to personal computers and the wide spread of the internet. By that time, Japan's investment in information technology had shown repeated cyclical fluctuations that marked the decade.

Figure 2. Growth of IT assets : Japan and the United States



Source: InfoCom Research, Inc. (2007) and U.S. Department of Commerce NIPA tables.

That pattern of investment trend change – the boom in the 1980s and the slump in the 1990s – affected

the accumulation of information technology assets. Figure 2 portrays that the annual growth rate of Japan's IT capital assets accelerated in the 1980s up to 18 percent. Nevertheless, the rate of increase fell drastically in the early 1990s and has never since achieved the high shown in the 1980s. Indeed, it is much more illustrative to examine the United States. The rate of accumulation of Japan's IT assets jumped to more than double of the U.S. rate in the latter 1980s; it then slid to a lower level than that of the U.S. by the end of the 1990s. Therefore, it can be concluded that Japan missed a window of opportunity to ride a dynamic wave of information technology innovation in the 1990s, whereas the United States has ridden them and reaped the benefits of the internet revolution.

4. Japan's economic performance before and after the "lost decade"

Based on the formula and dataset described above, we can analyze the long-run economic performance of Japan and the contribution of information technology. Table 1 shows results of measurements of economic growth, 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 the fundamental trend.

Table 1. Economic growth, labor productivity, TFP, and the contribution of IT

	76-80	81-85	86-90	91-95	96-00	01-05	changes from previous five years				
	a	b	c	d	e	f	b-a	c-b	d-c	e-d	f-e
Growth rate of output	4.8	3.3	5.0	1.6	0.9	1.5	-1.5	1.6	-3.3	-0.7	0.5
Growth rate of labor input	1.4	0.9	1.3	-0.3	-0.5	-0.8	-0.4	0.3	-1.5	-0.3	-0.3
Output per hour	3.4	2.4	3.7	1.9	1.5	2.3	-1.1	1.3	-1.8	-0.4	0.8
Business cycle effect	1.2	-0.0	0.3	-0.8	0.1	0.3	-1.2	0.3	-1.1	0.9	0.2
Fundamental trend	2.3	2.4	3.4	2.7	1.4	2.0	0.1	1.0	-0.7	-1.3	0.6
Capital deepening	1.7	1.5	1.8	1.6	1.0	0.8	-0.2	0.3	-0.2	-0.5	-0.3
of non-IT assets	1.6	1.3	1.3	1.2	0.6	0.4	-0.3	0.0	-0.1	-0.6	-0.2
of IT assets	0.1	0.2	0.4	0.3	0.4	0.4	0.1	0.3	-0.1	0.1	-0.0
Total factor productivity	0.6	1.0	1.6	1.2	0.4	1.2	0.4	0.7	-0.5	-0.8	0.8
Addendum											
[Income shares (percentage)]											
α share Ko	31.1	29.6	29.8	25.5	22.3	21.7	-1.6	0.2	-4.3	-3.2	-0.6
β share Ki	1.9	1.9	3.0	3.6	4.5	5.9	-0.0	1.1	0.6	0.9	1.4
γ s share Lh	66.9	68.5	67.3	71.0	73.2	72.4	1.6	-1.3	3.7	2.2	-0.8
[Annual growth rate of inputs]											
dKo	6.5	5.3	5.7	4.5	2.2	1.0	-1.2	0.4	-1.2	-2.3	-1.3
dKi	5.3	8.9	15.8	9.0	8.6	5.9	3.6	6.9	-6.8	-0.4	-2.7
dU	3.5	-0.1	0.9	-2.6	0.2	0.8	-3.5	0.9	-3.5	2.8	0.6

