CHAPTER 3

The IT Revolution and New Production Functions for the IT Economy

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1. IT Revolution Raised U.S. Potential Growth

Economists in the United States were pessimistic about potential U.S. growth in the early 1990's. In those days the consensus about the U.S. potential growth rate among economists was 2.0% - 2.5%. The thinking behind this was they believed that the U.S. economy had matured and that most great innovations had already taken place. However, a few economists noticed that the ongoing economic recovery was different from the usual patterns of the past, such as when the U.S. economy started to recover from the recession of 1990Q4-1991Q1[1]. Namely, in the traditional pattern of economic recovery, capacity utilization of capital stock rose first, followed by employment increases. This time, however, the traditional economic recovery pattern was not there. In short, economic recovery was brought about by an increase in productivity. In particular, output rose due to factors other than capital and labor input. It was an economic recovery by increase in total factor productivity (TFP).

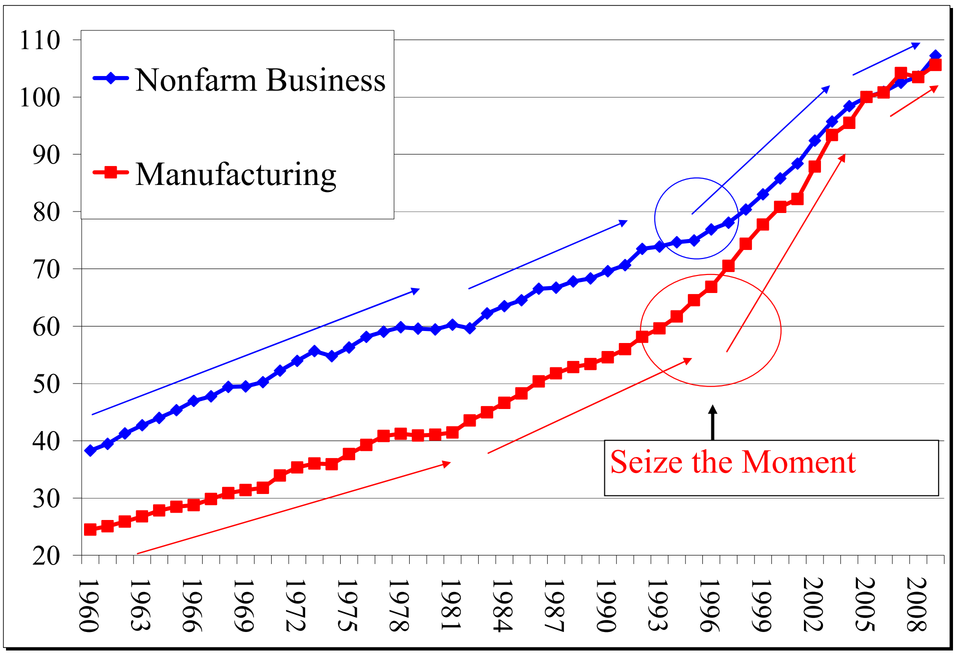
Since 1994, as seen in graph 3.1, there has been a sharp increase in the productivity trend in the U.S. manufacturing sector. It usually takes at least 3-5 years for a productivity trend change to clearly appear in economic statistics. It is important, therefore, whether economic policymakers can make economic policies that will respond to the increase in productivity trend. They would need to be aware of this productivity trend increase sooner rather than later, in 1995 for example, in the 1990s period. It was propitious for the U.S. economy that there were some economists who insisted that the productivity trend had been improving in the middle of the economic recovery. In the book "The Rising Tide" edited by Jerry Jasinowski, economists insisted that there was the possibility that the U.S. economy could grow faster than the conventional wisdom, which held that U.S. potential economic growth was 2%-2.5%, without accelerating inflation[2]. In addition, then-Federal Reserve Chairman Alan Greenspan admitted there was the possibility of an increase in the U.S. potential growth rate due to a rise in the productivity trend brought about by the IT revolution. Alan Greenspan said in March 1997: "The nation's productivity is greater than the statistics

[1]For example, Lawrence R. Klein &YuzoKumasaka"The Re-Opening of the U.S. Productivity-Led Growth Era" NLI Research report, 1995, No.76

[2]see "The Rising Tide" edited by Jerry J. Jasinovwski (John Wiley & Sons, Inc. 1998) for detail.

acknowledge" and told Congress that Fed policymakers would have to decide whether the expansion "will continue to be met by solid productivity growth."[3] Greenspan hardly raised interest rates even though the economy was growing at an annual rate of more than the conventional potential growth rate of 2.0%-2.5% (graphs 3.2 and 3.3). For example, the average growth rate of real GDP during the period of 1995Q3 ~ 1999Q4 was 4.5%, much higher than the conventional potential growth rate. Nonetheless, the Federal funds target rate was cut from 5.75% in 1995Q3 to 5.00% in 1999Q4. As a result, in the 1990s, the economy achieved economic growth rates that were much higher than the traditional idea of 2%-2.5% without accelerating the inflation rate, resulting in the longest economic expansion since the end of World War II. The Federal budget had a surplus during the period of 1998-2001. Economists finally admitted among themselves that the U.S. potential economic growth had risen from 2% - 2.5% to about 3.5% - 4.5%.

Graph 3.1：Productivity Trends for U.S. Business and Manufacturing Sectors 1992=100

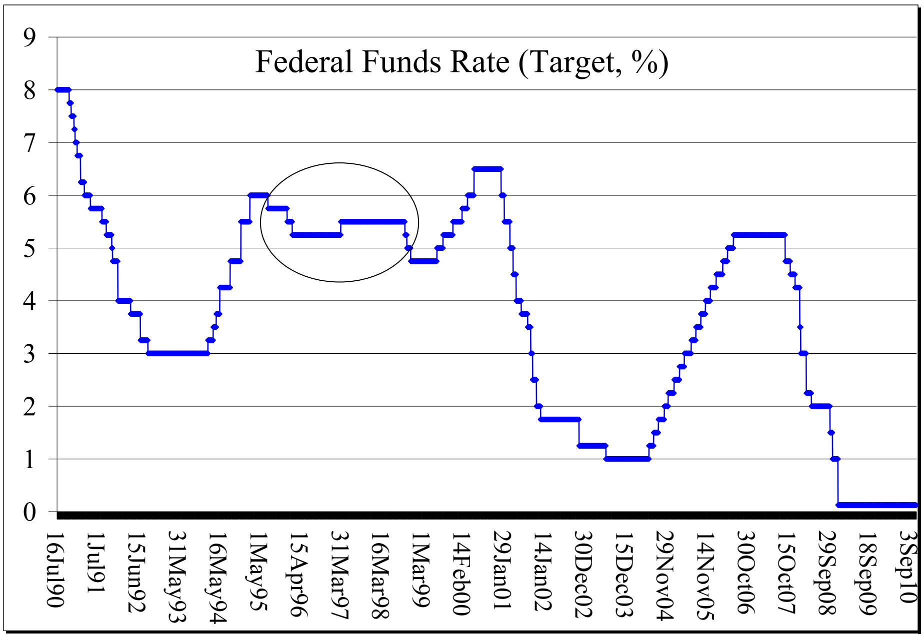


[3]New York Times, "Greenspan's Limited Faith in the Nation's Productivity"March 26, 1997.

It is an obvious fact that this increase in the potential output growth was brought about by the IT revolution. According to Dale W. Jorgenson's study, the average labor productivity growth rate during the period of 1995-2002 was 2.43%, 1% higher than both the 1.36% during the period of 1973-89 and the 1.40% during the period of 1989-95 (table 3.1). IT contributed more than half of this 2.43%. The IT contribution to labor productivity during the 1995-2002 period was 1.35% with 0.88% from IT capital deepening and 0.47% from the rise of TFP due to IT.

What is more fortunate for the U.S. economy is that the effect of the IT revolution has been very visible in the U.S. manufacturing sector. Indeed, it was Jerry J. Jasinowski, then president of the National Association of Manufacturers, who proposed the "The Rising Tide" Project. As seen in graph 3.1, productivity trends in the nonfarm sector and especially in the manufacturing sector have improved since 1995 and show signs of a "New Economy." The average growth rate of labor productivity in the U.S. manufacturing sector rose by 1.5% from 3.0% during the 1981-1994 period to 4.5% during the 1995-2005 period and that in the nonfarm sector also increased by 1.0 from 1.7% during the period of 1981-1994 to 2.7% during the period of 1995-2005.

Graph 3.2 : U.S. Monetary Policy : Federal Funds Rate (Target, %)



Graph 3.3: Real GDP vs. Conventional Potential Growth Rate (%,saar)

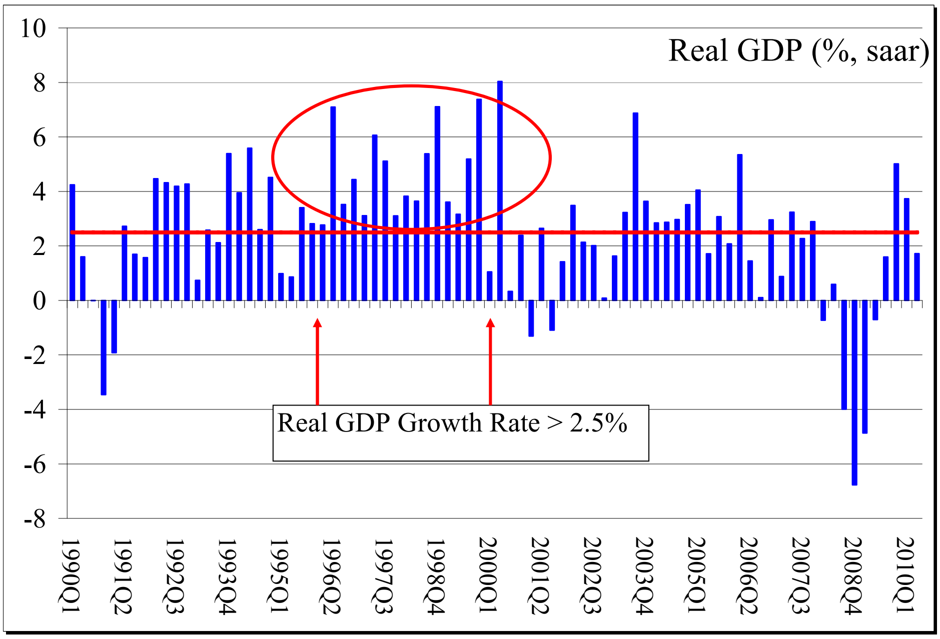


Table 3.1：Sources of Average U.S. Labor Productivity Growth

	1973-89	1989-95	1995-2002
Average Labor Productivity	1.36	1.40	2.43
Capital Deepening	0.85	0.78	1.52
IT	0.34	0.44	0.88
NonIT	0.51	0.34	0.64
Quality of Labor	0.23	0.36	0.2
Total Factor Productivity	0.29	0.26	0.71
IT	0.2	0.23	0.47
NonIT	0.09	0.03	0.24

Source: summarized from Table 2.7 "Sources of Average Labor Productivity Growth" "Productivity" Volume 3, Dale W. Jorgenson, Mun S. Ho, and Kevin J. Sitroh, 2005

2. Why was Japan's Potential Growth Rate Considered to be So Low?

Japan overlooked the effect of the IT revolution on its economy in the latter half of the 1990s because, unlike in the United States, the effects of the IT revolution were not all that obvious. As seen in the official report "Japan's 21st Century Vision"[4] published by the Japanese Cabinet Office in April 2005, Japanese policymakers considered 1.5% to be the Japanese potential growth rate and they tried to formulate economic policies under that assumption, thus underestimating Japan's economic potential, even though the IT revolution was been progressing. What is worse is that Bank of Japan reported in the December 2009 *Outlook for Economic Activities and Prices* that the potential growth rate during the current projection period declined to "around 0.5%" from "around 1 percent" estimated in the April 2009 *Outlook for Economic Activities and Prices*."[5]

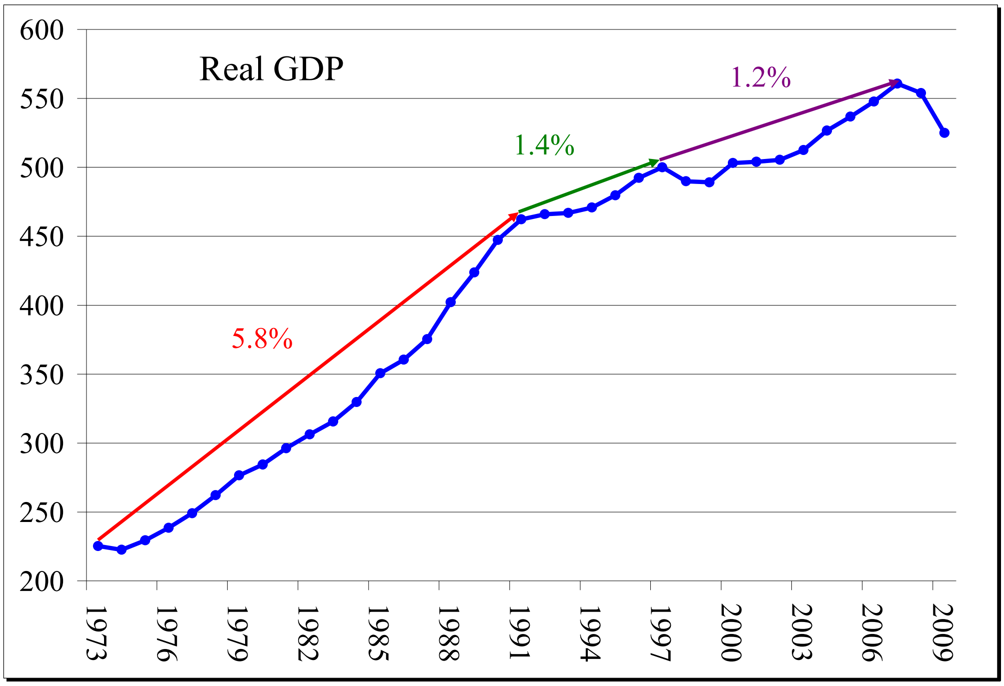
So, why did Japanese economists and policymakers fail to appreciate Japan's potential growth rate? The reason is that they measured Japan's potential growth rate without considering the effect of the IT revolution on the economy. They came to their conclusions using the traditional methods explained below.

2.1. Peak-to-Peak Approach

This is the simplest method and is often used to understand the potential growth rate. Draw a graph of the real GDP and connect the peaks. The average growth rate between the peaks is considered the potential growth rate (graph 3.4). According to graph 3.4, the potential growth rate during the 1973-91 period was about 6% and declined to 1.4% during the 1991-1997 period and to 1.2% after 1997. Or it can also be concluded that Japan's potential economic growth has been about 1% ~ 1.5% since 1991. If there were no structural changes in the Japanese economy in the 2000s, this would be correct. Indeed, there were no explicit statistics for improving Japanese labor productivity due to the IT revolution in the latter half of 1990s, but the IT revolution has been steadily affecting the Japanese economy. We need to analyze how the IT revolution has been influencing the Japanese economy in order to correctly measure Japan's potential growth.

[4]http://www5.cao.go.jp/keizai-shimon/english/publication/pdf/050419visionsummary_fulltext.pdf
[5]http://www.boj.or.jp/en/type/release/teiki/tenbo/gor0910a.pdf

Graph 3.4：Measuring Japan's Potential Growth Rate using the Peak-to-Peak Approach



2.2. Labor Productivity Approach:

Economic Growth Rate ＝ Labor Productivity Growth Rate ＋ Labor Input Growth Rate

The real GDP is separated into labor productivity （GDP/L） ＊ labor input (L). Thus, the potential growth rate as a sustainable economic growth rate without accelerating inflation is calculated as follows:

Potential Growth Rate ≡ Growth Rate of Labor Productivity Trend + Maximum Growth Rate of Labor Input

Table 3.2 shows that the average growth rate of labor productivity during the period of 1991-2006 was 1.4%. It may be acceptable for economists to conclude that the growth rate of labor productivity will continue to be about 1.5% in the future because the effects of the IT revolution on the economy have not been obvious in statistics during the first half of 2000s. As for labor input, the average growth rate of the employed for the same period was almost zero but there were negative growth rates during the period of 1998 – 2003 where the average growth rate was -0.97%. Even if economic policies are adopted that gear toward increasing the participation rate for older people, women, and immigrant workers in the labor market, it is realistic that the growth rate of labor input will be in a range of zero ~ -0.5% in the future. In short, it might have been reasonable for economists to conclude in the early 2000s that Japan's potential growth rate would be 1.0% ~ 1.5%.

Table 3.2 : Japan's Labor Productivity Growth Rate and the Growth Rate of Labor Input (%)

	Employed	Labor Productivity
1991	2.04	1.69
1992	1.12	−0.51
1993	0.38	−0.32
1994	0.10	0.55
1995	0.12	1.59
1996	0.41	3.04
1997	0.70	0.67
1998	−1.18	−0.55
1999	−1.37	1.46
2000	−0.63	2.97
2001	−0.75	0.31
2002	−1.56	2.23
2003	−0.33	2.31
2004	0.22	2.49
2005	0.37	2.74
2006	0.44	1.28
Average	0.01	1.37

2.3. Production Function Approach

Most economists often measure the potential growth rate using a production function. They estimate a production function of the real GDP using capital stock (K), labor input (L) and time trend (t), which is a proxy to obtain technical progress rate per year (λ) (eq. 3.1a and eq. 3.1b). Once they have estimated this production function, they can calculate the potential output by using the maximum input of both capital stock and labor inputs.

$$Y_t = A_t * K_t^{\alpha} L_t^{\beta}$$ ………………………... eq. 3.1a

Where

$A_t = \exp(\lambda * time)$ ……………………………………………………..eq. 3.1b

In order to estimate eq. 3.1a, economists usually assume constant returns to scale and decreasing marginal product of both capital and labor. This production function has the following characteristics:

- Constant returns to scale （$\alpha + \beta = 1$） where α and β are constant.
- Marginal products w.r.t. K and L are decreasing.
- Disembodied technical progress, which applies equally and alike to all resources of men and machines in current use, is assumed. The technical progress rate is constant (λ).

