Japan's Economic Growth and Information Technology : Potential despite Fumbled Innovation

篠崎, 彰彦
九州大学大学院経済学研究院 国際経済経営部門 国際企業分析 : 教授

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篠﨑　彰彦
Akihiko SHINOZAKI

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Potential despite Fumbled Innovation

Akihiko SHINOZAKI[**]
Kyushu University, Japan

[Abstract]

The purpose of this paper is to measure the influence of information technology (IT) on Japanese economic growth. For this purpose, we first conduct growth accounting analysis for data acquired over the last 30 years, reviewing the contribution of information technology to economic growth. Then we estimate and simulate production function models that incorporate IT capital stock and network effects explicitly. These analyses yield four observations. First, the Japanese economy has experienced sluggish IT investment since the 1990s, although it had a massive investment boom in the late 1980s. Second, growth accounting analysis reveals that information technology has not contributed changes of productivity growth since the 1990s, when new types of open-network technology prevailed throughout the world, although it had surely influenced the productivity growth until the late 1980s. Third, estimation of the production function model proves that IT capital stock and network effects significantly influenced the economy, which suggests that sluggishness of IT investment plunged the economy into a lower growth path since the 1990s. Fourth, simulations of the production function model demonstrate that the economy has potential to grow at a higher rate than the consensus belief of less than two percent. Consequently, it could be argued that the Japanese economy, for which we have not yet seen a "new economy," still has fair room to accelerate economic growth if it were somehow able to maximize the benefits of innovation, which the economy has fumbled during the last decade.

Keywords: information technology, new economy, Solow paradox, productivity, Japanese economy

JEL classification number: E22, L16, O47, O53

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[**] Kyushu University, Japan. E-mail: shino@en.kyushu-u.ac.jp

Contents

1. Introduction

A controversial discussion has arisen related to the potential growth rate of the Japanese economy. The majority view claims that the economy can grow at merely one and half percent annually at most[1], although some analysts argue that it is feasible to raise the growth rate to around three percent annually[2]. In this argument, apparently, the major difference between pessimism and optimism derives from whether the Japanese economy can reap the benefits of globalization and innovation in information technology (IT).

As described herein, we specifically examine the magnitude of the information technology on the Japanese economic growth because recent empirical studies elucidate that information technology has surely contributed to the surge in productivity in the United States and its consequent economic growth since the mid-1990s[3]. In the U.S., a driving force of that drastic change has been massive investment in information technology since the early 1990s. Eventually, the consensus has formed that a "new economy" has emerged, even as the "Solow paradox," as derived from Solow's famous quip, "You can see the computer age everywhere but in the productivity statistics[4]," 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 and what is going on in the next

[1] See, for example, Council on Economic and Fiscal Policy (2005).
[2] See, for example, Adams, et al. (2007).
[3] For detailed arguments, see Jorgenson, et al. (2008), Oliner, et al. (2007).
[4] 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.

few decades. To address this question, we first conduct growth accounting analysis over the last 30 years, reviewing Japan's economic growth and the contribution of information technology to the growth; then we overview the periodic changes of Japan's productivity and IT investment to assess whether the "new economy" as well as the "Solow paradox" has been true for Japan. Secondly, we estimate production function models in which IT capital stock and network effects are incorporated explicitly. Using them, we explore whether it is realistic to assume that information technology contributes and accelerates Japan's economic growth. Based on the estimation results, we simulate the economy's growth paths in the next few decades under the country's diminishing demographic trend.

2. Analytical framework

2-1. Growth accounting model

For the first 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 fundamental concept of the 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 reason 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) $Q=TK_o^{\alpha}K_i^{\beta}L^{\gamma}$,

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, and L is the labor input representing work hours of total employees. Consequently, eqn. (1) can be transformed to

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

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 average labor productivity, $\dot{T}$ represents changes in TFP, and $\dot{K}-\dot{L}$ represents changes in capital assets per hour worked, which is designated as 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 well known to be so pro-cyclical that the structural trend of productivity must be distinguished from business-cycle-related changes of productivity. For this discussion, the utilization rate of capital assets is used as a proxy of business cycle effects to remove the influence of the business cycle from labor productivity. The second adjustment we must make is to consider labor quality. An important trend that drives economic development is known to be knowledge. In a knowledge-based economy, economic prosperity depends deeply on labor quality as well as capital stock and technology. We employ the education record as a proxy of labor quality for these analyses. Therefore, eqn. (1) can be modified to