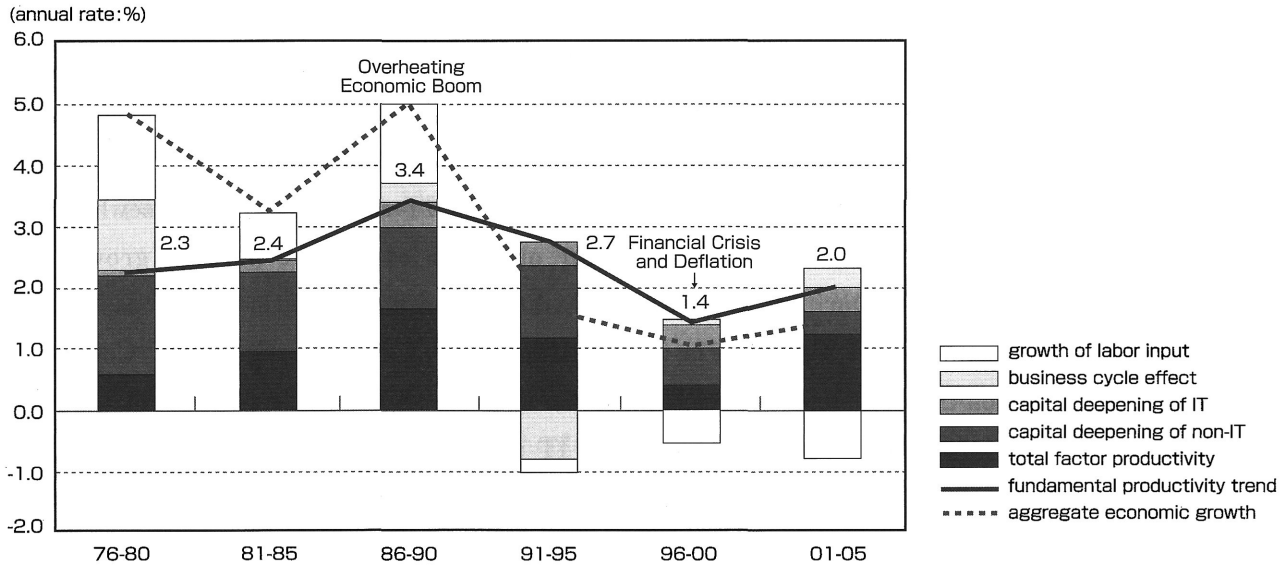
Source: Author's calculation.

Japanese macroeconomic performance has changed drastically over the last three decades. Figures in the first line illustrate the transformation well. Apparently, the economy enjoyed a powerful boom in the

late 1980s and plunged into a deep slump in the 1990s. The economy grew at healthy 3.3 percent annually in the early 1980s and at 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 at 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 of productivity improvement. More precisely, it was driven by the surge in TFP and capital deepening of IT assets.

In the 1990s, however, the economy plunged into a deep slump, especially in the second half of the decade. The economy grew at a mere 1.3 (1.6 in the first half, 0.9 in the second half) percent annually with sluggish productivity improvement during the 1990s. The growth rate of the economy was less than one-third of the rate in the late 1970s or late 1980s, and less than half of the rate in the early 1980s. This sluggishness is also apparent in productivity figures. The fundamental trend of output per hour rose at 2.7 percent annually in the early 1990s and at the even worse pace of 1.4 percent in the late 1990s. The trend of productivity growth in the latter 1990s fell sharply by two percentage points from that in the late 1980s. In fact, TFP also fell by more than one percentage point. These figures well represent the stagnant economic condition that is often referred to as the "lost decade" of the Japanese economy.

Figure 3. Economic growth and sources of productivity growth



Source: Table 1 in this paper.

Nevertheless, the economy finally seemed to show slight signs of recovery in the early 2000s when Japan underwent several important reforms led by the Koizumi Administration. Although the aggregate growth rate of the economy was one and half percent in the first half of the 2000s, that was true mainly because of the decreasing trend of labor input, which reflects the private business sector's efforts at downsizing and restructuring. Regarding the fundamental productivity trend, productivity apparently bailed the country out of its deepest slump of the late 1990s. The productivity trend has recovered by 0.6

percentage points from 1.4 percent to 2.0 percent since 2001, mainly because of the resurgence of TFP. The annual growth rate of TFP, which plunged to 0.4 percent in the late 1990s, has improved by 0.8 percentage points to 1.2 percent now: it compensates somewhat for the weak contribution of capital deepening. The resurgence of TFP reflects the recovery of aggregate efficiency in the Japanese economy.

5. Neither a "Solow paradox" nor a "new economy" in Japan

In the discussion presented in this subsection, we specifically address the contribution of information technology to productivity improvement and resultant economic growth. As Table 1 presents, 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, and 2001–2005 were, respectively, 2.3, 2.4, 3.4, 2.7, 1.4, and 2.0 percent (see the fifth line of the table), of which capital deepening contributed 1.7, 1.5, 1.8, 1.6, 1.0, and 0.8 percentage points, respectively (see the sixth line of the table).

Although the overall contribution of capital deepening seems to have changed little, the composition of that capital deepening shifted substantially. The capital deepening of IT assets gained in influence, from 0.1 in the late 1970s to 0.4 in the late 1980s. It has remained almost unchanged until now (see the eighth line of the table), whereas non-IT assets have become less important, from 1.6 to 0.4 percent (see the seventh line of the table). The surge of IT capital deepened in the late 1980s, reflecting the increased importance of information technology (see increase of income share in addendum of Table 1) and the faster growth in information technology assets (see growth rate of input in addendum of Table 1).