Table 3.3 shows the estimation result for the eq. 3.1a. We find the following:

- Disembodied technical progress occurs at an annual rate of 1.04% (λ) every year.
- $\alpha = 0.18$: Real GDP increases by 0.18% when capital stock (K) increases by 1%.
- $\beta = 0.82$: Real GDP rises by 0.82% when labor input increases by 1%.

The average growth rates of K and LH (Man-hours) during the sample period of 1991-2006 were 2.62% and -0.76% respectively. By assuming these growth rates in the future, the growth rate of the real GDP is calculated to be 0.89% (table 3.4). We can understand why the Bank of Japan reported in the December 2009 *Outlook for Economic Activities and Prices* that the potential growth rate during the current projection period declined to “around 0.5%” from “around 1 percent” estimated in the

April 2009 *Outlook for Economic Activities and Prices.* If the growth rate of man-hour (LH) is assumed to be zero, the potential growth rate is calculated to be about 1.5% (=0.47%+1.04%), which is similar to the conclusions derived using the previous two approaches.

Table 3.3 Estimation Results of Eq. 3.1a

Dependent Variable: LOG(V_112)

Method: Least Squares

Date: 10/12/10 Time: 10:46

Sample: 1991 2006

Included observations: 16

LOG(V_112) = C(1)+C(2)*LOG(CU*K)+(1-C(2))*LOG(LH*L_Q) +C(3)*T

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-19.86072	2.955956	-6.718883	0.0000
C(2)	0.181104	0.059353	3.051335	0.0093
C(3)	0.010421	0.001547	6.734078	0.0000

R-squared	0.985768	Mean dependent var	20.01503
Adjusted R-squared	0.983578	S.D. dependent var	0.054457
S.E. of regression	0.006979	Akaike info criterion	-6.924601
Sum squared resid	0.000633	Schwarz criterion	-6.779740
Log likelihood	58.39680	Durbin-Watson stat	2.139349

Note：V_112: Real GDP, CU: capacity Utilization, K: Net Capital Stock

LH: Man-Hour labor input, L_Q: Quality of Labor (2000=1.0) and T: Time trend

Table 3.4: Calculation of Potential Growth Rate from the Estimation Results

	Contribution to Growth	
K	0.47%	(=0.18*2.62%)
LH	-0.62%	(=0.82*(-0.76))
Technical Progress	1.04%	
Total	0.89%	

KEY QUESTION: "Is Japan's potential growth rate only 1.5%", which would mean that it takes about 50 years for income to double? If the Bank of Japan were right, it takes about 140 years for Japan to make income double.

What we should focus on in these three methods is that any method does not fully incorporate the effect of the IT revolution on the economy.

3. S-Shape Production Function

3.1. Characteristics of the IT Revolution[6]

A key to the IT revolution is the improvement of the productivity trend, which leads to an increase in the potential growth rate. The IT revolution has brought about extremely rapid technical progress. It not only has constructed the global information highway but also has enabled shared software and resources through cloud computing. The IT revolution formed an IT capital stock that is different from the traditional capital stock such as machinery and equipment. IT capital stock consists of the following:

- Computer hardware and information equipment.
- Software as a type of human capital.

[6]See in detail "Infrastucture and Productivity: An Extension to Private Infrastructure and IT Productivity" by Vijaya G. Duggal, Cynthia Salzman and Lawrence R. Klein.

- Infrastructure of the information highway such as wireless telecommunications, broadband and the Internet, which create a global network connecting hardware and software.
- Cloud computing, which is Internet-based computing, whereby shared resources, software, information are provided to computers and other devices on demand.

In order to analyze the IT revolution, a new production function is essential to take into account at least the following two topics:

- While the prices of IT assets have been rapidly falling, compared to those of other capital assets, we must explain the relationship between IT capital stock and non IT capital stock. When total capital stock increases, IT capital stock increases more rapidly than the other capital stock. As a result, the quality of total capital stock improves and shifts the production function upward like technical progress.
- The above former effect of IT capital stock on the economy can be treated just like an increase in the input factor of IT capital stock. The effect on the economy of the information highway infrastructure created by IT capital stock is more important. The improvement of the information highway infrastructure contributes to raising economic efficiency for people, firms and government. For example, transaction and search costs are dramatically reduced and network systems combining computers and software bring about the possibility of a scale economy. Specifically, IT capital stock or IT capital intensity can raise Total Factor Productivity (TFP) through the network effect.

In order to analyze the above effects of IT capital stock we have to consider the following factors in a new production function:

- There is the possibility that marginal product w.r.t. IT capital stock is increasing during some period.
- Constant returns to scale should not be assumed.

- Since IT capital stock is considered to be one of the factors in TFP components, we have to introduce endogenous technical progress explained by IT variables.
- Technical progress due to IT capital stock affects the marginal products of labor and non-IT capital stock differently. (We are assuming that IT capital stock influences the marginal product of labor much more than that of non-IT capital stock through the learning effect of IT).
- The effect of IT capital stock on the economy is not the same every year. For example, the output elasticity w.r.t. IT capital stock will be different in 1995 and in 2005. It will increase as the IT revolution penetrates into the economy.

When we grasp the IT revolution above, it is easy to understand that the traditional production function is inadequate in an IT Economy, which suggests that the growth accounting method is not adequate to analyze the effect of the IT revolution on the economy. This is because this method assumes "constant returns to scale" and "perfect competition in input factor markets" where the input factor share is equal to the output elasticity of the input factor. This approach must lead to the conclusion that the effect of the IT revolution on the economy is minor in the beginning of the IT revolution. This is because IT capital stock is very small, compared to non-IT capital stock in the beginning of the IT revolution. Many economists made the same mistake when the first oil crises occurred. They concluded that the effect of the oil crisis was minimal because the energy share in the output was very small. But, the effect of the oil crisis turned out to be huge as the subsequent stagflation showed. Namely, these economists had not analyzed the effect of the energy input factor on the economy using the empirical work of estimating a production function that explicitly includes the energy input factor. Although energy input was small, it was an inevitable input factor for the production. Based on this oil crisis lesson, we need a new production function that clearly includes the IT input factor. In addition, the empirical work for the IT revolution is much more difficult than that for an oil crisis because the IT revolution also affects the economy through the effect of network systems on TFP. For example, if we attach an additional \$150 display screen to our PC or laptop and work with two screens, our productivity will dramatically increase. This suggests the importance of analyzing the effect of IT on TFP.

Since the IT revolution influences not only countries very differently but also industries in a country differently, we have to estimate various specifications in a new production function that will fit with each country and each industry in order to propose economic policies in an IT Economy. We can summarize the shift from a traditional production function to a new production function as follows:

Assumptions with a traditional production function:

- Constant returns to scale
- Decreasing marginal product of input factors
- Constant exogenous technological progress

Considerations using a new production function:

- Possibility of scale economy
- Possibility of increasing marginal product of input factor over a certain range.
- Possibility of increasing output elasticity w.r.t. IT capital stock.
- Role of IT input factor as one of the components in endogenous technological progress.
- Non-neutral effect of endogenous technological progress on the marginal products of non-IT capital stock and labor input.

3.2. The S-Shape Production Function[7]

Before we show some examples of a new production function, we will introduce a graph of the S-Shape production function that represents the characteristics of the IT revolution. Graph 3.5 shows the output of Y axis and IT capital stock by X axis. This illustrates the relationship between IT capital stock and output, given that other input factors are fixed at a certain level. Since the production function looks like an S, it is called the S-Shape production function. This production function is more realistic than

[7]See http://cepa.newschool.edu/het/essays/product/prodfunc.htm

a traditional production function, which always shows a decreasing marginal product of any input factor. In particular, since the new input factor of IT capital stock was introduced, the S-Shape production function has played an important role. In the beginning of the IT revolution, the effect of IT capital stock may be very small. But once the revolution reaches a certain level, the effect on the economy will be substantial until it reaches another level. This is illustrated by the range of I1-I2 on X axis on the S-shape production function of S1. And once IT capital stock exceeds the IT capital stock level of I2, the effect will become small again, which is shown by the relationship between output and IT capital stock in a traditional production function where marginal product of IT capital stock is decreasing.

A traditional production function shows the relationship between output and input in the phase of G0-F-I0 where the marginal product of the input is always decreasing. For example, when assuming output to be coal and input to be labor, the labor input has to be more in order to produce an additional one ton of coal than to produce the previous one ton of coal. This is because more labor is needed to dig deeper to produce the additional one ton of coal. The law of decreasing marginal product holds. However, IT capital stock is different. When computers are first introduced, the effect on productivity is small, such as being used primarily as a substitute for typewriters. However, when the speed and capacity of computers develop so quickly and many computers are connected to each other through the improvement of IT infrastructure, the effect of additional computers on the economy becomes much larger than that of the previous generation of computers. Specifically the marginal product of IT capital stock increases in some range. "Metcalfe's Law" is a good example of this. Robert Metcalfe, the founder of 3M corporation, said "The more people there are on a network, the greater the value of the network to each other." This idea is a key to thinking a rise in potential growth rate in an IT Economy.

It is important to find out when the effect of the IT revolution on the economy will start to accelerate in each country and in each industry. If it takes less time for IT capital stock to reach the I1 level in the S-shape production function of S1 and the slope of the S-Shape production function is sharp and large, the IT revolution will significantly affect the economy in a short time.

Now we can develop a hypothesis to solve this problem: "The U.S. economy raised its potential output in the latter half of 1990's due to the IT revolution, while Japan could not." We can assume an S-shape production function of S1 for the U.S. economy and S2 for the Japanese economy. As S1 shows, IT capital stock reached the I1 level in the latter half of the 1990s, indicating that the U.S. economy was significantly affected by the IT revolution in that period. During the I1-I2 range, the marginal product of IT capital stock shows an increase, bringing about the possibility of increasing returns to scale. As a result, the U.S. economy was able to raise its potential output growth from 2%-2.5% to i.e. 3.5%-4.5%.

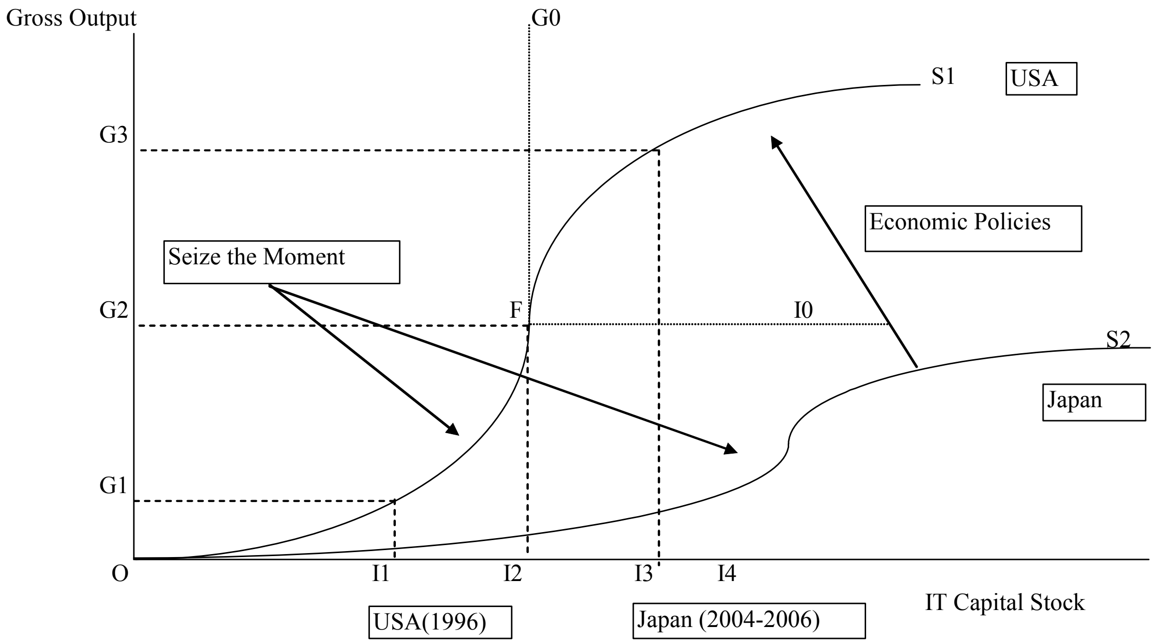
In the case of the Japanese economy, IT will start to significantly affect the economy when IT capital stock reaches I3 on S2. We may interpret that it takes more time for Japan to realize a significant effect caused by the IT revolution than it does for the United States. S1 and S2 show that Japan is behind the United States by 10 years or more. In addition, it is assumed that the effect of the IT revolution is much smaller in Japan than in the United States because the S-shape of S2 is much flatter than that of S1.

Now we have another quandary. The IT revolution has been progressing globally. Japan and the United States have been using the same computers, broadband system and so on. The broadband spread is much wider in Japan than in the United States, so why is Japan behind the United States by 10 years or more, with the effect of the IT revolution on the economy smaller? The answer will also explain why the productivity trend improved in the United States in the second half of 1990s while in Japan it did not.

The IT revolution is different from the traditional technological revolution such as the invention of the steam engine, light bulb and so on. People need education and organizations such as firms and governments must be flexible in order to utilize IT efficiently. To be precise, human capital and culture in countries or firms are very important to the efficacy of the IT revolution. For example, whether there are expert venture capitalists who can find and develop promising start-ups in a country is one important factor. Since the IT revolution has been progressing globally, English-speakers have much more of an advantage than non-English speakers. U.S. companies can outsource some jobs such as call-center and data input work to other English-speaking countries like the Philippines and India. Can firms realize a scale economy through mergers & acquisitions, which take advantage of the IT revolution? Although firms become one company through M&A, the resultant large company may not have improved efficiency because the employees in each company often adhere to their own company's culture. This often happens in the M&As of Japanese companies. Another factor is that people in the United States have their own social security number, which is very convenient in the IT economy. And attitude is important as well. The Japanese have the habit of too readily apologizing, hiding, acquiescing, and being jealous of others' success as shown in the proverb "Go farther and fare worse." These habits do not work with a global economy brought about by the IT revolution. The "hiding" habit is not adequate in the openness of an IT society where people benefit from sharing information. The culture of "Go farther and fare worse" is not going to foster entrepreneurship for innovative and successful young people in the IT Economy. Namely, in a country where the culture and organizations do not fit with the IT revolution and the quality of human capital is low, the S-shape production function becomes flatter. If S1 and S2 represent the United States and Japan respectively, the S-Shape production function for India, Singapore, Taiwan and Korea may be between S1 and S2.

Therefore, in order to improve the productivity trend as well as raise potential economic growth, we should propose economic policies that shift S2 to S1. Nowadays, English capability and computer usage are basic skills in the IT Economy. People, firms and government must be very flexible in order to use IT efficiently.

Graph 3.5：The S-Shape Production Function



3.3. Specifications for the S-Shape Production Function - Example of the Japanese Manufacturing Sector

Theoretically, we set up a transcendental production function that is one of the generalized Cobb-Douglas production function forms[8]. With this function it is possible for marginal products to rise before eventually falling. A key to estimating the S-Shape production function is how we specify Total Factor Productivity (TFP) using input factors including IT variables. Since endogenous technological progress is different for each industry and for each country, we must always find the unique TFP specification that fits each industry and each country[9]. We show, therefore, as one example, the S-Shape production function of the Japanese manufacturing sector, which will give

[8]See "Econometric Models, Techniques, and Application" edited by M.D. Intriligator, R.D. Bodkin and C. Hsiao for Generalized Cobb-Douglas Production Function., p297.

[9]See the following papers for concrete specifications of the S-Shape production function;
"Information technology and productivity: the case of the financial sector",Survey of Current Business, August, 2003 by Lawrence R. Klein, Cynthia Saltzman, Vijaya G. Duggal and their paper in footnote 9
"The Effect of Information Technology on the Japanese Macro-Economy" by YuzoKumasaka and Toshiko Tange, presented at the conference of the Japanese Economic Association on June 10 and 11, 2004.

standard numerical value for the output elasticity w.r.t. IT capital stock when we will estimate the S-Shape production functions for other industrial groups.

In order to analyze the effect of the IT revolution on the economy more correctly, Prof. Klein replaced a Cobb-Douglas production function (eq. 3.1a) with a generalized KLEM production function[10] (eq. 3.2).

$$G = K^{c(2)}L^{c(3)}M^{c(4)}\exp[t^{c(5)}]\ \exp[c(6)*K/(KIT*L)]\ \exp[c(7)*(KIT)(I) - c(8)*L/(KIT*I)]\ \exp[c(1)]$$

…………………………………………………….eq. 3.2

where G: Real Gross Output

K: Real NetTotal Capital Stock

L: Labor Input

M: Real All Intermediate Inputs, excluding Information Service Input (I)

KIT: Real Net Capital Stock of IT (IT capital stock)

I: Real Information Technology Service Input (B to B)

t: Time trend to proxy Disembodied Technology Change

We considered the following characteristics of the IT revolution in the generalized Cobb-Douglas production function:

1: Constant returns to scale (sum of coefficients for primary inputs = 1) is not assumed. We can therefore measure the economies of scale.