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

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

$$(4)\ \dot{Q}\text{-}\dot{L}=\dot{T}+\alpha(\dot{K}_o\text{-}\dot{L})+\beta(\dot{K}_i\text{-}\dot{L})+(\alpha+\beta)\dot{p}+\gamma\,\dot{edu}$$

Here, 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 hour worked (capital deepening of non-IT: $\dot{K}_o\text{-}\dot{L}$), IT capital assets per hour worked (capital deepening of IT: $\dot{K}_i\text{-}\dot{L}$), the utilization rate of capital assets ($\dot{p}$) as a proxy of the business cycle effect, and the education record of employees ($\dot{edu}$)as a proxy of labor quality.

2-2. Production function model

For the second analysis, we use a production function model describing a mapping from quantities of inputs to quantities of an output as generated by a production process. We employ and modify a traditional Cobb–Douglass model to estimate and simulate the Japanese economic growth path in several scenarios. We estimate production function models of three types: a base model of a traditional Cobb–Douglass function with two simple input factors of total capital assets and labor input; an IT assets model, in which the impact of IT capital assets can be measured respectively by dividing total capital assets into IT and non-IT capital assets; and a network effect model, which accommodates increasing returns of scale, where network externality is incorporated in those two ways as the spread of IT infrastructure and sufficient use of them.

[Base model]

Equation (5) presents the fundamental Cobb–Douglass type production function model with capital assets and labor input in which labor quality is incorporated.

$$(5)\ Q=A(eduL)^{\alpha}(pK_{all})^{\beta}$$

In that equation, α and β respectively signify output elasticity with respect to labor input and capital stock, assuming constant returns to scale (i.e. $\alpha+\beta=1$). In addition, Q is the private output, A is the level of technology, edu is the education record of employees, L is the labor input representing work hours of total employees, p is the capital asset utilization rate, and K_{all} represents total capital assets without distinguishing IT and non-IT capital assets ($K_{all} = K_i + K_o$).

[IT assets model]

Based on the model shown above as eq. (5), it is impossible to estimate and simulate the impact of IT investment to the economic growth explicitly because IT capital assets are contained in total capital assets in the base model. Therefore, the base model must be modified to a model in which IT capital assets are represented explicitly by dividing capital assets into IT and non-IT capital assets, as

$$(6)\ Q=A(eduL)^{\alpha}K_o^{\beta}K_i^{\gamma},$$

where α, β, and γ respectively signify output elasticity with respect to labor input, non-IT capital stock, and IT capital stock assuming constant returns to scale (i.e. $\alpha+\beta+\gamma=1$).

[Network effect model]

Equations (5) and (6) portray the hypothesis of constant returns to scale (i.e., $\alpha+\beta=1$ or

$\alpha+\beta+\gamma=1$). The theory of the information economy, however, demonstrates a "network effect" or a "network externality" that loosens the hypothesis of constant returns to scale: it supports increasing returns to scale (i.e. $\alpha+\beta+\gamma>1$). The following model, in which network effects are considered, was estimated by JCER (2000).

$$(7)\ Q=A(eduL)^{\alpha}K_{all}^{\beta}K_i^{\gamma}$$

Therein, $\alpha+\beta=1$, $\gamma>0$, and $K_{all} = K_i + K_o$, implying that IT capital assets (K_i) contribute to the output in two such paths that they ordinarily serve as a capital input for their own production processes and that they additionally serve as a kind of public good, or infrastructure, for others' production processes. In the former path, their contribution is represented in a part of K_{all} input, although it is exhibited in the form of explicit contribution of K_i in the latter path.

When JCER (2000) conducted estimation of the model in eqn. (7), it proved that IT capital assets (K_i) show a positive network externality, or 9% of increasing returns of scale (i.e. $\alpha+\beta+\gamma=1.091>1$, $\gamma=0.091$) as does Shinozaki (2003), with an estimate of 16% increasing returns of scale (i.e. $\alpha+\beta+\gamma=1.162>1$, $\gamma=0.162$).

The model shown above as eqn. (7), however, does not incorporate an important aspect of network effect. Given the same amount of IT capital assets value, the model does not distinguish a small number of mainframe computers from a large number of personal computers. For example, the network effects of a single mainframe computer valued at 1 million US dollars and one thousand personal computers of 1,000 US dollars (total value of PCs is 1 million US dollars) differ greatly, but the model of eqn. (7) treats them as equal.

