Simulating Japan’s Alternative Growth Paths: Production Function Model Analysis on the Impact of Information Technology

Shinozaki, Akihiko
Faculty of Economics, Kyushu University

出版情報：InfoCom REVIEW. 47, pp.44-53, 2009-03. InfoCom Research

論文

Simulating Japan's Alternative Growth Paths

Production Function Model Analysis on the Impact of Information Technology

Akihiko Shinozaki*

Abstract

The purpose of this paper is to explore whether it is realistic to assume that information technology (IT) will contribute and accelerate Japan's future economic growth. For this purpose, we estimate and simulate production function models that incorporate IT capital stock and network effects explicitly. These analyses yield three observations. First, the Japanese economy has experienced sluggish IT investment since the 1990s, when new types of open-network technology prevailed throughout the world, although it had a massive investment boom in the late 1980s. Second, estimation of the production function model proves that IT capital stock and network effects markedly influenced the economy, which suggests that sluggishness of IT investment plunged the economy into a lower growth path since the 1990s. Third, 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 can be argued that the Japanese 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.

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 few decades. To address this question, we first review Japan's IT investment over the last 30 years. Secondly, we estimate production function models in which IT capital stock and network effects are incorporated explicitly. Thirdly, based on the estimation results, we simulate the economy's growth paths in the next few decades. Through these analyses, we explore whether it is realistic to assume that information technology contributes and accelerates Japan's economic growth under the country's diminishing demographic trend.

2. Analytical framework

In this paper, 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 (1) presents the fundamental Cobb-Douglass type production function model with capital assets and labor input in which labor quality is incorporated.

$$(1)\ Q=A(eduL)^{\alpha}(pK_{all})^{\beta}$$

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 eqn. (1), 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

$$(2)\ Q=A(eduL)^{\alpha}(pK_o)^{\beta}(pK_i)^{\gamma}$$

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 (1) and (2) 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).

$$(3)\ Q=A(eduL)^{\alpha}(pK_{all})^{\beta}(pK_i)^{\gamma}$$

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 the explicit contribution of K_i in the latter path.

When JCER (2000) conducted estimation of the model in eqn. (3), it proved that IT capital assets (K_i) show a positive network externality, or 9% 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. (3), 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. (3) 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.

$$(3')\ Q=A(eduL)^{\alpha}(pK_{all})^{\beta}(ubq\ pK_i)^{\gamma}$$

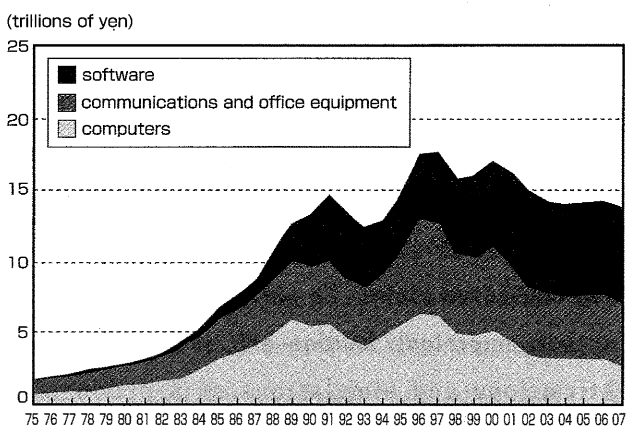
Therein, $\alpha+\beta=1$, and $K_{all}=K_i+K_o$, *ubq* is the ubiquitous index that comprises the number of

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. Japan's nominal investment in IT



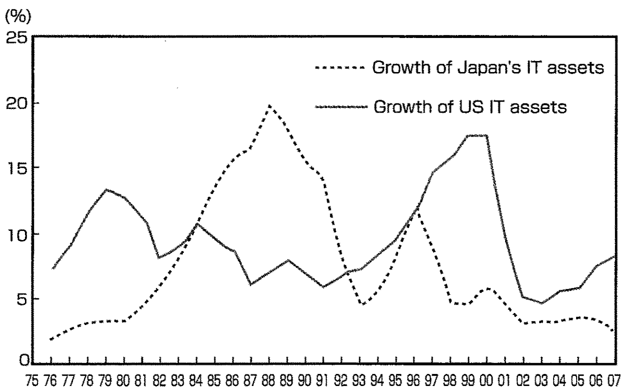
As Fig. 1 depicts, the total investment in information technology amounts to 14 trillion yen (120 billion US dollars) in 2007, which accounts for 2.7 percent of the nominal Gross Domestic Product (GDP), and 16.9 percent of total nonresidential fixed investment. The amount of investment in software technology, approximate 6.8 trillion yen (57 billion dollars), is as much as that in hardware, which amounted to 7.2 trillion yen (61 billion US dollars). However, the amount of investment in hardware including computers, communications, and office equipment was as twice as 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 2.7 trillion yen (23 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 steady 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. Growth of IT assets and non-IT assets



Source: InfoCom Research, Inc. (2008) and U.S. Department of Commerce NIPA tables.