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[10] Prof. Klein first introduced a generalized Cobb-Douglas production function to analyze the effect of IT on the auto and parts sector in his and his colleagues' paper "Contributions of input-output analysis to the understanding of technological change: the information sector in the United States", p.p. 311-336 in "*Biographical Memoir of Wassily Leontief*", *Proceedings of the American Philosophical Society*, 194 4 (December 2000)

2: Variable elasticities of production w.r.t. input factors and variable elasticity of substitution over the certain range of inputs are permitted.

3: Real gross output is used for the real GDP. Information service flow as an intermediate input may play an important role in the production function.

4: Not only disembodied technical progress but also embodied technical progress is clearly defined. Embodied technical progress is endogenously determined.

Prof. Klein applied this production function to the U.S. automobile and parts sector and financial sector respectively (see footnotes 11 and 12). We modified eq. 3.2 and applied eq. 3.3 to the Japanese manufacturing sector. The estimation result of the aggregated manufacturing industries will be a standard case to compare those of other industries.

$$G = K^{c(2)}L^{c(3)}M^{c(4)}\exp\left[(t*KIT/K)^{c(5)} + c(6)*K/(KIT*L) + c(7)*(KIT)(I) - c(8)*L/(KIT*I) + c(1)\right] \quad \text{eq. 3.3}$$

In this form, one might consider technological change as having both disembodied and embodied elements. The possibility of interaction between embodied and disembodied technological change is considered as $\exp[(t*KIT/K)^{c(5)}]$ in the equation (eq.3.3). KIT/K means quality of capital. The functional form $\exp[(t*KIT/K)^{c(5)}]$ for the time trend is used instead of the more common exp. [c(5)*t] because it allows for a non-constant growth rate over time and is more likely to yield trend stationary dependent variables.

The functional form, exp [c(6)*K / (KIT * L) + c(7)*(KIT)(I) – c(8)*L /(KIT * I)], reveals embodied technological change. [c(6)*K/(KIT*L)] shows that embodied technological change depends on the capital/labor ratio (capital intensity) with labor weighted by IT capital stock. [c(7)*(KIT)(I)] means the interaction of KIT and I. [-c(8)*L/(KIT*I)] indicates that the increase in KIT or I enhances the marginal productivity of labor. Embodied technological change will increase or decrease, depending on the interaction of the values of c(6), c(7), c(8), K, KIT, I and L. The functional form of the information service input and information capital stock, depending on the coefficient values, c(6), c(7) and c(8), specifically allows for an increasing marginal product of I and KIT over some range of I and KIT values.

By forming the natural logarithm of eq. 3.3 we have the structural equation to be estimated:

$$\ln G = c(1) + c(2)*\ln K + c(3)*\ln L + c(4)*\ln M + (t*KIT/K)^{c(5)} + c(6)* K / (KIT * L) + c(7)*KIT * I - c(8) * L / (KIT * I) \quad \text{eq. 3.4}$$

This functional form was developed to analyze the effect of IT on the economy. This is one of several functional forms used to generalize the Cobb-Douglas production function (see footnotes 11 and 12). The implication of this generalization allows for the possibility of a variable returns to scale coefficient, as well as a variable elasticity of substitution.

We used Cu: capacity utilization and Q: quality of labor in the actual estimation for the Japanese manufacturing sector as seen in eq. 3.5.

$$\ln G = -1.359020 + 0.213476*\ln(cu* K) + 0.252301*\ln (L*Q) + 0.607110*\ln M$$

(t=-9.2) (t=5.0) (t=3.7) (t=8.9)

$$+ (t*KIT(-1)/K)^{0.036945} + 0.017612* K / (KIT * L) + 0.019347*KIT * I$$

(t=2.6) (t=2.6) (t=1.9)

$$- 0.292552/1000 * L / (KIT * I) \quad \text{eq. 3.5}$$

(t=5.0)

Sample: 1975-2006, D-W: 1.72, R_2: 0.99

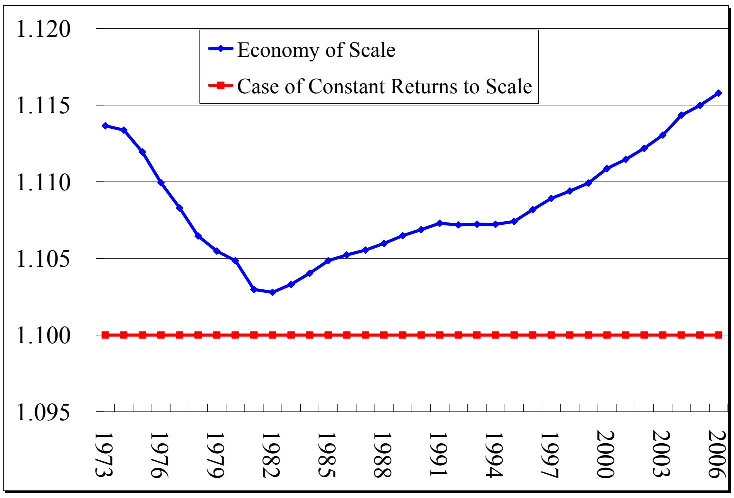
We summarize the most relevant findings as follows:

(i) Variable Returns to Scale

We can calculate the variable economy of scale from eq. 3.5, where we assume that all input grows at 10% every year. In the case of constant returns to scale, output increases by 10% (see the red line in graph 3.6). Returns to scale declined from 1.113 in 1973 to 1.103 in 1981 and then started to increase to 1.116 in 2006. There are very small increasing returns to scale. Although the IT revolution has been steadily advancing, the Japanese manufacturing sector has not benefitted significantly yet from it.

Graph 3.6: Economies of Scale for the Japanese Manufacturing Sector

Assumption: All inputs grow at an annual rate of 10%



(ii) Interaction between Embodied and Disembodied Technical Progress

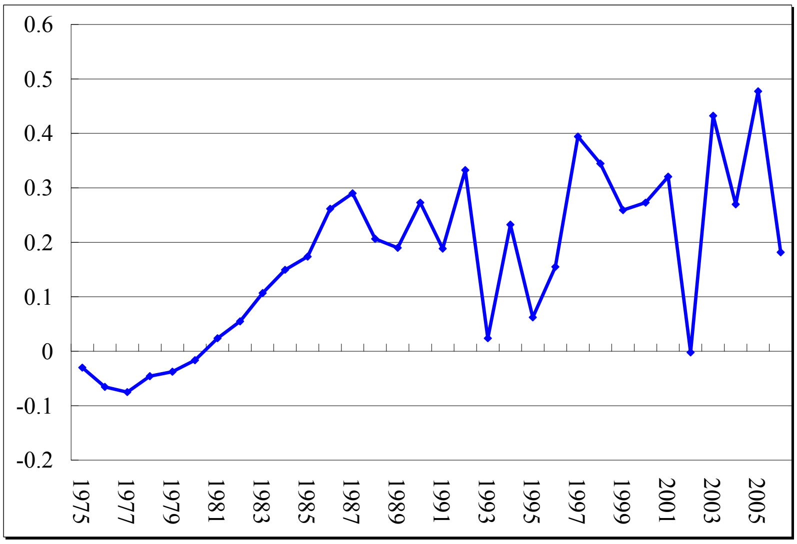
We assume a stationary trend for disembodied technical progress multiplied by the quality of capital. We examine how $\{t*KIT(-1)/K\}^{c(5)}$ affects the growth rate of G in the following calculation:

$$G\_Time \equiv \frac{\partial \ln G}{\partial t} = \{t * \frac{KIT(-1)}{K}\}^{c(5)} * c(5) * \frac{KIT(-1)}{K} \quad \text{..... eq. 3.6a}$$

c(5) = 0.036945 in eq. 3.5.

$$DG\_Time \equiv G\_Time - G\_Time(-1) \quad \text{.................................. eq.3.6b}$$

Graph 3.7: Contribution to the growth rate of G by Interaction between Embodied and Disembodied Technical Change (%, DG_Time *100)



The average contribution to economic growth by the interaction between embodied and disembodied technical progress increases by about 0.2% every year (graph 3.7).

Although this specification works for the aggregated manufacturing sector, it is too complicated to apply to several industrial groups. Also, the economy of scale in the manufacturing sector did not fluctuate significantly at all, as shown in graph 3.6. Therefore, we will apply a less complicated specification to explain TFP by capital intensity (IT capital stock / Labor input) or the quality of capital (IT capital stock / total capital stock). Although we can not measure variable returns to scale in this specification, we do not assume constant returns to scale. We still can measure variable output elasticity w.r.t. IT capital stock and check whether the marginal product of IT capital stock is increasing or decreasing.

We estimate a traditional production function with TFP (time) and a new production function with TFP(IT variables) as follows:

A traditional production function for the Japanese manufacturing:

ln G = -15.83384 + 0.137122*ln(cu* K) + 0.334864*ln (L*Q) + 0.624251*ln M

(t=-6.3) (t=4.6) (t=5.8) (t=10.7)

+ 0.007558*Time ………………………………………………. eq. 3.7a

(t=5.8)

Sample: 1973-2006, D-W: 1.85, R_2: 0.99, ma(1)

Sum of coefficients: 1.096

where

Q: Quality of labor

A new production function for the Japanese manufacturing:

ln G = -13.73593 + 0.078802*ln(cu* K) + 0.349677*ln (L*Q) + 0.733352*ln M

(t=-6.9) (t=2.8) (t=7.9) (t=13.8)

+ 0.005888*Time + 2.481674*{(KIT/L)*(KIT/K)} ……………………. eq. 3.7b

(t=5.5) (t=3.9)

Sample: 1973-2006, D-W: 1.85, R_2: 0.99, ma(1)

Sum of coefficients: 1.162

KIT/L: IT capital intensity (IT capital stock / labor input)

KIT/K: Quality of capital (IT capital stock / Total capital stock)

Since Time was statistically significant in eq.3.7b, we left it in the equation. This was expected because the interaction between embodied and disembodied technological change was statistically significant in eq. 3.5. We can calculate output elasticity w.r.t. IT capital stock as well as the marginal product of IT capital stock from eq. 3.7b.

(iii) **Output Elasticity w.r.t. IT Capital Stock (=ela_MF**G)

We can calculate output elasticity w.r.t. IT capital stock from eq. 3.7a as follows:

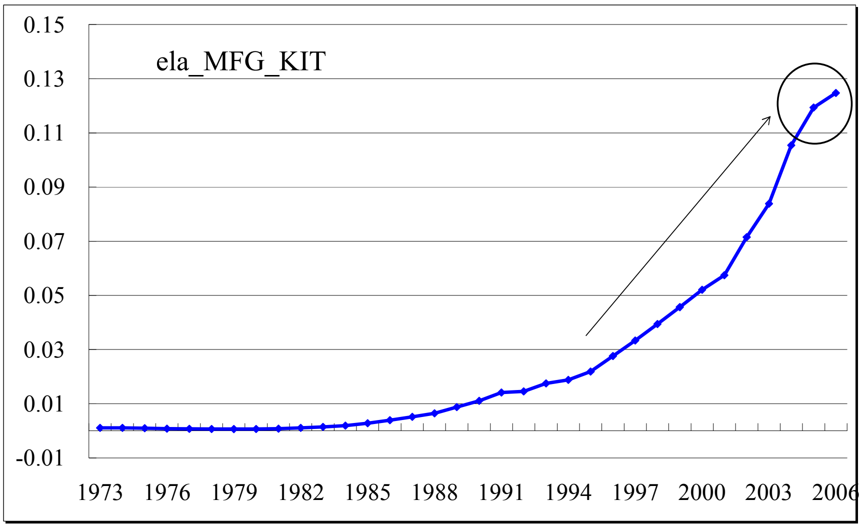
$$ela\_MFG = KIT * \{\frac{c(2)}{K} + \frac{c(6)}{L} * KIT(\frac{2K - KIT}{K^2})\}$$ ……………. eq. 3.8

where

c(2)=0.078802 and c(6)=2.481674 in eq. 3.7b.

Output elasticity w.r.t. IT capital stock started to increase sharply in the mid-1990s when the Internet began to permeate the economy (graph 3.8). Its value is 0.12 in 2006. We can consider this value as a kind of standard when we calculate the output elasticity w.r.t. IT capital stock in other industrial sectors.

Graph 3.8: Output Elasticity w.r.t. IT capital Stock (ela_MFG)



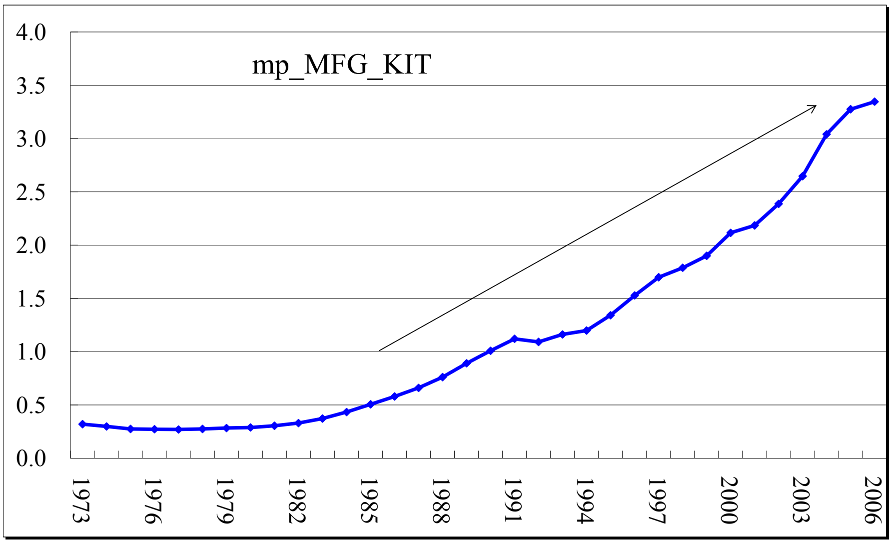
(iv) The Marginal Product of IT Capital Stock (= mp_MFG)

Eq. 3.9 shows the marginal product of IT capital stock calculated from eq. 3.7b.

$$mp\_MFG = G * \{\frac{c(2)}{K} + \frac{c(6)}{L} * KIT(\frac{2K - KIT}{K^2})\} \qquad \text{.................... eq. 3.9}$$

The marginal product of IT capital stock has an increasing trend since the mid-1980s (graph 3.9). As long as both output elasticity w.r.t. IT capital stock and the marginal product of IT capital stock are increasing, the Japanese manufacturing sector will have the possibility of having benefited from increasing IT capital intensity or improving quality of capital.

Graph 3.9: Marginal Product of IT Capital Stock (mp_MFG) for the Japanese Manufacturing Sector



(v) Output Growth Rates calculated from traditional and new production functions for the Japanese Manufacturing Sector: A Comparison

We made simulations for how much the output in the Japanese manufacturing sector will grow, using the same assumptions about the growth rates of input factors for both traditional and new production functions (eq. 3.7a and eq. 3.7b). We calculated the average growth rates of output and input for three periods, 1975-2006 (total period: from the end of the first oil crisis to the last sample period), 1975-1992 (pre-bubble period) and 1993-2006 (post-bubble period) in order to make reasonable assumptions for the growth rates of inputs in the 2nd ~ 4th rows in each simulation study table (table 3.5a and 3.5b). We show that a traditional production function will produce much lower growth rates of output than a new production function, as IT investment increases. The output growth rate calculated by a traditional production function is lower by 0.35% in the Pessimistic case, by 0.86% in the Standard case, by 1.16% in the Optimistic case and by 1.06% in the Intensive IT investment case (tables 3.5a and 3.5b). Namely, we may underestimate potential output by using a traditional production function. If we assume that IT capital stock increases by 12.0% instead of 9.0% in the Standard case (table 3.5b), output will increase 3.52%, only 0.35% below the average growth rate of the pre-bubble output growth rate.

Since the effect of the IT revolution is quite different among industries as well as countries, we will analyze several Japanese industry groups classified by their stages on the development ladder, implying some similarities with ASEAN countries.

We simplify the new production function of eq. 3.4 introduced by Prof. Klein without losing our primary purpose that a new production function will show higher potential output than does a traditional one.