Furthermore, the model does not consider whether IT assets are sufficiently used or not, i.e., aggressive use and lackluster use of the technology are identical given the same amount of IT assets, even though their network effects must quite differ. To address these limitations and improve the network effect model, we modify the model to the following.

(7') $Q=A(eduL)^{\alpha}K_{all}^{\beta}(ubqK_i)^{\gamma}$

Therein, $\alpha+\beta=1$, and $K_{all}=K_i+K_o$, *ubq* is the ubiquitous index that comprises the number of PC users, cellular phone users, circulation volume of information, and several other related figures. Consequently, *ubq* is considered as an appropriate proxy to denote the pervasion and effective use of the information technology[5]. In this model, the network effect is identified if we attain the statistically significant parameter $\gamma>0$, i.e. $\alpha+\beta+\gamma>1$.

3. Dataset and overview of IT investment in Japan

All datasets described in this paper are taken from officially published data compiled by government ministries or research institutes: output data and overall capital input data from the Cabinet Office, labor input data and education record of employees from the Ministry of Health, Labour and Welfare, utilization rates from the Ministry of Economy, Trade and Industry, and information technology assets and the ubiquitous index from InfoCom Research, Inc.

(Figure 1)

Before carrying out growth accounting analysis and production function analysis, it will be useful to review Japan's IT investment history. As Fig. 1 depicts, 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

[5] For details, see Noguchi, et al. (2008).

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. Regarding computer investment, it was for a time the largest component of IT investment, but it is now merely 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. The first is a long-run investment boom in the late 1980s. Second is decreased technology investment in the early 1990s and a cyclical fluctuation from the mid-1990s to the late 1990s. The third is the end of the downward trend and a slight sign of recovery in hardware investment that was 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 businesses invested aggressively 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 new open-network technology in the 1990s.

In Japan, deregulation had just begun in the telecommunications market in 1985, but 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 even as U.S. firms were confronting the productivity paradox.

The Japanese IT investment boom, however, halted abruptly in the early 1990s when new types of open-network technology surged throughout the world; they were downsizing from mainframe computers and adopting 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)

That change of investment trend—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 increased 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 rate 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 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. In sharp contrast, the United States has ridden them and reaped the benefits of the internet revolution.

4. Results of growth accounting analysis

4-1. Japan's past economic performance

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 portrays 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)

Japanese macroeconomic performance has changed drastically over the last three decades. Figures in the first line portray 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 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 designated as the “lost decade” of the Japanese economy.

(Figure 3)

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 0.0 percent in the late 1990s, has improved by 0.9 percentage points to 0.9 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.

4-2. Neither "Solow paradox" nor "new economy"

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), although 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 the 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 remained almost 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 tenth line) and the contribution from 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 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."[6] It was, demonstrably, a "Solow paradox."

(Table 2)

The Japanese economy is a case in contrast. For example, during 1981–1985, TFP increased by 0.2 percentage points from the preceding five year period 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 -0.4 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 preceding five-year period, with a 0.1 percentage point positive contribution of IT capital assets; during 2001–2005, 0.9 percentage point TFP growth with unchanged (-0.0 percent point) IT capital assets contribution. Therefore, it seems that larger changes of TFP, from 0.8 to 0.0 to 0.9, 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.

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

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.

4-3. Implications of the new economy in the U.S.

As our analysis shows, Japan seems to have missed the chance to ride on the "new economy." It could be argued, however, that huge potential beckons in its current economy. In other words, the Japanese economy could even now accelerate productivity and resultant economic growth if it were to embrace the "new economy" and take full advantage of the dynamism of the IT innovation as the U.S. economy certainly did over the last decade. Therefore, in this subsection, we will conduct some simple measurements of Japan's potential growth rate given that the Japanese economy reaps the benefits of IT investment, as the U.S. economy has done since the mid-1990s.

Before we make such an estimate, it is useful to review the long-run trace of Japan's fundamental productivity trends for measurement of a baseline of potential growth rate. As examined in section 4-1, the growth rate of the economy has fluctuated greatly over the last three decades. Regarding the fundamental productivity trend, however, the changes were not so drastic: they were moderate because fluctuation effects of labor input and the business cycle were removed, as Fig. 3 illustrates well.