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 20 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. Estimation of the production function model

As demonstrated above, Japan seems to have fumbled 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. Indeed, the U.S. economy accelerated its productivity by more than one percentage point over the last decade (Table1). Major contributions to this rising tide derive from IT assets and consequent productivity improvement.

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.

As explained in section 2, we will estimate production function models of three types: a base

Table 1. 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 add precisely because of rounding.

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. (1), (2), and (3') shown in section 2 are transformed to eqns. (4), (5), and (6) respectively, dividing both sides by eduL and taking logarithms of both sides.

[Base model]

$$(4)\ \ln(Q/eduL) = \ln A + \beta \ln (pK_{all}/eduL) + e$$

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, and e is an error term.

[IT assets model]

$$(5)\ \ln(Q/eduL) = \ln A + \beta \ln (pK_o/eduL) + \gamma \ln (pK_i/eduL) + e$$

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

[Network effect model]

$$(6)\ \ln(Q/eduL) = \ln A + \beta \ln (pK_{all}/eduL) + \gamma\ ubq\ pK_i + e$$

Therein, $\alpha + \beta = 1$, $K_{all} = K_i + K_o$, and *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. (4), (5), and (6) are shown in Table 2 as (4'), (5'), and (6') respectively, demonstrating that IT capital assets significantly affect the economic growth and identifying a positive network effect even though Japan has not reached

Table 2. Results of estimation

	Base model (4')			IT assets model (5')			Network effect model (6')		
	coefficient		t-statistics	coefficient		t-statistics	coefficient		t-statistics
C	-2.303	**	-16.010	-0.888		-1.814	-1.542	**	-5.341
Kall/eduL	0.537	**	23.510				0.359	**	6.056
Ko/eduL				0.229	*	2.250			
Ki/eduL				0.149	**	3.725			
ubq*Ki							0.018	*	2.189
AR(1)	0.570	**	3.316	0.662	**	3.008	0.952	**	17.315
Labor share	0.463			0.622			0.641		
Capital share	0.537			0.378			0.359		
(of non-IT)				0.229					
(of IT)				0.149					
$_{adj}R^2$	0.994			0.996			0.993		
D.W.	1.728			1.654			1.519		
growth rate	%			%			%		
(2010-20)	1.6			2.4			2.7		
(2010-25)	1.6			2.1			2.6		

Source: Author' s calculation.

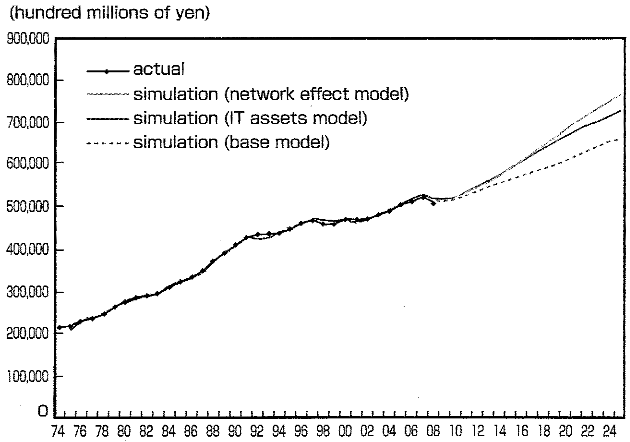
the "new economy" yet. These results suggest that sluggish IT investment drove the economy into a lower growth path since the 1990s and that the economy, nevertheless, has the potential to introduce the benefits of IT innovation through intensive investment in the technology hereinafter. Accordingly, 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. 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. (4'), we can not explicitly measure opportunities of IT innovation, although we can simulate another growth path based on eqn. (5') or (6'), where we can incorporate IT innovation into economic projections.

For the simulation, we use the following assumptions. As for a short term business cycle we assume that during 2008 and 2010 is a recession period, whereas the economy will recover from 2011. Regarding the labor input, we adopt the moderate 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 assets 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 will compete more vigorously in several innovative markets generated by technological progress of digital convergence in telecommunications and broadcasting as well as further deregulation. We also use the average growth rate of the ubiquitous index during 2000-2005 for our robust projection period from 2011 to 2020, assuming it will meet faster capital deepening of the IT assets and will grow as fast as it has in the early 2000s, when broadband networks and mobile internet services had just begun to be adopted.

Figure 3. Simulation of Japan's next growth path



Source: Author's calculation.

Figure 3 portrays the simulation results. The average growth rate of the economy in the base model is measured as one and half percent annually, whereas the IT assets model shows a half percentage point higher growth rate of two percent or more. Moreover, the network effect model proves the economy can grow at two and half percent or more annually, one percentage point faster than base model suggests (6). Therefore, it could be concluded that simulations of the production function model more strongly support the possibility of a faster growth path than the pessimistic views, which is suggested by the experience of the U.S. economy.