Table 3.5a: Simulation Studies of the Japanese Manufacturing Sector from a Traditional Production Function. eq. 3.7a

History		G	KO	KIT	LH	L_Q	M	KIT/LH(KI)	K_IT/K(KQ)
Average Growth Rate	1975-2006	2.28	3.29	10.49	-1.01	0.52	1.93	11.62	6.78
	1975-1992	3.87	4.08	12.68	0.19	0.46	3.68	12.45	8.05
	1993-2006	0.49	2.40	8.01	-2.38	0.59	-0.05	10.69	5.33
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			2.0	5.0	-2.5	0.5	0.0	7.7	2.8
Contribution to Growth Rate of Manufacturing			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		0.36	0.29		-0.68		0.0	0.76	
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			3.0	9.0	-1.0	0.5	2.0	10.1	5.5
Contribution to Growth Rate of Manufacturing			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		2.26	0.44		-0.17		1.23	0.76	
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			4.0	12.0	0.0	0.6	3.0	12.0	7.3
Contribution to Growth Rate of Manufacturing			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		3.39	0.59		0.20		1.85	0.76	
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			2.0	15.0	-2.5	0.5	0.0	17.9	12.1
Contribution to Growth Rate of Manufacturing			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		0.43	0.35		-0.68		0.00	0.76	

Table 3.5b: Simulation Studies of the Japanese Manufacturing Sector from a New Production Function. eq. 3.7b

History		G	KO	KIT	LH	L_Q	M	KIT/LH(KI)	KIT/K(KQ)
Average Growth Rate	1975-2006	2.28	3.29	10.49	-1.01	0.52	1.93	11.62	6.78
	1975-1992	3.87	4.08	12.68	0.19	0.46	3.68	12.45	8.05
	1993-2006	0.49	2.40	8.01	-2.38	0.59	-0.05	10.69	5.33
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			2.0	5.0	-2.5	0.5	0.0	7.7	2.8
Contribution to Growth Rate of Manufacturing			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	TFP (KI*KQ)
		0.71	0.17		-0.71		0.0	0.59	0.66
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			3.0	9.0	-1.0	0.5	2.0	10.1	5.5
Contribution to Growth Rate of Manufacturing			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	TFP (KI*KQ)
		3.12	0.25		-0.18		1.45	0.59	1.00
Assumed Growth Rate (%) **Optimistic Case**		G							
			4.0	12.0	0.0	0.6	3.0	12.0	7.3
Contribution to Growth Rate of Manufacturing			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	TFP (KI*KQ)
		4.55	0.34		0.21		2.17	0.59	1.25
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			2.0	15.0	-2.5	0.5	0.0	17.9	12.1
Contribution to Growth Rate of Manufacturing			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	TFP (KI*KQ)
		1.49	0.21		-0.71		0.00	0.59	2.00

4. Estimation of Traditional and New Production Functions for 7 Japanese Industrial Groups Classified by the Stages of Development Ladder and Public Activities Group: A Comparison

4.1. Classification of Industries

We used the Japan Industrial Productivity (JIP) database constructed by the Research Institute of Economy, Trade and Industry (RIETI)[11] because time series data of IT variables such as IT capital stock have not been prepared yet in most ASEAN countries. The JIP database has 108 industrial sectors (table 3.6). According to the "Stages of Development Ladder" in figure 2.2, we classify 108 industries into 4 stages and public activities so that these classified groups are considered to have similarities with ASEAN countries in the Stages of Development Ladder (table 3.6).

Stage 1 has three categories, including "Primary Products (1a)", "Resource Related (1b)" and "Local Services (1c)". Stage 2 includes "Labor Intensive Manufacturing (2a)" and "General Manufacturing (2b)". Stage 3 is "High-Tech manufacturing". Stage 4 is "High-Level Services". We aggregate public related industries as "Public activities (9)".

We will estimate a traditional production function with TFP (Time) and a new production function with TFP (KI: IT capital intensity or KQ: Quality of capital), if IT variables are statistically significant in order to explain TFP. We can compare the possible output growth rates calculated from the two production functions using the same assumptions about the growth rates of input factors. As a result, we will prove that the IT revolution can raise the potential growth rate for Japan and ASEAN countries higher than is thought by many economists who use the traditional production function.

[11] see http://www.rieti.go.jp/en/database/d05.html

Table 3.6: Classification of Industries based on the Stages of Development Ladder

		Stages of Development Ladder							
		1			2		3	4	
JIP Code	Industries	Primary Products	Resouce Related	Lcal Services	Labor Intensive Mfg.	General Mfg.	High-Tech. Mfg.	High-Level Services	Public Activities
1	Rice, wheat production	1a							
2	Miscellaneous crop farming	1a							
3	Livestock and sericulture farming	1a							
4	Agricultural services	1a							
5	Forestry	1a							
6	Fisheries	1a							
7	Mining	1a							
8	Livestock products		1b						
9	Seafood products		1b						
10	Flour and grain mill products		1b						
11	Miscellaneous foods and related products		1b						
12	Prepared animal foods and organic fertilizers		1b						
13	Beverages		1b						
14	Tobacco		1b						
15	Textile products				2a				
16	Lumber and wood products				2a				
17	Furniture and fixtures				2a				
18	Pulp, paper, and coated and glazed paper					2b			
19	Paper products				2a				
20	Printing, plate making for printing and bookbinding						3		
21	Leather and leather products				2a				
22	Rubber products				2a				
23	Chemical fertilizers					2b			
24	Basic inorganic chemicals					2b			
25	Basic organic chemicals					2b			
26	Organic chemicals						3		
27	Chemical fibers						3		
28	Miscellaneous chemical products						3		
29	Pharmaceutical products						3		
30	Petroleum products		1b						
31	Coal products		1b						
32	Glass and its products				2a				
33	Cement and its products				2a				
34	Pottery				2a				
35	Miscellaneous ceramic, stone and clay products				2a				
36	Pig iron and crude steel				2a				
37	Miscellaneous iron and steel				2a				
38	Smelting and refining of non-ferrous metals				2a				
39	Non-ferrous metal products				2a				
40	Fabricated constructional and architectural metal products						3		
41	Miscellaneous fabricated metal products						3		
42	General industry machinery						3		
43	Special industry machinery						3		
44	Miscellaneous machinery						3		
45	Office and service industry machines						3		

(continued)

46	Electrical generating, transmission, distribution and industrial apparatus						3		
47	Household electric appliances				2a				
48	Electronic data processing machines, computer equipment and accessories						3		
49	Communication equipment						3		
50	Electronic equipment and electric measuring instruments						3		
51	Semiconductor devices and integrated circuits						3		
52	Electronic parts						3		
53	Miscellaneous electrical machinery equipment						3		
54	Motor vehicles						3		
55	Motor vehicle parts and accessories						3		
56	Other transportation equipment						3		
57	Precision machinery & equipment						3		
58	Plastic products						3		
59	Miscellaneous manufacturing industries						3		
60	Construction							4	
61	Civil engineering							4	
62	Electricity		1b						
63	Gas, heat supply		1b						
64	Waterworks		1b						
65	Water supply for industrial use		1b						
66	Waste disposal		1b						
67	Wholesale			1c					
68	Retail			1c					
69	Finance							4	
70	Insurance							4	
71	Real estate							4	
72	Housing (imputed rent)								
73	Railway			1c					
74	Road transportation			1c					
75	Water transportation			1c					
76	Air transportation							4	
77	Other transportation and packing			1c					
78	Telegraph and telephone							4	
79	Mail								9
80	Education (private and non-profit)							4	
81	Research (private)							4	
82	Medical (private)							4	
83	Hygiene (private and non-profit)			1c					
84	Other public services								9
85	Advertising							4	
86	Rental of office equipment and goods							4	
87	Automobile maintenance services							4	
88	Other services for businesses							4	
89	Entertainment							4	
90	Broadcasting							4	
91	Information services and internet-based services							4	
92	Publishing							4	
93	Video picture, sound information, character information production and distribution							4	
94	Eating and drinking places			1c					

(continued)

95	Accommodation			1c					
96	Laundry, beauty and bath services			1c					
97	Other services for individuals			1c					
98	Education (public)								9
99	Research (public)								9
100	Medical (public)								9
101	Hygiene (public)								9
102	Social insurance and social welfare (public)								9
103	Public administration								9
104	Medical (non-profit)								9
105	Social insurance and social welfare (non-profit)								9
106	Research (non-profit)								9
107	Other (non-profit)								9
108	Activities not elsewhere classified								

4.2. Estimation of Production Functions for Classified Groups

(1) Group-1a: Primary Products industries (1a) in Stage 1

Group-1a includes the first seven industries, including rice, wheat products (JIP:1) ~ mining (7), which are classified as “Primary Products in Stage 1” in table 3.6.

All industries in Group-1a, except agricultural services, have very low IT capital intensity and a low quality of capital (Appendix A). When the TFP calculated using the average factor shares during the sample period has a declining trend, we usually cannot explain the TFP by either Time or IT variables with any statistical significance.

Estimation Result for Group-1a:

Log(G) = 1.712384 + 0.219403*log(cu*K) + 0.296591*log(LH*L_Q) + 0.392921*log(M)

(t=0.9) (t=2.2) (t=4.7) (t=4.9)

……………………………………………………………………………………… eq. 3.10

Sample: 1973-2006, D-W:1.84, R_2:0.96, ma(1)

Sum of Coefficients: 0.909

where

G: Real gross output

K: Real net capital stock (IT capital stock (KIT) + Non-IT capital stock (KO))

LH: Labor input (Man-hours)

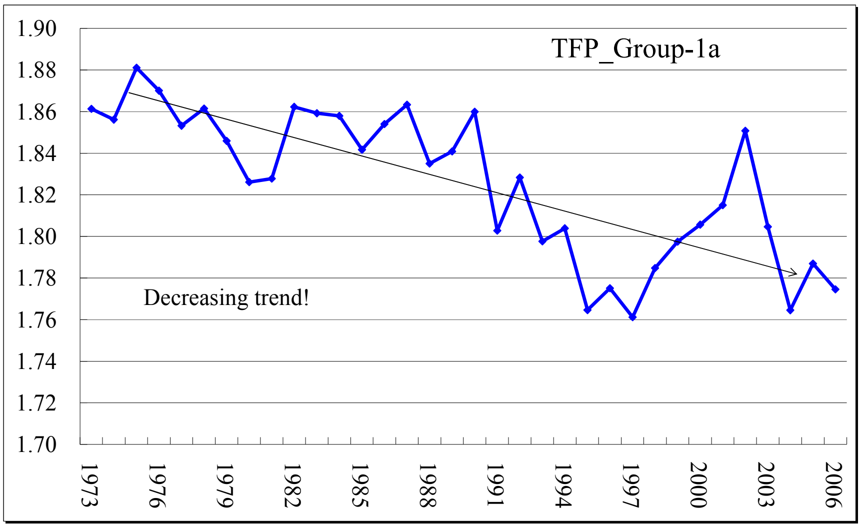
L_Q: Quality of Labor (2000=1.0)

M: Intermediate input.

Findings:

- TFP could not be explained with statistical significance by either Time or IT variables such as IT capital intensity and quality of capital. This is seen in the graph of TFP, which shows a decreasing trend (graph 3.10). We can find neither exogenous nor endogenous technical progress in Group-1a.
- There is decreasing returns to scale (sum of coefficients =0.909).

Graph 3.10: TFP calculated for Group-1a of "Primary Products Industries"



Simulation Studies for Real Output Growth for Group-1a

We can simulate how much output (G) in Group-1a will grow by assuming the growth rates for input factors. First, we calculated the historical average growth rates for output and input for 1975-2006 (total period: from the end of the first oil crisis to 2006), 1975-1992 (pre-bubble period) and 1993-2006 (post-bubble period) respectively in Rows 2, 3 and 4 in table 3.7. Based on the actual average growth rates of input factors for the three periods, we assumed their growth rates for four simulation cases: the "Pessimistic case", "Standard case", "Optimistic case" and "Intensive IT investment case" and calculated the output growth rates for the four cases.

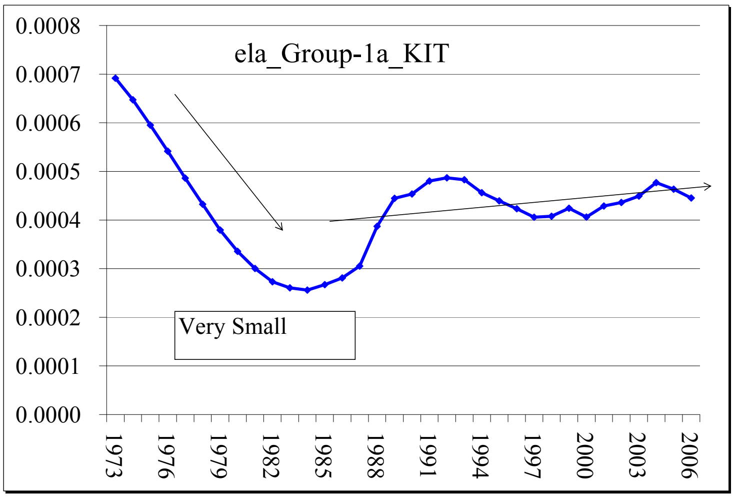
We usually compare the simulation cases with the results from a traditional production function with TFP (Time) and those from a new production function with TFP (IT variables). But, we show only the results from a traditional production function without TFP (Time) for Group-1a.

We can conclude the following from eq. 3.10 and table 3.7:

- Low output growth in Group-1a is caused by a sharp reduction in labor input.
- Neither Time nor IT variables can explain TFP statistically.
- Since IT variables do not affect TFP, output elasticity w.r.t. IT capital stock (KIT) included in total capital stock (K) is very small, 0.003 ~ 0.007 (graph 3.11). This is calculated from eq. 3.10 by

$$ela\_Group-1a\_KIT = KIT * \frac{\partial \log(G)}{\partial K} * \frac{\partial K}{\partial KIT} \ .$$

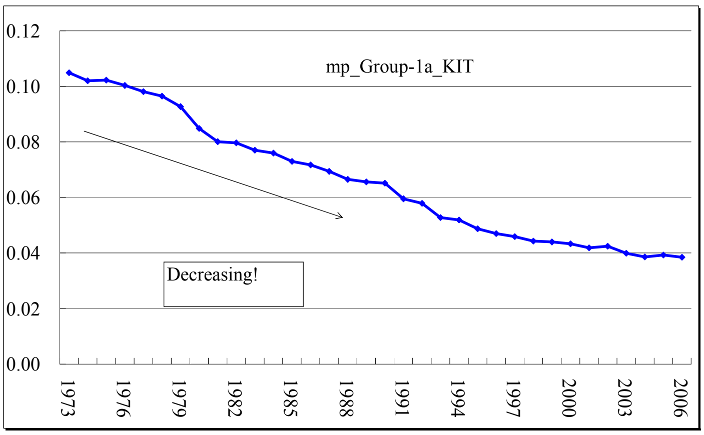
Graph 3.11: Output Elasticity w.r.t. IT capital stock in Group-1a (ela_Group-1a_KIT)



- Marginal product of IT capital stock is decreasing (graph 3.12). This is calculated from eq. 3.10 as follows:

$$mp\_Group-1a\_KIT = G * \frac{\partial \log(G)}{\partial K} * \frac{\partial K}{\partial KIT}.$$

Graph 3.12: Marginal Product of IT capital stock in Group-1a (mp_Group-1a_KIT)



- Quality of capital (KIT/K≡KQ) was decreasing (see the last column in table 3.7), suggesting that IT capital stock did not increase faster than non-IT capital stock.
- It will be difficult for Group-1a to achieve the growth rate in the pre-bubble period without increasing labor input.
- It will be very hard for Group-1a to achieve 3% as the macroeconomic target growth rate proposed by the "Rising Tide Policy" in Japan.
- Group-1a has not yet benefitted from the IT revolution. This group should consider utilizing IT effectively in order to increase output instead of depending intensively on labor input

Table 3.7: Simulation Studies for Group-1a

History		G	KO	KIT	LH	L_Q	M	KIT/LH (KI)	KIT/K (KQ)
Average Growth Rate	1975-2006	-0.62	2.44	1.55	-3.74	0.14	0.01	5.53	-0.84
	1975-1992	0.20	3.40	2.13	-3.58	-0.10	1.61	5.96	-1.20
	1993-2006	-1.54	1.34	0.90	-3.92	0.43	-1.80	5.03	-0.43
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			1.0	1.0	-4.0	0.0	-1.0		
Contribution to Growth Rate of Group-1a			K(=KO+KIT)		L(LH+L_Q)		M		
		-1.39	0.22		-1.21		-0.39		
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			2.0	1.5	-3.0	0.0	0.5		
Contribution to Growth Rate of Group-1a			K(=KO+KIT)		L(LH+L_Q)		M		
		-0.27	0.43		-0.9		0.2		
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			3.0	2.0	-2.0	0.5	1.5		
Contribution to Growth Rate of Group-1a			K(=KO+KIT)		L(LH+L_Q)		M		
		0.78	0.65		-0.45		0.59		
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			1.0	5.0	-4.0	0.0	-1.0		
Contribution to Growth Rate of Group-1a			K(=KO+KIT)		L(LH+L_Q)		M		
		-1.38	0.22		-1.21		-0.39		

(2) Group-1b: Resource Related industries (1b) in Stage 1

Group-1b consists of Livestock products (JIP:8) ~ Tobacco (14), Petroleum products (30), Coal products (31) in the manufacturing sector and Electricity (62) ~ Waste disposal (66) in the service sector. Neither Time nor IT variables explain TFP in Group-1b. We focus on the industries in the service sector (≡Group-1bs), which are Electricity (62), Gas, heat supply (63), Waterworks (64), Water supply for industrial use (65) and waste disposal (66) because they are a form of infrastructure. We estimate both traditional and new production functions for Group-1bs below:

Estimation Results for Group-1bs:

We used factor share as a coefficient for labor input because of the multicollinearity among explanatory variables.