Furthermore, disregarding the exceptional periods of the late 1980s, a period of an overheating economic boom or bubble, and the late 1990s, a period of financial crisis and deflation, the fundamental productivity trends are stable: 2.3 percent in the late 1970s, 2.4 percent in the early 1980s, 2.7 percent in the early 1990s, and 2.0 percent in the early 2000s. As the data in Table 3 underscore, the average growth rate of fundamental productivity trend in these stable periods is around two and half percent. It therefore seems appropriate to conclude that an annual productivity growth rate of two and half percent is the baseline that the Japanese economy preserves as a minimum potential.

(Table 3)

For measurement of economic growth, demographic trends must be considered as well as the productivity baseline. The Japanese national population is predicted to decrease for some time. According to the National Institute of Population and Social Security Research, the working-age population will be decreasing just less than one percent annually over the next few decades. Under this diminishing demographic trend, the potential economic growth rate would be less than two percent annually even if the recent level of IT contribution were examined.

What should not be disregarded is the fact that the U.S. economy accelerated its productivity by more than one percentage point over the last decade. Major contributions to this rising tide derive from IT assets and TFP. If we simply presume that the Japanese economy catches up with a level of the U.S. or achieves a similar rate of acceleration to that of the U.S., the economy will grow at a healthy clip, two and half percent or more annually, rather than just below the two percent that has been generally accepted in Japan.

Although adaptation of figures of the U.S. to the Japanese economy might seem simplistic and naïve, it suggests that the Japanese economy has the potential to realize faster economic growth than consensus views. To verify these potentials, further empirical studies are needed, such as estimations and simulations of a production function model that elucidate explicit contribution of IT innovation. We will explain them in the following section.

5. Results of the production function model analysis

5-1. Estimation of the production function model

As explained in section 2-2, to explore whether it is realistic to assume that information technology contributes and accelerates Japan's economic growth, we will estimate production function models of three types: a base model, an IT assets model, and a network effect model. Constant returns to scale are assumed in the base model and the IT assets model, whereas the network effect model allows increasing returns of scale.

To estimate each model, eqns. (5), (6), and (7') shown in section 2-2 are transformed to eqns. (8), (9), and (10) respectively, dividing both sides by *eduL* and taking logarithms of both sides.

[Base model]

$$(8)\ \ln(Q/eduL) = \ln A + \beta \ln (pK_{all}/eduL) + e$$

In that equation, α and β represent output elasticity with respect to labor input and capital stock respectively, assuming constant returns to scale (i.e., $\alpha+\beta=1$), Q is the private output, A is the level of technology, edu is the education record of employees, L is the labor input representing work hours of total employees, p is the utilization rate of capital assets, K_{all} represents total capital assets without distinguishing IT and non-IT capital assets ($K_{all} = K_i + K_o$), and e is an error term.

[IT assets model]

(9) $\ln(Q/eduL) = \ln A + \beta \ln (pK_o/eduL) + \gamma \ln (pK_i/eduL) + e$

where α, β, and γ represent output elasticity with respect to labor input, non-IT capital stock, and IT capital stock respectively, assuming constant returns to scale (i.e. $\alpha+\beta+\gamma=1$).

[Network effect model]

(10) $\ln(Q/eduL) = \ln A + \beta \ln (pK_{all}/eduL) + \gamma\, ubqK_i + e$

Therein, $\alpha+\beta=1$, $\gamma>0$, and $K_{all} = K_i + K_o$, ubq clarify the ubiquitous index, assuming increasing returns to scale (i.e. $\alpha+\beta+\gamma>1$).

Each estimation is conducted taking first order serial correlation (AR[1]) into account. Estimation results of eqs. (8), (9), and (10) are shown respectively in the following eqs. (8'), (9'), and (10').

[Base model]

(8') $\ln(Q/edu\,L) = -2.368 + 0.545 \ln(K_{all}/edu\,L) + 0.584$ AR[1]

(-18.16) (26.38) (3.16)

$_{adj}R^2 = 0.994$, D.W. $= 1.675$, t-statistics: shown in (), sample year: 1976-2005.

[IT assets model]

(9') $\ln(Q/edu\,L) = -0.936 + 0.238 \ln(K_o/edu\,L) + 0.144 \ln(K_i/edu\,L) + 0.703$ AR[1]

(-1.61) (1.99) (3.20) (2.78)

$_{adj}R^2$ = 0.996, D.W. = 1.608, *t*-statistics: shown in ( ), sample year: 1976–2005.