6. Conclusion

As described in this paper, we examine the impact of information technology on Japanese economic growth, estimating and simulating the production function models that elucidate explicit contribution of IT assets and network effects. These analyses revealed that the Japanese economy missed the chance to reap the benefit of information technology innovation since the 1990s, although empirical results show that IT assets and network effects 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.

(Note)

(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.

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

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

[References]

〔1〕 Adams, Gerard F., Lawrence R. Klein, Yuzo Kumasaka, and Akihiko Shinozaki (2007) *Accelerating Japan's Economic Growth*, Routledge Studies in the Growth Economies of Asia, Taylor & Francis, UK., October 2007.

〔2〕 Baily, Martin Neil (2002) "The New Economy: Post Mortem or Second Wind?" *Journal of Economic Perspectives*, Spring 2002, 16:2, pp. 3-22.

〔3〕 Brynjolfsson, Erik and Lorin Hitt (1996) "Paradox Lost?: Firm-level Evidence on the Returns to Information Systems Spending," *Management Science*, April 1996, 42:4, pp. 541-558.

〔4〕 Council on Economic and Fiscal Policy (2006) *The Report of the Special Board of Inquiry for Examining "Japan's 21st Century Vision,"* Cabinet Office, April 2005.

〔5〕 InfoCom Research, Inc. (2008) *InfoCom ICT Keizai Houkoku* (*InfoCom Economic Report on ICT*), November 2008, in Japanese.

〔6〕 JCER (2000) *Nihon Keizai no Sai Shuppatsu II: IT Kakushin no Shogeki to Sono Hyoka (Born Again of the Japanese Economy: Impact of IT innovation and its estimation)*, Japan Center for Economic Research, May 2000, in Japanese.

〔7〕 Jorgenson, Dale W. (2001) "Information Technology and the U.S. Economy," *American Economic Review*, March 2001, 91:1, pp. 1-32.

〔8〕 Jorgenson, Dale W., Mun S. Ho, and Kevin J. Stiroh (2004) "Will the U.S. Productivity Resurgence Continue?" *Current Issue*, Vol. 10, No. 13, Federal Reserve Bank of New York, pp.1-7.

〔9〕 Jorgenson, Dale W., Mun S. Ho, and Kevin Stiroh (2008) "A Retrospective Look at the U.S. Productivity Growth Resurgence," *Journal of Economic Perspectives*, 22:1, pp. 3-24.

〔10〕 Noguchi, Masato, Akihiko Shinozaki, Yusuke Yamamoto, and Shota Yamasaki (2008) "Yubikitasu Shisu no Suitei ni Tsuite (How to Compose Ubiquitous Index)" InfoCom Research, Inc., *Technical Papers on ICT related Economic Indices*, No. 08-2, February 2008, pp. 1-15, in Japanese.

〔11〕 Oliner, Stephen D. and Daniel E. Sichel (2000) "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?" *Journal of Economic Perspectives*, 2000, 14:4, pp. 3-22.

〔12〕 Oliner, Stephen D., Daniel E. Sichel, and Kevin J. Stiroh (2007) "Explaining a Productive Decade," *Brookings Papers on Economic Activity*, 1:2007, pp. 81-153.

〔13〕 Shinozaki, Akihiko (2003) "Tsuushin Sangyo ni Okeru Setsubitoushi no Keizai Koka Bunseki (Economic Impact of Investment in Telecom Industry)" InfoCom Research, Inc., *InfoCom REVIEW*, No.31, August 2003, pp.36-45, in Japanese.

〔14〕 Shinozaki, Akihiko (2006) "Does the sun rise again in the ubiquitous information age?: Feasibility of a vigorous economic growth for Japan under the diminishing demographic trend," Kyushu University, *Journal of Political Economy (Keizaigaku-Kenkyu)*, March 2006, 72:5-6, pp. 99-124.

〔15〕 Shinozaki, Akihiko (2008) "Japan's IT puzzle: Neither a Solow paradox nor a new economy," InfoCom Research, Inc., *InfoCom Review*, March 2008, 44, pp. 22-31.

〔16〕 Stiroh, Kevin J. (2002) "Information Technology and the U.S. Productivity Revival: What Do the Industry Data Say?" *American Economic Review*, 92:5, pp. 1559-1576.

〔17〕 Solow, Robert M. (1957) "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, 39:3, pp. 312-320.

〔18〕 Solow, Robert M. (1987) "We'd Better Watch Out," *New York Times Book Review*, July 12, 1987.

〔19〕 U.S. Department of Labor (1994) *Integrating Technology with Workers in the New American Workplace*, Washington D.C., Government Printing Office.

---

* The auther wishes to thank anonymous referees for providing helpful comments.

An earlier version of this paper was prepared for the research workshop, "Impact of the Information Technology on the Japanese Business Cycle and Economic Growth," held at the Palace Hotel, Tokyo, Japan on October 5, 2008. The workshop is a part of the International Collaboration Projects in Economic and Social Research Institute (ESRI). Some analyses presented in this paper are parts of research achievements supported by a Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science (JSPS).

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