Log(G) = -13.62756 + 0.208748*log(cu*K) + 0.155232*log(LH*L_Q) + 0.381525*log(M)

(t=-3.5) (t=2.8) (Factor Share) (t=7.0)

+ 0.009220*Time ……………………………………………… eq. 3.11a

(t=3,7)

Sample: 1974-2006, D-W:1.95, R_2:0.99, ar(1)

Sum of Coefficients: 0.746

Log(G) = 2.368825 + 0.304795*log(cu*K) + 0.155232*log(LH*L_Q) + 0.414463*log(M)

(t=3.7) (t=6.4) (Factor Share) (t=8.0)

+ 10.31675*(KIT/K) …………………………………………… eq. 3.11b

(t=3.5)

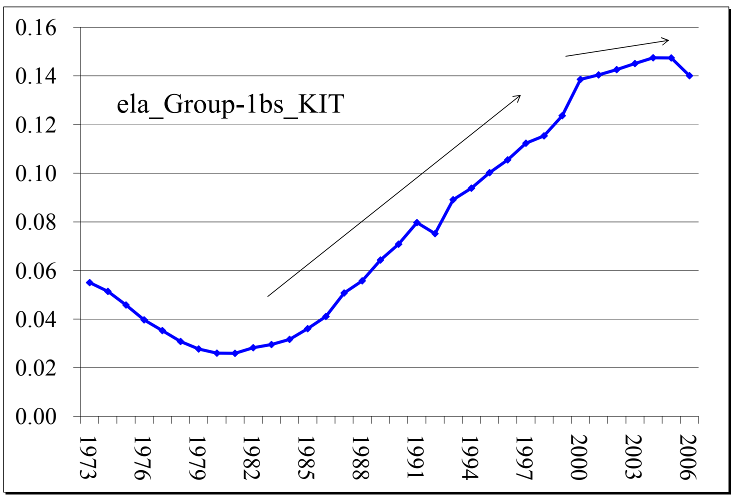
Sample: 1974-2006, D-W:2.05, R_2:0.99, ar(1))

Sum of Coefficients: 0.874

Findings:

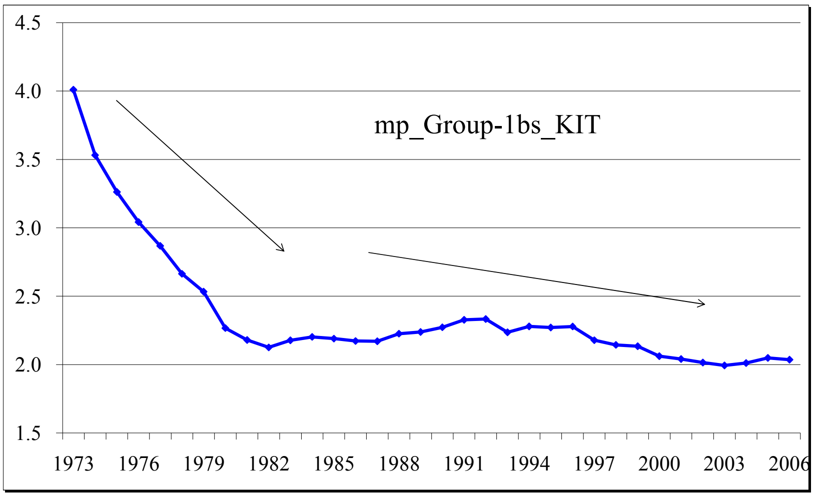
- Both equations of eq. 3.11a and eq. 3.11b show significant decreasing returns to scale (see sum of coefficients).
- If we use a traditional production function, the exogenous technological progress rate is estimated to be 0.922% per year (eq. 3.11a).
- TFP is also explained by quality of capital (eq. 3.11b). Group-1bs can increase output through TFP by improving quality of capital (KIT/K ≡KQ).
- Output elasticity w.r.t. IT capital stock calculated from eq. 3.11b is increasing after 1985. Its value is 0.14 in 2006 (graph 3.13), almost equal to the 0.12 calculated from the manufacturing sector (graph 3.8).

Graph 3.13: Output elasticity w.r.t. IT capital stock for Group-1bs(ela_Group-1bs_KIT)



- Although output elasticity w.r.t. IT capital stock has seen an increasing trend after 1985, marginal product of IT capital stock has seen a decreasing trend, suggesting that it will be difficult for this group to improve the economy of scale (graph 3.14).

Graph 3.14: Marginal product of IT capital stock for Group-1bs (mp_Group-1bs_KIT)



<u>Simulation Studies for Real Output Growth for Group-1bs</u>

- TFP(Time) in a traditional production function always contributes to output growth rate by 0.92% (table 3.8a) while the contribution to output growth of TFP (KQ: Quality of capital) in a new production function increases from 0.40% in the pessimistic case to 1.73% in the Intensive IT investment case (table 3.8b).
- In the standard case, TFP contributes 0.92% to output growth in a traditional production function and 0.79% in a new production function (tables 3.8a and 3.8b). However, a new production function proves that output will grow by more than 3%, because the output elasticity w.r.t. total capital stock is larger in a new production function than in a traditional production function.
- But it may not be easy for this group to achieve the average growth rate of the pre-bubble period, 4%, unless IT capital stock increase more than 12% (table 3.8b).

Table 3.8a: Simulation Studies for Group-1bs: In case of TFP(Time)

History		G	KO	KIT	LH	L_Q	M	KIT/LH (KI)	KIT/K (KQ)
Average Growth Rate	1975-2006	2.83	4.59	8.23	0.67	0.33	2.81	7.52	3.64
	1975-1992	3.98	6.57	9.68	0.99	0.20	4.05	8.62	3.28
	1993-2006	1.53	2.35	6.59	0.30	0.48	1.40	6.27	4.04
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			2.0	5.0	0.3	0.2	1.5		2.9
Contribution to Growth Rate of Group-1bs			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		1.99	0.42		0.08		0.57	0.92	
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			3.0	9.0	0.6	0.3	2.5		5.7
Contribution to Growth Rate of Group-1bs			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		2.82	0.63		0.14		1.13	0.92	
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			4.0	12.0	1.0	0.5	4.0		8.1
Contribution to Growth Rate of Group-1bs			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		3.49	0.84		0.23		1.50	0.92	
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			2.0	15.0	0.3	0.2	1.5		12.6
Contribution to Growth Rate of Group-1bs			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		2.02	0.45		0.08		0.57	0.92	

Table 3.8b: Simulation Studies for Group-1bs: Case of TFP (KQ)

History		G	KO	KIT	LH	L_Q	M	KIT/LH (KI)	KIT/K(KQ)
Average Growth Rate	1975-2006	2.83	4.59	8.23	0.67	0.33	2.81	7.52	3.64
	1975-1992	3.98	6.57	9.68	0.99	0.20	4.05	8.62	3.28
	1993-2006	1.53	2.35	6.59	0.30	0.48	1.40	6.27	4.04
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			2.0	5.0	0.3	0.2	1.5		2.9
Contribution to Growth Rate of Group-1bs			K(=KO+KIT)		L(LH+L_Q)		M		TFP (KQ)
		1.71	0.62		0.08		0.62		0.40
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			3.0	9.0	0.6	0.3	2.5		5.7
Contribution to Growth Rate of Group-1bs			K(=KO+KIT)		L(LH+L_Q)		M		TFP (KQ)
		3.08	0.92		0.14		1.23		0.79
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			4.0	12.0	1.0	0.5	4.0		7.6
Contribution to Growth Rate of Group-1bs			K(=KO+KIT)		L(LH+L_Q)		M		TFP (KQ)
		4.12	1.23		0.23		1.63		1.04
Assumed Growth Rate (%) **Intensive IT Investment Improvement Case**		G	KO	KIT	LH	L_Q	M		
			2.0	15.0	0.3	0.2	1.5		12.6
Contribution to Growth Rate of Group-1bs			K(=KO+KIT)		L(LH+L_Q)		M		TFP (KQ)
		3.08	0.66		0.78		0.62		1.73

(3) Group-1c: Local Services industries (1c) in Stage 1

Group-1c includes wholesale trade (67) and retail trade sale (68) industries. Other industries are local transportation such as railway (73), road transportation (74) and water transportation (75), hygiene (private and non-profit) (83), eating and drinking establishments (94), accommodation businesses (95), laundry, beauty and bath services (96) and other services for individuals (97).

Estimation Results for Group-1c:

We used factor share as a coefficient for intermediate input (M) because of multicollenearity among explanatory variables.

Log(G) = -15.12046 + 0.143502*log(cu*K) + 0.402584*log(LH*L_Q) + 0.395592*log(M)

(t=-2.9) (t=3.6) (t=3.7) (Factor share)

+ 0.008575*Time ………………………………………………… eq. 3.12a

(t=3.1)

Sample: 1975-2006, D-W:2.05, R_2:0.99, ar(2), ma(1,2,3,4)

Sum of Coefficients: 0.942

Log(G) = -4.364040 + 0.226604*log(cu*K) + 0.672553*log(LH*L_Q) + 0.395592*log(M)

(t=-1.5) (t=4.1) (t=3.8) (Factor share)

+ 20.36989*(KIT/L)*(KIT/K)………………………………………… eq. 3.12b

(t=2.4)

Sample: 1973-2006, D-W:1.99, R_2:0.99, ma(1,2,3,4,5)

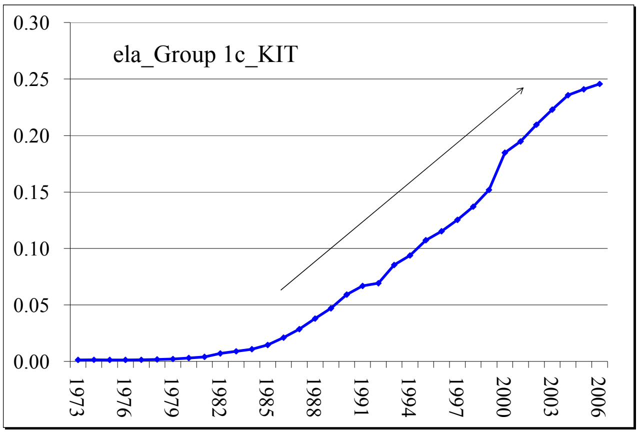
Sum of Coefficients: 1.295

Findings:

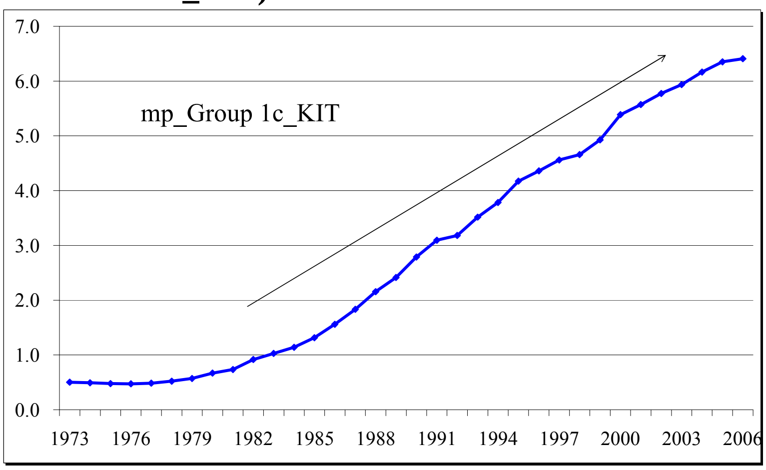
- A traditional production function shows decreasing returns to scale while a new production function illustrates increasing returns to scale. This group, especially wholesale and retail sale industries, has the potential of realizing economy of scale through the IT revolution.
- The multiplier of IT capital intensity and quality of capital explains TFP (eq. 3.12b).
- Output elasticity w.r.t. IT capital stock (KIT) has increased sharply since 1985. Its value is 0.25 in 2006 (graph 3.15), much higher than that of the manufacturing sector, 0.12.

- Similarly, marginal product of IT capital stock has kept increasing since the early 1980s (graph 3.16).
- As graphs 3.15 and 3.16 illustrate, Group-1c can benefit significantly from the increase in IT capital stock.
- When we aggregated wholesale trade (67) and retail trade (68) industries only, the output elasticity w.r.t. to IT capital stock became much higher, 0.6 at 2006 (graph 3.17). This is because these two industries have been utilizing IT effectively.

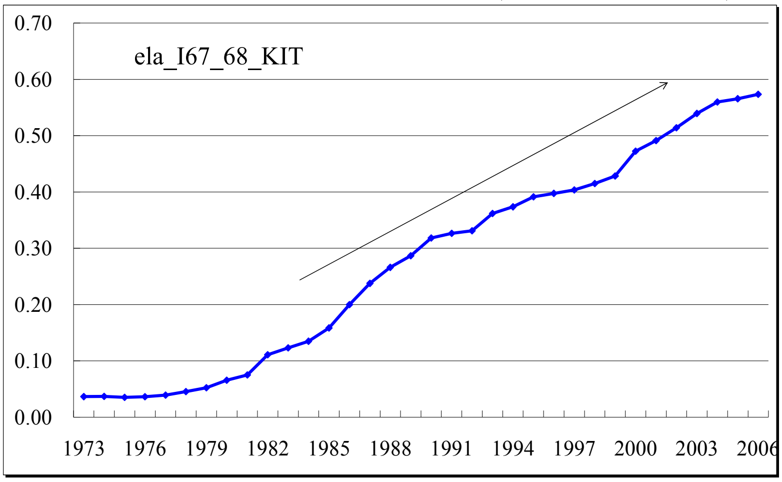
Graph 3.15: Output elasticity w.r.t. IT capital stock for Group-1c (ela_Group 1c_KIT)



Graph 3.16: Marginal product of IT capital stock for Group-1c (mp_Group 1c_KIT)



Graph 3.17: Output elasticity w.r.t. IT capital stock for Wholesale Trade and Retail Trade Industries (ela_I67_68_KIT)



<u>Simulation Studies for Real Output Growth for Group-1c</u>

- Tables 3.9a and 3.9b illustrate quite different simulation results for the output growth rates of a traditional production function and a new production function, with the exception of the pessimistic case.
- Contribution to output growth rates of TFP(KI*KQ) in a new production function increases from 0.98% in the Pessimistic case to 3.84% in the Intensive IT investment case (table 3.9b). (KI: Capital intensity = KIT / LH and KQ: Quality of capital = KIT / K.) This group is able to utilize the IT revolution significantly to raise TFP.
- TFP(Time) in a traditional production function always contributes to output growth by 0.86% (table 3.9a).
- A new production function proves that this group can achieve more than 3% growth in the standard case and an average growth rate during the pre-bubble period in the optimistic case where the assumed growth rates of input are realistic (table 3.9b).
- Even if we assume that IT capital stock increases 15% instead of 8% in the Standard case in table 3.9b, output will increase 5.19%. Group-1c can recover the pre-bubble output growth by increasing IT capital stock.

- Group-1c is one of the best examples of how we underestimate potential output when we use a traditional production function.

Table 3.9a: Simulation Studies for Group-1c: Case of TFP (Time)

History		G	KO	KIT	LH	L_Q	M	KIT/LH (KI)	KIT/K(KQ)
Average Growth Rate	1975-2006	2.75	3.25	11.65	0.17	0.60	2.79	11.42	7.97
	1975-1992	4.44	5.18	17.69	1.01	0.61	4.19	16.52	11.82
	1993-2006	0.85	1.06	4.81	-0.78	0.58	1.21	5.64	3.62
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			1.0	4.0	-1.0	0.5	1.0	5.1	2.9
Contribution to Growth Rate of Group-1c			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		1.41	0.16		0.00		0.39	0.86	
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			2.0	8.0	0.0	0.6	2.0	8.0	5.7
Contribution to Growth Rate of Group-1c			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		2.19	0.31		0.24		0.78	0.86	
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			3.0	12.0	1.0	0.6	3.0	10.9	8.4
Contribution to Growth Rate of Group-1c			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		3.13	0.46		0.64		1.17	0.86	
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			1.0	15.0	-1.0	0.5	1.0	16.2	13.3
Contribution to Growth Rate of Group-1c			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		1.25	0.21		-0.20		0.39	0.86	

Table 3.9b: Simulation Studies for Group-1c: Case of TFP (KI*KQ)

History		G	KO	KIT	LH	L_Q	M	K_IT/LH (KI)	K_IT/K (KQ)
Average Growth Rate	1975-2006	2.75	3.25	11.65	0.17	0.60	2.79	11.42	7.97
	1975-1992	4.44	5.18	17.69	1.01	0.61	4.19	16.52	11.82
	1993-2006	0.85	1.06	4.81	-0.78	0.58	1.21	5.64	3.62
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			1.0	4.0	-1.0	0.5	1.0	5.1	2.9
Contribution to Growth Rate of Group-1c			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		1.28	0.25		-0.34		0.39	0.98	
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			2.0	8.0	0.0	0.6	2.0	8.0	5.7
Contribution to Growth Rate of Group-1c			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		3.32	0.49		0.34		0.78	1.71	
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			3.0	12.0	1.0	0.6	3.0	10.9	8.4
Contribution to Growth Rate of Group-1c			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		5.36	0.73		1.00		1.17	2.45	
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			1.0	15.0	-1.0	0.5	1.0	16.2	13.3
Contribution to Growth Rate of Group-1c			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		4.22	0.33		-0.34		0.39	3.84	

(4) Group 2a: Labor Intensive Manufacturers (2a) in Stage 2

Group-2a of Labor intensive manufacturers in stage 2 consists of mainly two groups. The first group includes industries from textile products (JIP: 15) to lumber products (22) excluding pulp, paper, and coated and glazed paper (18) and printing, plate making for printing and bookbinding (20). The second group consists of industries from glass and its products (32) to non-ferrous metal products (39) (table 3.6). The household electric appliance industry (47) is also added to Group-2a.

Estimation Results for Group-2a:

TFP can be explained by Time or quality of capital. But, IT capital intensity was not statistically significant in explaining TFP.