[Network effect model]

(10') $\ln(Q／edu\ L) = -1.600 + 0.357 \ln(K_{all}／edu\ L) + 0.021(ubq\ K_i) + 0.946$ AR[1]

(-5.39) (5.96) (2.50) (14.77)

$_{adj}R^2$ = 0.993, D.W. = 1.472, *t*-statistics: shown in ( ), sample year: 1976–2005.

(Table 4)

Table 4 presents a summary of the estimation results of three production function types, demonstrating that IT capital assets significantly affect the economic growth and identifying a positive network effect even though Japan has not reached the new economy yet. These results suggest that sluggish IT investment drove the economy into a lower growth path since the 1990s and that the economy, nevertheless, has the potential to introduce the benefits of IT innovation through intensive investment in the technology hereinafter. Accordingly, the estimation results lead us to another empirical study: to simulate alternative perspectives of the Japanese economic outlook, using the production function models described above.

5-2. Simulation of Japan's next growth path

Now we attempt to simulate Japan's economic growth path toward 2025 based on the estimation results of three types shown above. Based on eqn. (8'), we can not explicitly measure opportunities of IT innovation, although we can simulate another growth path based on eqn. (9') or (10'), where we can incorporate IT innovation into economic projections.

For the simulation, we use the following assumptions. Regarding the labor input, we adopt the decreasing trend of working age population projected by National Institute of Population and Social Security Research, while we assume that labor quality continues to improve at the same clip as the average rate of improvement during 1991–2005. For capital input, we employ the average growth rate of types of capital asset during 1991–2005, except for IT capital assets. Regarding IT capital assets, we assume that capital deepening of the IT assets (i.e. IT assets per hour worked) during 2011–2020 will grow as fast as it did in the late 1980s because it is predicted that information network industries will be vitalized and compete harder in several innovative markets generated by technological progress of media convergence, digital broadcasting, etc., as well as further deregulation. We also use the average growth rate of the ubiquitous index during 2000–2005 for our projection toward 2025, assuming it will continue growing as fast as it has since 2000, when broadband networks and mobile internet services had just begun to be adopted.

(Figure 4)

Figure 4 portrays the simulation results. The average growth rate of the economy in the base model is measured as 1.5% annually, whereas the IT assets model shows a half percentage point higher growth rate of 2.0%. Moreover, the network effect model proves the economy can grow at 2.8% annually, 1.3% faster than base model suggests[7]. Therefore, it could be concluded that simulations of the production function model strongly support the possibility of a faster growth path, which is suggested by the growth accounting analysis we conducted in section 4-3.

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[7] Several other empirical studies also suggest faster economic growth of Japan. See Adams, et al. (2007).

6. Conclusion

As described in this paper, we examine the impact of information technology on Japanese economic growth, conducting empirical analysis of the growth accounting model and production function model. These analyses 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 has been neither a "Solow paradox" nor a "new economy" in Japan. Results also show that IT assets and network effect significantly influenced the economy and that the economy has some potential to grow at a higher rate than the consensus belief of one and a half percent annually. Therefore, it might be argued that the Japanese economy, which has fumbled innovation to date, still has fair room to accelerate economic growth if intensive investment and efficient use of the technology are instilled throughout the economy.