In the first half of the 1990s, however, the capital deepening of IT assets lessened somewhat and has almost remained unchanged since then, accounting for one-fifth of the 2.0 percent growth of the productivity trend in the 2000s. During the same period, the capital deepening in non-IT assets became remarkably less productive, from 1.3 percent in the late 1980s to 0.4 in the early 2000s. Consequently, the impact of IT assets on the economy has recently become as great as that of non-IT assets.

The matter at issue, however, is not a comparison of IT assets to non-IT assets, but rather periodic changes in IT assets in terms of their contribution to productivity improvement and resultant economic growth. The last five columns of Table 1 present important data. Acceleration of the TFP (see the ninth line) and the contribution from IT assets (see the eighth line) are described as periodic changes in each of five years. The remarkable fact is that the changes of TFP and contribution of IT capital assets ran in the same direction instead of in opposite directions until the mid-1990s. This characteristic differs greatly from the fact that the growth rate of TFP and the contribution of IT assets ran in opposite directions in the U.S. until the mid-1990s (Table 2). In the United States, therefore, "economists were puzzled as to why productivity growth was so slow despite the widespread use of information technology." [3] It was, demonstrably, a "Solow paradox."

Table 2. Acceleration of the U.S. economy and the contribution of IT

	1959-73(a)	1973-95(b)	1995-2003(c)	(b)-(c)	(c)-(b)
Output per hour	2.9	1.5	3.1	-1.4	1.6
Capital deepening	1.4	0.9	1.8	-0.5	0.9
of IT assets	0.2	0.4	0.9	0.2	0.5
TFP*	1.5	0.6	1.3	-0.9	0.7

Source: Jorgenson et al. (2004), * TFP includes contribution of labor quality.

The Japanese economy is a case in contrast. For example, during 1981–1985, TFP increased by 0.4 percentage points from the previous five years with a 0.1 percentage point contribution of IT capital assets. There was 0.7 percentage point TFP growth with a 0.3 percent point IT capital assets contribution during 1986–1990, in addition to -0.5 percentage point TFP growth with a -0.1 percent point IT capital assets contribution during 1991–1995. Accordingly, TFP was positive when capital deepening of IT capital assets contributed positively, although TFP was negative when IT capital assets contributed negatively. In other words, we never saw the "Solow paradox" in Japan 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. For example, during 1996–2000, TFP decreased by 0.8 percentage points from the previous five years, with a 0.1 percentage point positive contribution of IT capital assets; during 2001–2005, 0.8 percentage point TFP growth with unchanged (-0.0 percent point) IT capital assets contribution. Therefore, it seems that larger changes of TFP, from 1.2 to 0.4 to 1.2, were never affected by capital deepening of IT assets, which remained almost unchanged during those periods. It follows that we can see neither the "Solow paradox" before the mid-1990s nor the "new economy" after the mid-1990s in Japan. Those observations are a clear contrast to those of the U.S., where the "paradox" was noticeable before the mid-1990s, as was the "new economy" after the mid-1990s.

Taken in light of the description presented in the above section, it seems reasonable to conclude that the former observation (lack of a "Solow paradox") represents successful investment in "legacy" information technology in the 1980s, and the latter observation (lack of a "new economy") represents unsuccessful investment in open-network technologies of the internet in the 1990s.

6. Conclusion

In this paper, we reviewed the contribution of information technology to Japan's economic growth over the last 30 years to examine the impact of the technology on the economy. This analysis revealed that the Japanese economy successfully introduced the "legacy" type of the IT before the mid-1990s but that it failed to keep pace with the drastic change of technology that occurred in the 1990s. Namely, there is neither a "Solow paradox" nor a "new economy" in Japan. They are sharp contrasts to the economic performances in the United States where the paradox apparently existed before mid 1990s while it disappeared and a new economy has emerged since late 1990s.

From this point another question emerged; why did the Japanese economy miss the window of opportunity to ride on the new waves of IT innovation since 1990s in spite of the success in the 1980s? We have to go on to an even more examination to address this puzzle.

(Note)

(1) For detailed arguments, see Brynjolfsson & Hitt (1996), Oliner & Sichel (2000), Jorgenson (2001), and Stiroh (2002).

(2) See Solow (1987). Until the early 1990s, most empirical studies of the U.S. economy found no evidence of a positive correlation, and some found negative correlation, between IT and productivity (U.S. Department of Labor [1994]). Therefore, it is likely that the "Solow paradox" pertained there.

(3) Baily (2002), p. 4.

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