Log(G) = -15.72735 + 0.140979*log(cu*K) + 0.268604*log(LH*L_Q) + 0.692020*log(M)

(t=-4.3) (t=3.1) (t=3.3) (t=7.3)

+ 0.007414*Time ……………………………………………………… eq. 3.13a

(t=3.9)

Sample: 1973-2006, D-W:2.09, R_2:0.99, ar(1), ar(2)

Sum of Coefficients: 1.102

Log(G) = -0.959980 + 0.139156*log(cu*K) + 0.258628*log(LH*L_Q) + 0.701379*log(M)

(t=-1.1) (t=2.5) (t=2.7) (t=8.2)

+ 3.506392*(KIT/K))……………………………………………………. eq. 3.13b

(t=1.9)

Sample: 1973-2006, D-W:1.81, R_2:0.99, ar(1)

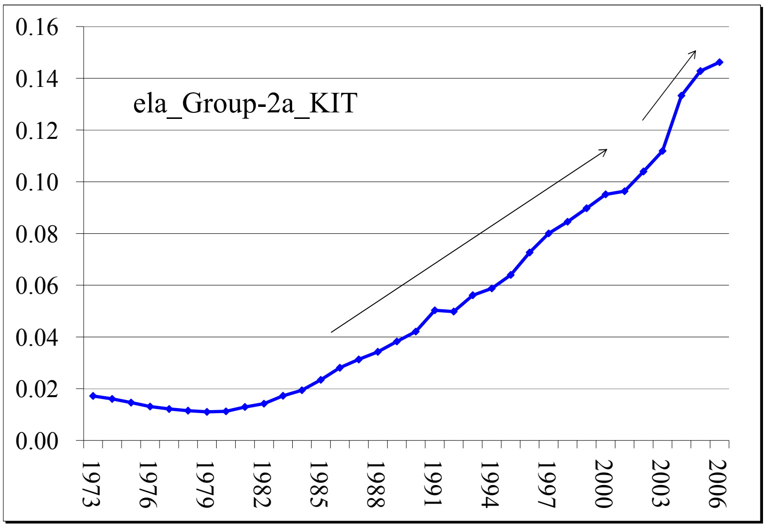
Sum of Coefficients: 1.099

Findings:

- Both equations of eq. 13a and eq.13b show the same increasing returns to scale (sum of coefficients is 1.1).
- Technological progress in a traditional production function is estimated to be 0.741% per year (eq. 3.13a).

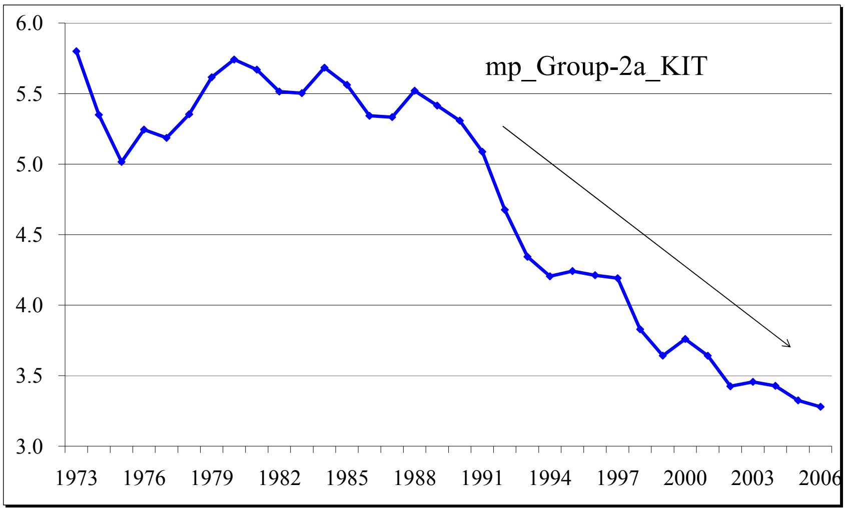
- Only quality of capital explains TFP (eq. 3.13b). IT capital intensity may not be a critical factor yet in labor intensive manufacturing group.

Graph 3.18: Output elasticity w.r.t. IT capital stock for Group-2a (ela_Group-2a_KIT)



- Output elasticity w.r.t. IT capital stock (KIT) has been increasing since 1985. Its value is about 0.15 in 2006 (graph 3.18), slightly higher than that of the manufacturing sector, 0.12.
- Marginal product of IT capital stock has been on a decreasing trend since after 1988 (graph 3.19).

Graph 3.19: Marginal product of IT capital stock for Group-2a (mp_Group-2a_KIT)



<u>Simulation Studies for Real Output Growth for Group-2a</u>

- Contribution to output growth by TFP (KQ) increases from 0.63% in the Pessimistic case to 2.01% in the Intensive IT investment case while that of TFP (Time) is constant, 0.74%.
- As output elasticity w.r.t. to IT capital stock has been increasing but the marginal product of IT capital stock has been decreasing since 1988, the effect of IT on this group may be moderate.
- Group-2a can achieve the average growth rate (2.19%) of output during the pre-bubble period in the optimistic cases simulated from both a traditional and new production functions while it cannot do so in the standard case.
- However, it seems to be difficult for this group to achieve a 3% growth rate because of the moderate effect of IT on the output.

Table 3.10a: Simulation Studies for Group-2a: Case of TFP (Time)

History		G	KO	KIT	LH	L_Q	M	KIT/LH (KI)	KIT/K (KQ)
Average Growth Rate	1975-2006	0.40	1.66	9.59	-2.80	0.52	0.05	12.83	7.62
	1975-1992	2.19	2.36	10.26	-1.05	0.44	1.90	11.48	7.56
	1993-2006	-1.62	0.87	8.84	-4.78	0.61	-2.04	14.36	7.68
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			0.5	5.0	-5.0	0.4	-2.0		
Contribution to Growth Rate of Group-2a			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		-1.83	0.10		-1.27		-1.4	0.74	
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			1.5	8.0	-2.0	0.5	1.0		
Contribution to Growth Rate of Group-2a			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		1.27	0.25		-0.41		0.69	0.74	
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			2.0	10.0	-1.0	0.6	2.0		
Contribution to Growth Rate of Group-2a			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		2.33	0.33		-0.11		1.37	0.74	
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			0.5	12.0	-5.0	0.4	-2.0		
Contribution to Growth Rate of Group-2a			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		-1.79	0.14		-1.27		0.69	0.74	

Table 3.10b: Simulation Studies for Group-2a: Case of TFP (KQ)

History		G	KO	KIT	LH	L_Q	M	KIT/LH (KI)	KIT/K(KQ)
Average Growth Rate	1975-2006	0.40	1.66	9.59	-2.80	0.52	0.05	12.83	7.62
	1975-1992	2.19	2.36	10.26	-1.05	0.44	1.90	11.48	7.56
	1993-2006	-1.62	0.87	8.84	-4.78	0.61	-2.04	14.36	7.68
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			0.5	5.0	-5.0	0.4	-2.0		4.3
Contribution to Growth Rate of Group-2a			K(=KO+KIT)		L(LH+L_Q)		M		TFP (KQ)
		-1.92	0.1		-1.22		-1.42		0.63
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			1.5	8.0	-2.0	0.5	1.0		6.1
Contribution to Growth Rate of Group-2a			K(=KO+KIT)		L(LH+L_Q)		M		TFP (KQ)
		1.44	0.24		-0.39		0.7		0.90
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			2.0	10.0	-1.0	0.6	2.0		7.5
Contribution to Growth Rate of Group-2a			K(=KO+KIT)		L(LH+L_Q)		M		TFP (KQ)
		2.70	0.32		-0.11		1.39		1.10
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			0.5	12.0	-5.0	0.4	-2.0		13.7
Contribution to Growth Rate of Group-2a			K(=KO+KIT)		L(LH+L_Q)		M		TFP (KQ)
		-0.7	0.15		-1.22		-1.42		2.01

(5) Group-2b: General Manufacturers (2b) in Stage 2

Group-2b includes four industries. They are pulp, paper and coated and glazed paper (18), chemical industries such as chemical fertilizer (23), basic inorganic chemicals (24), basic organic chemicals (25). Estimation results produced a very large coefficient for M while two coefficients for K and L were often negative because of typical multicollinearity. So, we had to use factor shares respectively as coefficients for K, L and M (eq. 3.14a and eq. 3.14b).

Estimation Results for Group-2b:

Log(G) = -10.37867 + 0.092647*log(cu*K) + 0.122120*log(LH*L_Q) + 0.715126*log(M)

(t=-5.8) (Factor share) (Factor share) (Factor share)

+ 0.006075*Time ………………………………………………… eq. 3.14a

(t=6.8)

Sample: 1973-2006, D-W:1.70, R_2:0.93, ma(1,2)

Sum of Coefficients: 0.930

Log(G) = 1.693586 + 0.092647*log(cu*K) + 0.122120*log(LH*L_Q) + 0.715126*log(M)

(t=3.0) (Factor share) (Factor share) (Factor share)

+ 0.552384*(KIT/LH)*(KIT/K)………………………………………eq. 3.14b

(t=3.3)

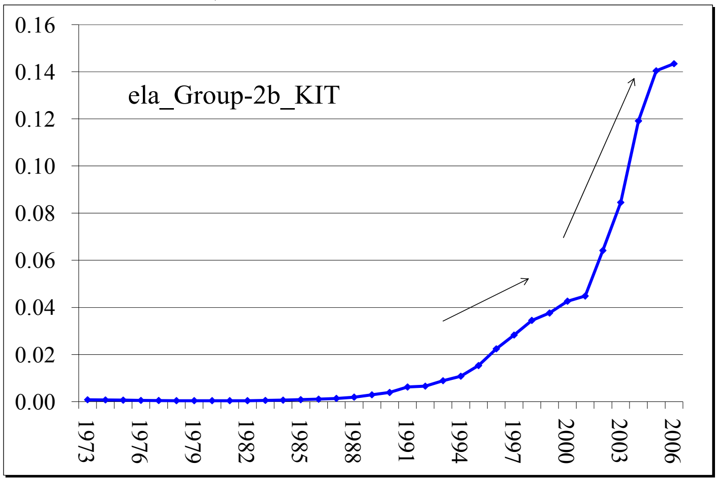
Sample: 1973-2006, D-W:1.92, R_2:0.89, ma(1,2,3)

Sum of Coefficients: 0.930

Findings:

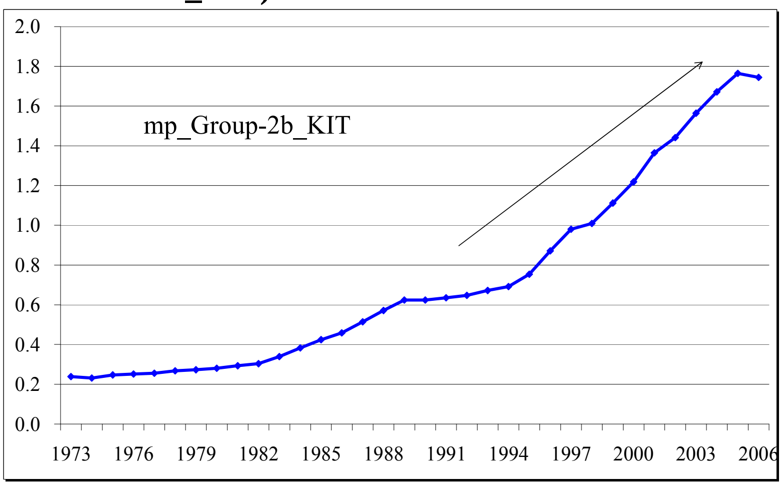
- This group shows decreasing returns to scale, the sum of coefficients =0.930.
- Output elasticity w.r.t. IT capital stock started to increase in the early 1990s and has accelerated since 2002 (graph 3.20). Its value is about 0.14 in2006, a bit higher than that of the manufacturing sector, 0.12.

Graph 3.20: Output elasticity w.r.t. IT capital stock for Group-2b (ela_Group-2b _KIT)



- Marginal product of IT capital stock was increasing (graph 3.21).

Graph 3.21: Marginal product of IT capital stock for Group-2b (mp_Group-2b_KIT)



- Since both output elasticity w.r.t. IT capital stock and the marginal product of IT capital stock have been increasing, especially in the 2000s, Group-2b can benefit from increasing IT capital stock from now on.

Simulation Studies for Real Output Growth

- The contribution to output growth of TFP (KI*KQ) increases from 1.16% in the Pessimistic case to 2.22% in the Intensive IT investment case (table 3.11b) while TFP (Time) constantly contributes to that by 0.61% (table 3.11a).
- This is another good case that shows that a traditional production function will conclude lower potential output than does the new production function (tables 3.11a and 3.11b).
- The Standard case in a new production function indicates the possibility that this group can achieve the average growth rate (1.84%) of output during the pre-bubble period while that using the traditional production function does not.
- Even if this group makes intense IT investment, it may be difficult to achieve a 3% growth rate.

Table 3.11a: Simulation Studies for Group-2b: Case of TFP (Time)

History		G	KO	KIT	LH	L_Q	M	KIT/LH (KI)	KIT/K (KQ)
Average Growth Rate	1975-2006	0.75	2.72	11.70	-1.76	0.50	0.23	13.76	8.47
	1975-1992	1.84	3.15	11.20	-1.30	0.60	1.04	12.67	7.55
	1993-2006	-0.48	2.23	12.27	-2.27	0.39	-0.70	14.99	9.50
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			2.0	8.0	-2.0	0.4	-0.5	10.2	5.5
Contribution to Growth Rate of Group-2b			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		0.27	0.22		-0.20		-0.36	0.61	
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			2.5	10.0	-1.0	0.5	0.5	11.1	6.9
Contribution to Growth Rate of Stage-2b			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		1.17	0.27		-0.06		0.36	0.61	
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			3.0	12.0	-0.5	0.6	1.0	12.6	8.2
Contribution to Growth Rate of Stage-2bb			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		1.65	0.32		0.01		0.71	0.61	
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			2.0	15.0	-2.0	0.4	-0.5	17.3	11.9
Contribution to Growth Rate of Stage-2b			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		0.30	0.25		-0.20		-0.36	0.61	

Table 3-11b: Simulation Studies for Group-2b: Case of TFP (KI* KQ)

History		G	KO	KIT	LH	L_Q	M	KIT/LH (KI)	K_IT/K(KQ)
Average Growth Rate	1975-2006	0.75	2.72	11.70	-1.76	0.50	0.23	13.76	8.47
	1975-1992	1.84	3.15	11.20	-1.30	0.60	1.04	12.67	7.55
	1993-2006	-0.48	2.23	12.27	-2.27	0.39	-0.70	14.99	9.50
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			2.0	8.0	-2.0	0.4	-0.5	10.2	5.5
Contribution to Growth Rate of Group-2b			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		0.82	0.22		-0.20		-0.36	1.16	
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			2.5	10.0	-1.0	0.5	0.5	11.1	6.9
Contribution to Growth Rate of Group-2b			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		1.89	0.27		-0.06		0.36	1.33	
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			3.0	12.0	-0.5	0.6	1.0	12.6	8.2
Contribution to Growth Rate of Group-2b			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		2.59	0.32		0.01		0.71	1.55	
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			2.0	15.0	-2.0	0.4	-0.5	17.3	11.9
Contribution to Growth Rate of Group-2b			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		1.91	0.25		-0.20		-0.36	2.22	

(6) Group-3: High-Tech Manufacturers in Stage 3

Stage 3 of High-tech manufacturers consists of 25 industries. They are printing, plate making for printing and bookbinding (20), industries from organic chemicals (26) to pharmaceutical products (29) and those from fabricated constructional and architectural metal products (40) to miscellaneous manufacturing industries (59) (see table 3.6). In order to avoid multicollinearity among explanatory variables we used factor share for a coefficient for M.

Estimation Results for Group-3:

Log(G) = -16.15706 + 0.137314*log(cu*K) + 0.320681*log(LH*L_Q) + 0.655194*log(M)

(t=0.1) (t=2.7) (t=5.6) (Factor Share)

+ 0.007586*Time ……………………………………………………….eq. 3.15a

(t=3.8)

Sample: 1973-2006, D-W:2.07, R_2:0.99, ma(1,2)

Sum of Coefficients: 1.121

Log(G) = -2.151557 + 0.191488*log(cu*K) + 0.325336*log(LH*L_Q) + 0.655194*log(M)

(t=0.1) (t=2.7) (t=5.6) (Factor Share)

+ 4.216209*(KIT/K)*(KIT/K) ………………………………………….eq. 3.15b

(t=2.3)

Sample: 1975-2006, D-W:2.22, R_2:0.99, ar(2), ma(1)

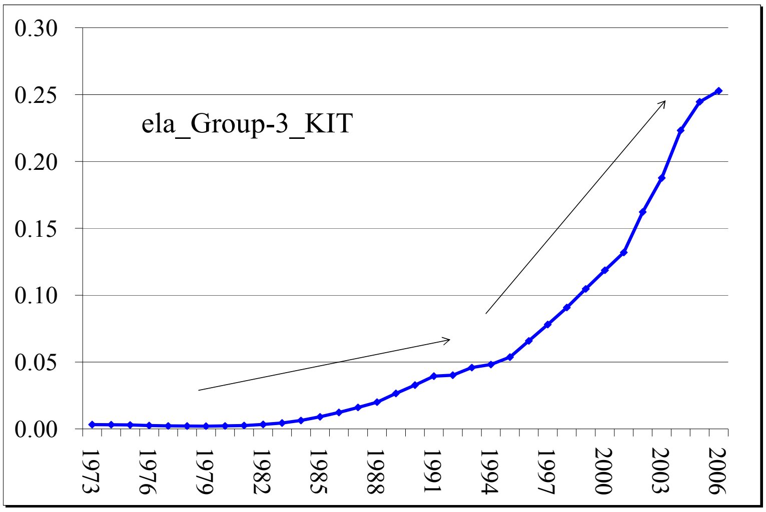
Sum of Coefficients: 1.171

Findings:

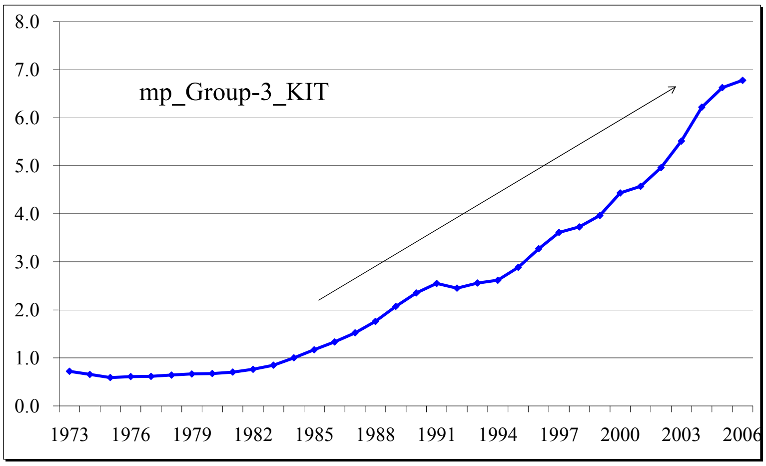
- Both equations of eq. 3.15a and eq. 3.15b show almost the same increasing returns to scale (see sum of coefficients),
- The disembodied technological progress rate is 0.7586% per year (eq. 3.15a).
- TFP in eq. 3.15b can be explained by the multiplier of IT capital stock and quality of capital.