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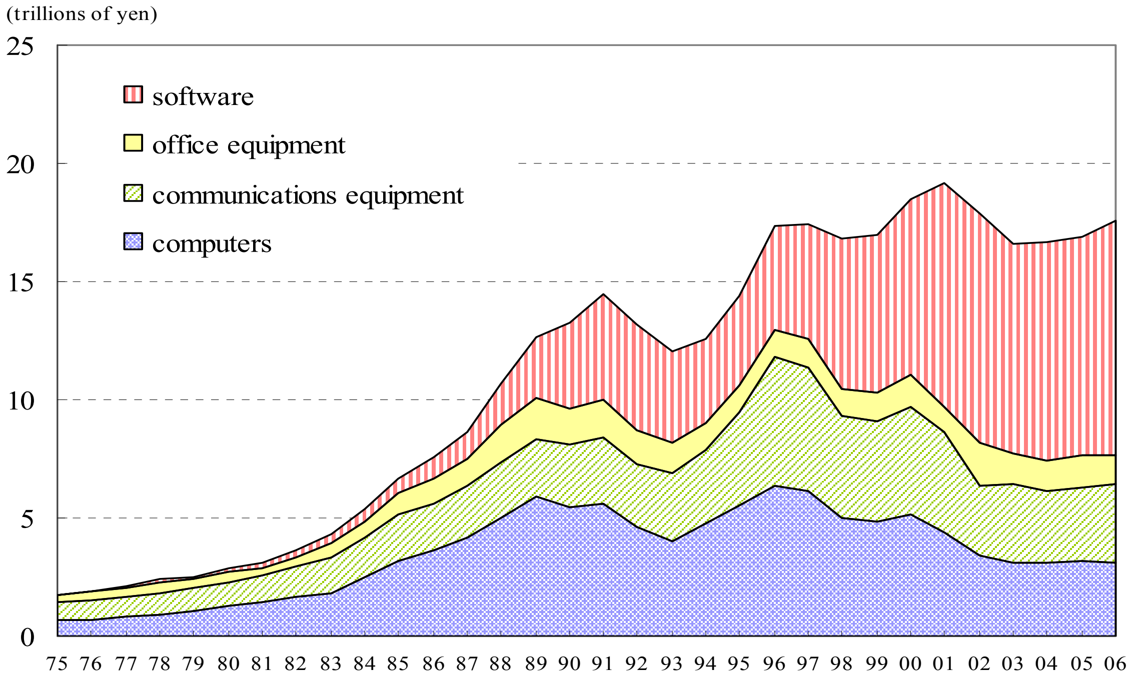
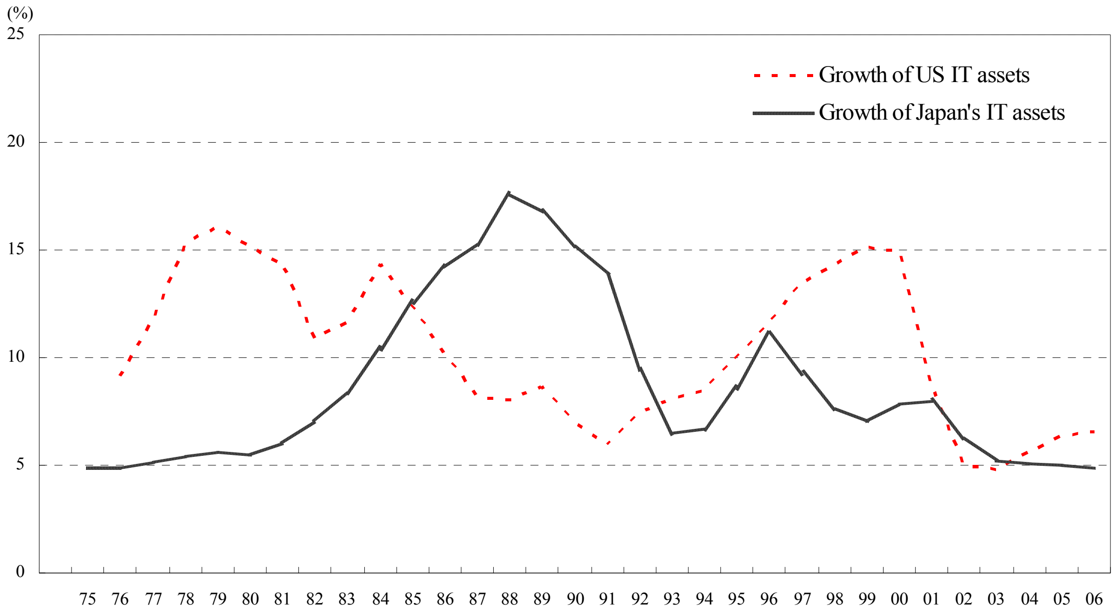
Tables and Figures

Figure 1. Japan's nominal investment in IT



Source: InfoCom Research, Inc. (2007).