- Output elasticity w.r.t. IT capital stock has increased sharply since 1995. Its value is about 0.25 in 2006 (graph 3.22), much higher than that of the manufacturing sector, 0.12.
- The marginal product of IT capital stock has been on an increasing trend since 1985 (graph 3.23).
- Since both output elasticity w.r.t IT capital stock and marginal product of IT capital stock are increasing, Group-3 can benefit significantly by increasing IT capital intensity and improving the quality of capital.

Graph 3.22: Output Elasticity w.r.t. IT Capital Stock for Group-3(=ela_group-3_KIT)



Graph 3.23: Marginal product of IT Capital Stock for Group-3(=mp_Group-3_KIT)



Simulation Studies for Real Output Growth

- Tables 3.12a and 3.12b illustrate the significant differences in the contribution to output by TFPs in traditional and the new production functions, suggesting that a traditional production function finds much lower potential output than does the new production function.
- The contribution to output growth by TFP in a new production function increases from 1.20% in the Pessimistic case to 3.85% in the Intensive IT Investment case, while that in a traditional production function is always 0.76%.
- A new production function proves that this group will easily achieve more than a 3% growth rate in the standard case as well as an average growth rate (5.49%) of output during the pre-bubble period in the optimistic case (table 3.12b).
- The assumed growth rates of KO and KIT in the optimistic case are both lower than their respective average actual growth rates during the pre-bubble period. Therefore, this group will be able to achieve the average growth rate of output during the pre-bubble period by increasing IT capital stock, which in turn will increase TFP's contribution to output.

Table 3.12a: Simulation Studies for Group-3 with TFP (Time)

History		G	KO	KIT	LH	L_Q	M	KIT/LH (KI)	KIT/K(KQ)
Average Growth Rate	1975-2006	3.61	4.19	10.75	-0.22	0.55	3.10	10.95	6.08
	1975-1992	5.49	5.26	13.56	1.02	0.52	5.08	12.33	7.62
	1993-2006	1.48	2.98	7.58	-1.62	0.58	0.87	9.39	4.33
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			2.0	5.0	-1.5	0.5	1.0		
Contribution to Growth Rate of Group-3			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		1.38	0.29		-0.32		0.65	0.76	
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			3.0	10.0	0.0	0.6	2.0		
Contribution to Growth Rate of Group-3			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		2.70	0.45		0.19		1.3	0.76	
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			4.0	12.0	1.0	0.6	3.0		
Contribution to Growth Rate of Group-3			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		3.80	0.59		0.51		1.94	0.76	
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			2.0	15.0	-1.5	0.5	1.0		
Contribution to Growth Rate of Group-3			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		1.44	0..36		-0.32		0.65	0.76	

Table 3.12b: Simulation Studies for Group-3 with TFP (KI*KQ)

History		G	KO	KIT	LH	L_Q	M	KIT/LH (KI)	KIT/K(KQ)
Average Growth Rate	1975-2006	3.61	4.19	10.75	-0.22	0.55	3.10	10.95	6.08
	1975-1992	5.49	5.26	13.56	1.02	0.52	5.08	12.33	7.62
	1993-2006	1.48	2.98	7.58	-1.62	0.58	0.87	9.39	4.33
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			2.0	5.0	-1.5	0.5	1.0	6.6	2.8
Contribution to Growth Rate of Group-3			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		1.92	0.41		-0.33		0.65	1.20	
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			3.0	10.0	0.0	0.6	2.0	7.4	10.0
Contribution to Growth Rate of Groupp-3			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		4.21	0.45		0.19		1.3	2.27	
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			4.0	12.0	1.0	0.6	3.0	10.9	7.0
Contribution to Growth Rate of Group-3			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		5.66	0.87		0.52		1.94	2.33	
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			2.0	15.0	-1.5	0.5	1.0	16.8	12.1
Contribution to Growth Rate of Group-3			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		4.67	0.5		-0.33		0.65	3.85	

(7) Group-4: High-Level Services industries in Stage 4

Group-4 has 19 industries classified into high-level services in Stage 4 (see table 3.6). There are various kinds of industries in Group-4 from construction (60) to video, sound, character information production and distribution (93). The aggregation of these 19 industries did not produce statistically significant results for the estimation of production functions. So, we focus on the so-called FIRE industries of Finance (69), Insurance (70) and Real Estate (71) as Group-4FIRE.

<u>Estimation Results for Group-4FIRE:</u>

Log(G) = -8.694937 + 0.304729*log(cu*K) + 0.352573*log(LH*L_Q) + 0.283617*log(M)

(t=-1.8)   (t=5.1)   (t=3.2)   (Factor share)

+ 0.005340*Time ……………………………………………… eq. 3.16a

(t=2.2)

Sample: 1974-2006, D-W:1.82, R_2:0.99, ma(1)

Sum of Coefficients: 0.941

Log(G) = 0.447681 + 0.332785*log(cu*K) + 0.418178*log(LH*L_Q) + 0.280673*log(M)

(t=0.3) (t=6.9) (t=3.1) (t=12.6)

+ 2.324427*{(KIT/L)*(KIT/K)}…………………………………… eq. 3.16b

(t=1.9)

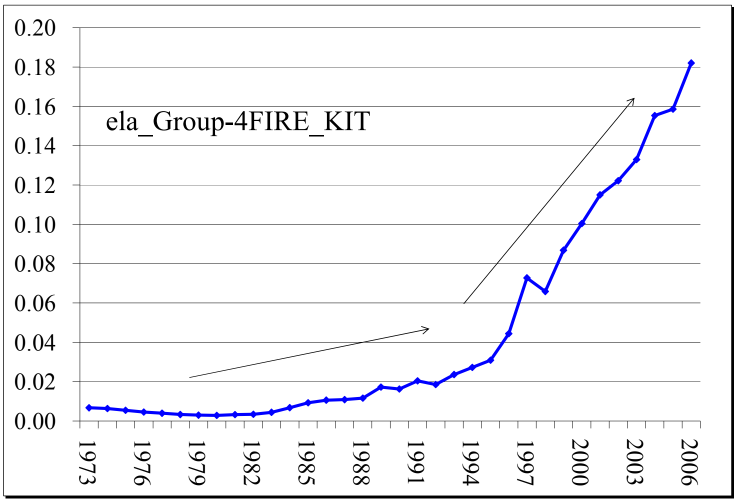
Sample: 1973-2006, D-W:1.72, R_2:0.99, ma(1,2)

Sum of Coefficients: 1.032

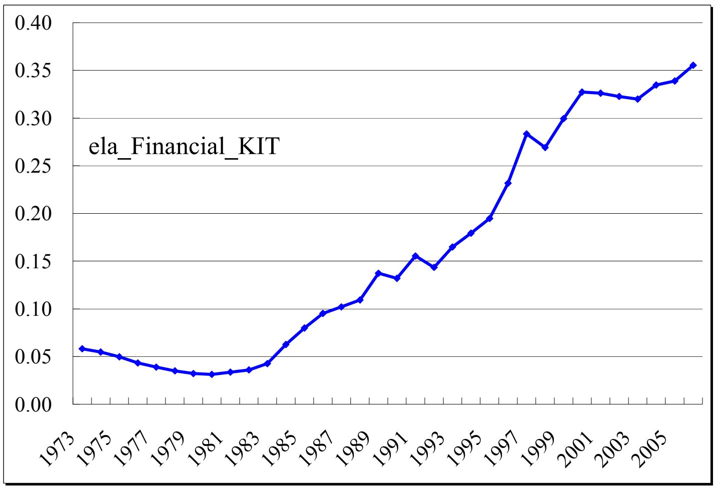
Findings:

- The disembodied technical progress rate is 0.534% per year. (eq. 3.16a).
- The multiplier of IT capital intensity and Quality of capital explains TFP (eq. 3.16b).
- Output elasticity w.r.t. IT capital stock (KIT) started to increase sharply after 1995 (graph 3.24a). Its value is 0.18 in 2006, higher than that of the manufacturing sector, 0.12. If we measure output elasticity w.r.t. finance industry only, output elasticity w.r.t. IT capital stock is much higher, 0.35 in 2006 (Graph 3.24b)

Graph 3.24a: Output elasticity w.r.t. IT capital stock for Group-4FIRE (ela_Group-4FIRE_KIT)

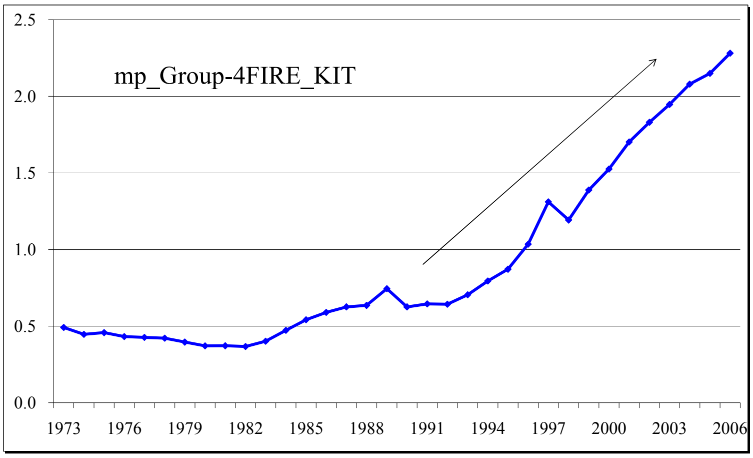


Graph 3.24b: Output elasticity w.r.t. IT capital stock for Group-4Financial (ela_Financial_IT)



- The marginal product of IT capital stock has been on an increasing trend since 1991 (graph 3.25).
- Since both output elasticity w.r.t. IT capital stock and the marginal product of IT capital stock are increasing, Group-4FIRE can increase output significantly by increasing IT capital intensity as well as improving the quality of capital.

Graph 3.25: Marginal product of IT capital stock for Group-4FIRE (mp_Group-4FIRE_KIT)



<u>Simulation Studies for Real Output Growth for Group-4FIRE</u>

- Contribution to output growth rates by TFP(KI*KQ) increases from 0.87% in the Pessimistic case to 2.72% in the Intensive IT investment case while that by TFP (Time) is constant, 0.53% (tables 3.16a).
- Comparing simulation studies, in particular the Intensive IT Investment Case, in tables 3.13a and 3.13b, it is obvious that FIRE industries can reap significant benefits by increasing IT capital intensity as well as improving quality of capital
- Although Group-4FIRE can achieve the average growth rate (5.80%) of the pre-bubble period in the Optimistic Case in table 3.13b, it cannot do so in the Standard Case. But it will be quite possible for Group-4FIRE to achieve a 3% growth rate.

Table 3.13a: Simulation Studies for Group-4FIRE: Case of TFP (Time)

History		G	KO	KIT	LH	L_Q	M	KIT/LH(KI)	KIT/K(KQ)
Average Growth Rate	1975-2006	4.03	5.09	10.43	0.93	0.63	4.66	9.54	4.98
	1975-1992	5.80	8.53	11.83	2.62	0.53	4.58	9.14	2.86
	1993-2006	2.02	1.18	8.83	-0.99	0.75	4.76	9.99	7.37
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			1.0	5.0	-1.0	0.5	4.0		
Contribution to Growth Rate of Group-4FIRE			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		1.82	0.35		-0.18		1.12	0.53	
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			4.0	8.0	1.0	0.6	4.5		
Contribution to Growth Rate of Group-4FIRE			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		3.59	1.24		0.56		1.25	0.53	
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			8.0	12.0	2.5	0.7	5.0		
Contribution to Growth Rate of Group-4FIRE			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		5.42	2.39		1.12		1.38	0.53	
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			1.0	15.0	-1.0	0.5	4.0		
Contribution to Growth Rate of Group-4FIRE			K(=KO+KIT)		L(LH+L_Q)		M	TFP (Time)	
		1.94	0.47		-0.18		1.11	0.53	

Table 3.13b: Simulation Studies for Group-4FIRE : Case of TFP (KI*KQ)

History		G	KO	KIT	LH	L_Q	M	KIT/LH(KI)	KIT/K(KQ)
Average Growth Rate	1975-2006	4.03	5.09	10.43	0.93	0.63	4.66	9.54	4.98
	1975-1992	5.80	8.53	11.83	2.62	0.53	4.58	9.14	2.86
	1993-2006	2.02	1.18	8.83	-0.99	0.75	4.76	9.99	7.37
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			1.0	5.0	-1.0	0.5	4.0	6.0	3.8
Contribution to Growth Rate of Group-4FIRE			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		2.14	0.38		-0.21		1.1	0.87	
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			4.0	8.0	1.0	0.6	4.5	6.9	3.7
Contribution to Growth Rate of Group-4FIRE			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		4.19	1.36		0.67		1.23	0.94	
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			8.0	12.0	2.5	0.7	5.0	9.3	3.6
Contribution to Growth Rate of Group-4FIRE			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		6.44	2.61		1.32		1.37	1.13	
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			1.0	15.0	-1.0	0.5	4.0	16.2	13.2
Contribution to Growth Rate of Group-4FIRE			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		4.12	0.51		-0.21		1.10	2.72	

(8) Group-9: Public Activities

We removed Public activities from the Stages of Developing Ladder. Group-9 of public activities includes the mail industry (79), other public services (84) and Education (public) (98) ~ Other (nonprofit) (107) in table 3.6. TFP could not be explained by Time.

Estimation Results for Group-9:

Log(G) = 5.657206 + 0.119326*log(cu*K) + 0.115392*log(LH*L_Q) + 0.499688*log(M)

(t=10.2) (t=5.7) (t=2.4) (t=16.0)

……………………………………………………eq.3.17a

Sample: 1973-2006, D-W:1.72, R_2:0.99, ma(1)

Sum of Coefficients: 0.734

Log(G) = 6.703913 + 0.168836*log(cu*K) + 0.187572*log(LH*L_Q) + 0.313634*log(M)

(t=5.9) (t=5.1) (t=2.3) (Factor share)

+ 2.62384*{(KIT/L)*(KIT/K)}…………………………………………eq. 3.17b

(t=2.3)

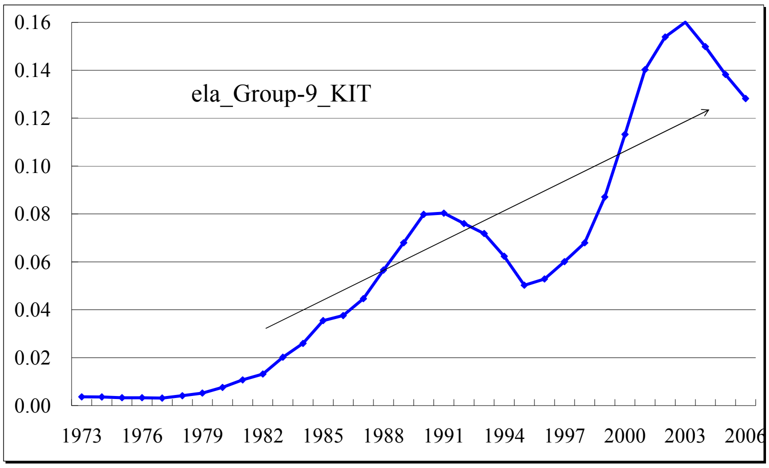
Sample: 1974-2006, D-W:2.05, R_2:0.99, ar(8), ar(2), ma(2)

Sum of Coefficients: 0.670

Findings:

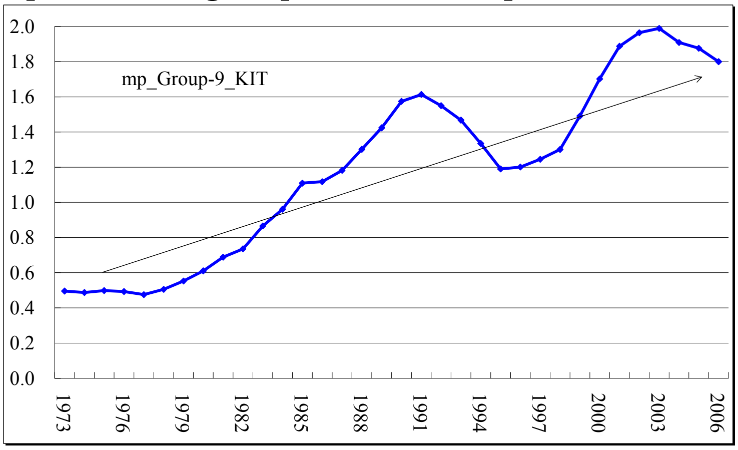
- Both equations show very small returns to scale (see sum of coefficients), because the estimated coefficient of labor input is much lower than the average factor share of labor input during the sample period, 0.613. This implies too much salary but too little output in public activities, suggesting inefficient industries.
- Disembodied technical progress was not found (eq. 3.17a).
- Multiplier of IT capital intensity and Quality of capital explains TFP (eq. 3.17b).
- Output elasticity w.r.t. IT capital stock (KIT) has been on an increasing trend (graph 3.26) since the early 1980s. Its value is 0.13 in 2006, almost the same as that of the manufacturing sector, 0.12.