Figure 2. Growth of IT assets and non-IT assets



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

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

	76-80	81-85	86-90	91-95	96-00	01-05	difference				
	a	b	c	d	e	f	b-a	c-b	d-c	e-d	f-e
Private output	4.8	3.3	5.0	1.6	0.9	1.5	-1.5	1.6	-3.3	-0.7	0.5
Hours worked	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
Labor quality	0.3	0.4	0.3	0.3	0.4	0.3	0.1	-0.1	-0.0	0.1	-0.0
Total factor productivity	0.3	0.6	1.3	0.8	0.0	0.9	0.2	0.7	-0.4	-0.8	0.9
[Income shares (percentage)]											
share Ko (α)	31.1	29.6	29.8	25.5	22.3	21.7	-1.6	0.2	-4.3	-3.2	-0.6
share Ki (β)	1.9	1.9	3.0	3.6	4.5	5.9	-0.0	1.1	0.6	0.9	1.4
share L (γ)	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]											
d Ko	6.5	5.3	5.7	4.5	2.2	1.0	-1.2	0.4	-1.2	-2.3	-1.3
d Ki	5.3	8.9	15.8	9.0	8.6	5.9	3.6	6.9	-6.8	-0.4	-2.7
d edu	0.4	0.6	0.5	0.4	0.5	0.4	0.2	-0.1	-0.1	0.1	-0.1

Source: Author's calculation.

Note: Figures might not add precisely because of rounding.

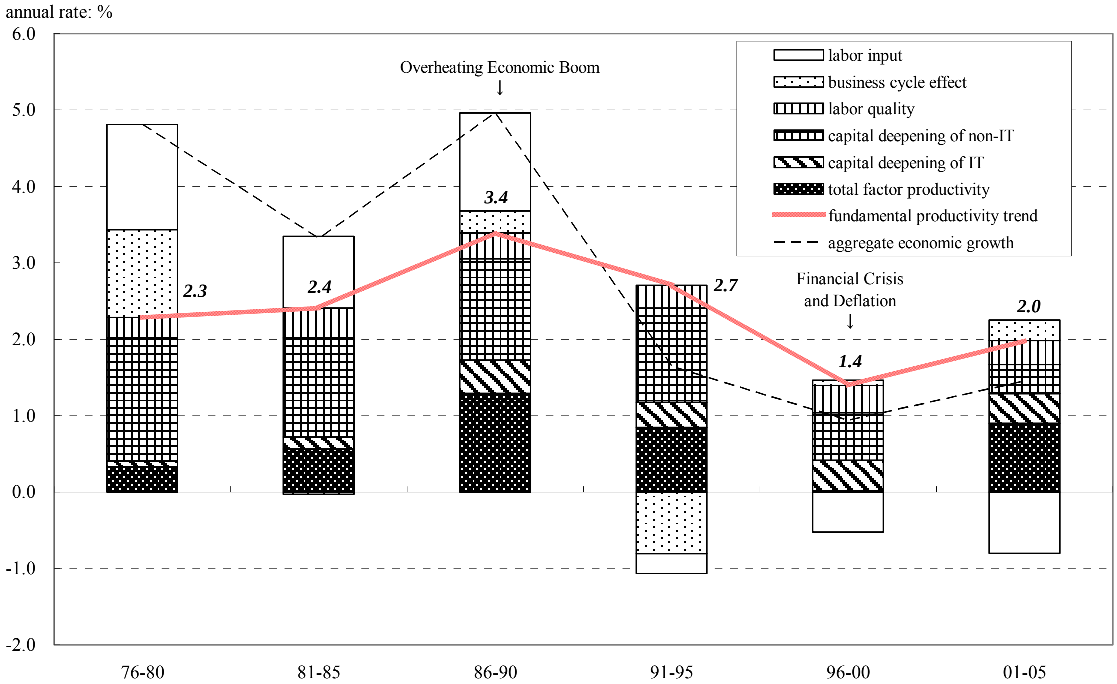
Table 2. Acceleration of the U.S. economy and the contribution of IT assets

	1959–73	1973–95	1995–2006		difference		
	(a)	(b)	(c)	95-2000 (d)	(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 add precisely because of rounding.

Figure 3. Economic growth and sources of productivity growth



Source: Table 1 in this paper.

Table 3. Japan's potential growth rate and estimation of its acceleration

	Japan's economic growth rate		Estimation of acceleration	
	Average	Potential rate	Case I	Case II
Growth rate	**2.81**	**1.63**	**2.33**	**2.58**
Labor input	**0.31**	**-0.86**	**-0.86**	**-0.86**
Labor Productivity	2.49	2.49	3.19	3.44
Business Cycle	0.15	—	—	—
Trend	**2.35**	**2.49**	**3.19 (+0.70)**	**3.44 (+0.95)**
Capital deepening	1.37	1.51	1.91	1.89
of non-IT	1.13	1.13	1.13	1.13
of IT assets	0.24	0.38	0.78	0.76
Labor quality	0.32	0.32	0.32	0.32
Total Factor Productivity	0.66	0.66	0.96	1.23

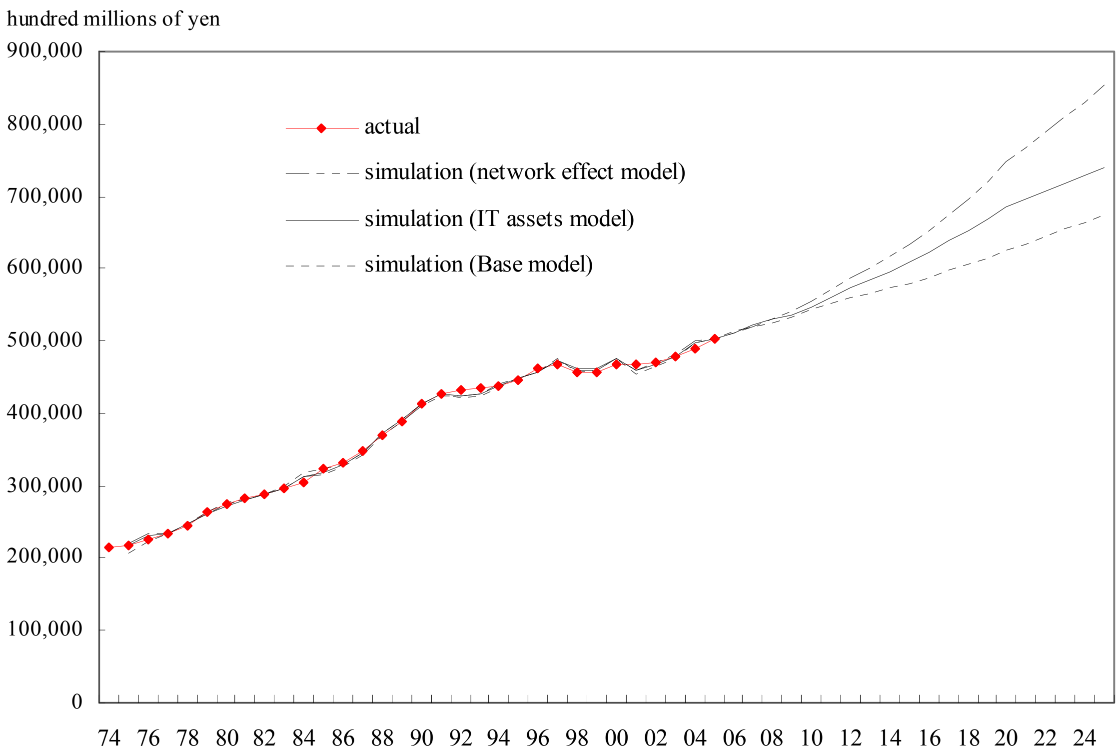
Note: Average excludes extraordinary periods of the late 1980s and the late 1990s. The potential rate incorporates demographic trends in the next few decades and recent contribution of IT assets. Case I represents that Japan's TFP and capital deepening of IT assets can catch up with those of the U.S. Case II represents that Japan can accelerate its productivity by 0.95 percentage points, as the U.S. has done since the late 1990s.

Table 4. Results of estimation

	Base model			IT assets model			Network effect model		
	coefficient		*t*-statistics	coefficient		*t*-statistics	coefficient		*t*-statistics
C	-2.368	**	-18.161	-0.936		-1.608	-1.600	**	-5.386
$K_{all}/eduL$	0.545	**	26.383				0.357	**	5.955
$K_o/eduL$				0.238	*	1.986			
$K_i/eduL$				0.144	**	3.199			
$ubq{*}K_i$							0.021	*	2.498
$AR(1)$	0.584	**	3.162	0.703	**	2.783	0.946	**	14.773
Labor share	0.455			0.618			0.643		
Capital share	0.545			0.382			0.357		
(of non-IT)				0.238					
(of IT)				0.144					
$_{adj}R^2$	0.994			0.996			0.993		
D.W.	1.675			1.608			1.472		
growth rate (2008-25)	1.5 %			2.0 %			2.8 %		

Source: Author’s calculation.

Figure 4. Simulation of Japan’s next growth path



Source: Author’s calculation.