Graph 3.26: Output elasticity w.r.t. IT capital stock for Grpup-9 (ela_Group-9_KIT)



- Marginal product of IT capital stock also has been on an increasing trend since the 1980s (graph 3.27).
- Group-9 can increase output significantly by increasing IT capital intensity as well as improving the quality of capital because both output elasticity w.r.t. IT capital stock and marginal product of IT capital stock are increasing.
- There is a lot of room for this Group to raise potential growth by utilizing IT such as e-government and e-education.

Graph 3.27: Marginal product of IT capital stock in Group-9 (mp_Group-9_KIT)



Simulation Studies for Real Output Growth for Group-9

- Contribution to output growth by TFP (IT variables) increases from 0.18% in the Pessimistic case to 1.89% in the Intensive IT Investment case.
- As the Standard case in table 3.14b shows, we can conclude that this group can achieve 3% output growth, although it may be somewhat difficult for this group to reach the average growth rate of output during the pre-bubble period.

Table 3.14a: Simulation Studies for Group-9: Case of TFP (None)

History		G	KO	KIT	LH	L_Q	M	KIT/LH(KI)	KIT/K(KQ)
Average Growth Rate	1975-2006	3.42	6.20	11.59	1.45	0.63	4.39	9.99	4.86
	1975-1992	4.50	7.73	17.44	1.46	0.56	5.74	15.71	8.72
	1993-2006	2.20	4.47	4.96	1.43	0.72	2.86	3.50	0.48
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M		
			4.0	4.0	1.0	0.5	2.0		
Contribution to Growth Rate of Group-9			K(=KO+KIT)		L(LH+L_Q)		M	TFP (none)	
		1.63	0.49		0.17		0.99		
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			5.0	10.0	1.3	0.6	3.0		
Contribution to Growth Rate of Group-9			K(=KO+KIT)		L(LH+L_Q)		M	TFP (none)	
		2.30	0.61		0.22		1.48		
Assumed Growth Rate (%) **Optimistic Case**		G	KO	KIT	LH	L_Q	M		
			6.0	15.0	1.5	0.7	5.0		
Contribution to Growth Rate of Group-9			K(=KO+KIT)		L(LH+L_Q)		M	TFP (none)	
		3.43	0.74		0.25		2.44		
Assumed Growth Rate (%) **Intensive IT investment Case**		G	KO	KIT	LH	L_Q	M		
			4.0	17.5	1.0	0.5	2.0		
Contribution to Growth Rate of Group-9			K(=KO+KIT)		L(LH+L_Q)		M	TFP (none)	
		1.70	0.54		0.17		0.99		

Table 3.14b: Simulation Studies for Public Activities: Case of TFP (KI*KQ)

History		G	KO	KIT	LH	L_Q	M	KIT/LH(KI)	KIT/K(KQ)
Average Growth Rate	1975-2006	3.42	6.20	11.59	1.45	0.63	4.39	9.99	4.86
	1975-1992	4.50	7.73	17.44	1.46	0.56	5.74	15.71	8.72
	1993-2006	2.20	4.47	4.96	1.43	0.72	2.86	3.50	0.48
Simulations									
Assumed Growth Rate (%) **Pessimistic Case**		G	KO	KIT	LH	L_Q	M	2.9	0.0
			4.0	4.0	1.0	0.5	2.0	3.0	0.0
Contribution to Growth Rate of Group-9			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		1.75	0.66		0.28		0.62	0.18	
Assumed Growth Rate (%) **Standard Case**		G	KO	KIT	LH	L_Q	M		
			5.0	10.0	1.3	0.6	3.0	8.6	4.5
Contribution to Growth Rate of Group-9			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		2.98	0.86		0.35		0.93	0.83	
Assumed Growth Rate (%) **Optimistic Case**		G							
			6.0	15.0	1.5	0.7	5.0	13.3	8.1
Contribution to Growth Rate of Group-9			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		4.37	1.05		0.41		1.53	1.39	
Assumed Growth Rate (%) **Intensive IT Investment Case**		G	KO	KIT	LH	L_Q	M		
			4.0	17.5	1.0	0.5	2.0	16.3	12.3
Contribution to Growth Rate of Group-9			K(=KO+KIT)		L(LH+L_Q)		M	TFP (KI*KQ)	
		3.55	0.76		0.28		0.62	1.89	

4.3 Summary of Estimation Results and Implication of S-Shape Production Functions for ASEAN Countries

We tried to quantitatively study the following things by estimating traditional and new production functions for the Japanese industrial groups classified by the Stages of Development Ladder which shows characteristics of ASEAN countries:

- Whether or not the effect of IT on the economic (output) growth through TFP increases as the economic development advances.
- Whether output elasticity w.r.t. IT capital stock is increasing or decreasing over a certain range.
- How much is the value of output elasticity w.r.t. IT capital stock?
- Whether marginal product of IT capital stock is increasing or decreasing.
- What kind of IT variables can explain TFP best?

- Whether each group in Japan can achieve the pre-bubble output growth by increasing IT capital intensity or improving quality of capital.
- Whether each group in Japan can achieve at least 3% economic growth by increasing IT capital intensity or improving quality of capital. A 3% growth rate is a reasonable target for the Japanese economy, refuting the potential growth rate of about 1.5% that prevails among the Japanese economist and policy-makers.

We summarize the estimation results regarding the above in table 3.15.

The primary findings include the following:

- IT does not play an important role in the very early stage of the development ladder (Group 1a).
- Improving the quality of IT capital plays a more important role in the early stage of the development ladder than increasing IT capital intensity (Group 1bs ~ Group 2a).
- IT capital intensity also becomes important as industries (countries) move up to a higher stage of the development ladder (Group 2b ~ Group 4FIRE).
- Both output elasticity w.r.t. IT capital stock and marginal product of IT capital stock have increasing trends in Group 1c and Group 2a ~ Group 4FIRE. Once a country moves up to the general manufacturing stage, it can benefit from improving the quality of capital as well as increasing IT capital intensity.
- Wholesale and retail trade industries can reap significant benefits from the IT revolution. Their output elasticity w.r.t. IT capital stock was about 0.6 in 2006.
- The average output elasticity of IT capital stock for the total Japanese manufacturing sector was 0.1 ~ 0.15 after 2005.
- If we use a traditional production function to calculate potential growth, it will miss the possibility of higher potential growth brought about by TFP (IT variables).
- As for Japanese potential growth, only the primary products group (Group 1a) and labor intensive group (Group 2a) have difficulty achieving a 3% growth rate of output, but all other industrial groups can achieve at least a 3% growth rate or

even the average growth rate of output during the pre-bubble period. As a result, we can conclude that Japan's potential growth is definitely more than a 3%.

Table 3.15: Summary of Estimation Results

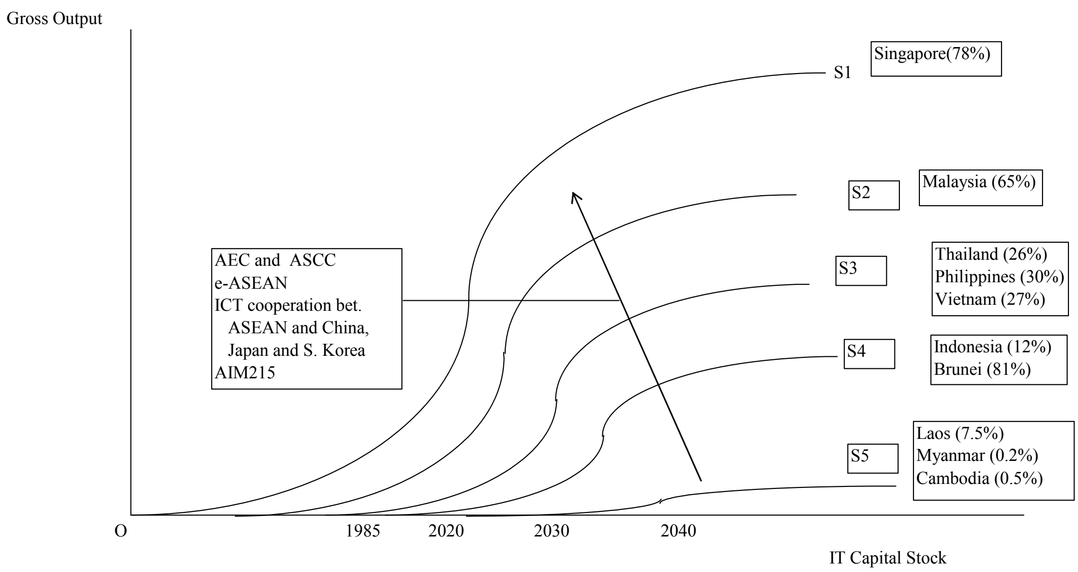
		Stages of Development Ladder										
		1				2		3	4			
		Primary Products (1a)	Resouce Related (1b)		Lcal Services (1c)	Labor Intensive Mfg. (2a)	General Mfg. (2b)	High-Tech. Mfg. (3)	High-Level Services (4)		Public Activities	Manufac-turing
	Industries			Service Sector (1bs)					60,61, 69~71 76,78, 80~82, 85~92	FIRE		
	JIP Industries	1 ~ 7	8~14 30, 31 62~66	62~66	67,68, 73~75, 83 94~97	15~17, 19, 21,22, 32~39,47	18, 23~25	20, 26~29 40~59		69~71	79, 99~107	8 ~ 59
1	TFP (Time) % per Year in a traditional production function	NA	NA	0.92%	0.86%	0.74%	0.61%	0.76%	NA	0.53%	NA	0.76%
2	TFP(IT variables) KI: IT capital Intensity KQ: Quality of Capital	NA	NA	KQ	KI*KQ	KQ	KI*KQ	KI*KQ	NA	KI*KQ	KI*KQ	KI*KQ
3	Output Elasticity w.r. Capital Stock											
3a	Decreasing or Iincreasing			Increasing	Increasing	Increasing	Increasing	Increasing		Increasing	Increasing	Increasing
3b	Value at 2006	Almost 0		0.14	0.25(*)	0.15	0.14	0.25		0.18(0.35**	0.13	0.12
4	Marginal Product of IT Capital Stock	Decreasing		Decreasing	Increasing	Decreasing	Increasing	Increasing		Increasing	Increasing	Increasing
5	Possibility to Achieve Economic Growt of the Pre-Bubble Peiod	x		△	◎	X	○	◎		△	△	△
6	Comparison of Output Growth in Intensive IT investment Case in Time (TFP) and Time (IT variables)											
6a	by TFP (Time)	na		2.02%	1.25%	2.02%	0.29%	1.44%		1.94%	1.70%	0.43%
6b	by TFP (IT variables)	na		3.08%	4.22%	3.08%	1.44%	4.67%		4.12%	3.55%	1.49%
	The Economy of Scale											
	a traditional production function	0.909		0.746	0.942	1.102	0.930	1.121		0.941	0.734	1.096
	a new production function			0.874	1.295	1.099	0.930	1.171		1.032	0.670	1.162

*	*: When we aggregate Wholesale trade and Retail trade industries only, the output elasticity w.r.t. IT capital stock is 0.6.
**	**: 0.35 is the case for financial industry only.
X	X: It is difficult to achieve neither the average growth rate of the pre-bubble period nor a 3% growth.
△	△: It is difficult to achieve the average growth rate of the pre-bubble period but possible for 3%.
○	○: It is possible to achieve the average growth rate of the pre-bubble period but difficult for a 3% growth.
◎	◎: It is possible to achieve both the average growth rate of the pre-bubble period and a 3% growth.

When we consider our empirical results from a viewpoint of the Stages of the Development Ladder including Internet dispersion, we may assume the S-Shape production functions for ASEAN countries (figure 3.1). Once each ASEAN country can formulate time series data such as real gross output, real net IT capital stock and real IT service flow, we can verify which S-Shape production function fits with each ASEAN country. For ASEAN to raise potential output and achieve higher economic growth ASEAN needs to introduce the right mix of policies that will shift the S-Shape production function upward through TFP. To this end, IT policies and human development policies designed particularly in the ASEAN Economic Community (AEC) Blueprint, ASEAN Socio-Cultural Community (ASCC) Blueprint, e-ASEAN Framework Agreement, ICT cooperation or collaboration between ASEAN and other East Asian countries such as China, Japan and S. Korea and AIM215, will be very effective.

Figure 3.1: Hypotheses of ASEAN Countries' S-Shape Production Functions

(%): Internet penetration among population



Appendix A:

IT capital intensity (KIT/LH) and Quality of Capital (KIT/K) for 108 Japanese Industries

JIP #		IT capital Intensity (KIT/LH) (Yen/ Man-hours)	Quality of Capita (KIT/K) (%)
1	Rice, wheat production	0.002	0.010
2	Miscellaneous crop farming	0.003	0.042
3	Livestock and sericulture farming	0.011	0.147
4	Agricultural services	0.142	2.018
5	Forestry	0.017	0.066
6	Fisheries	0.066	0.789
7	Mining	0.059	0.575
8	Livestock products	0.065	1.218
9	Seafood products	0.034	1.447
10	Flour and grain mill products	0.013	2.261
11	Miscellaneous foods and related products	0.049	1.311
12	Prepared animal foods and organic fertilizers	0.025	0.930
13	Beverages	0.169	1.124
14	Tobacco	0.782	1.427
15	Textile products	0.025	0.675
16	Lumber and wood products	0.021	0.641
17	Furniture and fixtures	0.036	1.481
18	Pulp, paper, and coated and glazed paper	0.242	1.378
19	Paper products	0.060	1.070
20	Printing, plate making for printing and bookbinding	0.062	1.643
21	Leather and leather products	0.024	1.117
22	Rubber products	0.055	1.136
23	Chemical fertilizers	1.147	2.454
24	Basic inorganic chemicals	1.140	3.226
25	Basic organic chemicals	0.537	1.234
26	Organic chemicals	0.365	1.031
27	Chemical fibers	0.262	0.751
28	Miscellaneous chemical products	0.191	1.490
29	Pharmaceutical products	0.624	3.749
30	Petroleum products	1.002	0.744
31	Coal products	0.195	0.767
32	Glass and its products	0.129	1.304
33	Cement and its products	0.052	0.806
34	Pottery	0.072	1.983
35	Miscellaneous ceramic, stone and clay products	0.062	0.705

(Continued)

36	Pig iron and crude steel	0.317	0.644
37	Miscellaneous iron and steel	0.265	0.921
38	Smelting and refining of non-ferrous metals	0.238	2.202
39	Non-ferrous metal products	0.117	0.844
40	Fabricated constructional and architectural metal product	0.054	1.861
41	Miscellaneous fabricated metal products	0.060	1.827
42	General industry machinery	0.104	1.296
43	Special industry machinery	0.127	1.668
44	Miscellaneous machinery	0.062	1.090
45	Office and service industry machines	0.125	1.992
46	Electrical generating, transmission, distribution and industrial apparatus	0.357	3.562
47	Household electric appliances	0.774	5.527
48	Electronic data processing machines, computer equipment	1.145	11.394
49	Communication equipment	0.652	6.956
50	Electronic equipment and electric measuring instruments	0.722	11.602
51	Semiconductor devices and integrated circuits	0.276	2.573
52	Electronic parts	0.291	7.382
53	Miscellaneous electrical machinery equipment	0.256	4.298
54	Motor vehicles	0.202	1.253
55	Motor vehicle parts and accessories	0.140	1.265
56	Other transportation equipment	0.148	1.620
57	Precision machinery & equipment	0.182	2.254
58	Plastic products	0.036	0.549
59	Miscellaneous manufacturing industries	0.129	2.560
60	Construction	0.037	2.268
61	Civil engineering	0.041	2.072
62	Electricity	1.955	0.921
63	Gas, heat supply	0.873	1.532
64	Waterworks	0.394	0.214
65	Water supply for industrial use	0.309	0.062
66	Waste disposal	0.018	0.394
67	Wholesale	0.132	3.357
68	Retail	0.097	4.615
69	Finance	0.482	9.934
70	Insurance	0.389	10.436

(continued)

71	Real estate	0.063	0.175
72	Housing (Imputed rent)	NA	0.000
73	Railway	0.633	0.536
74	Road transportation	0.055	0.625
75	Water transportation	0.167	0.612
76	Air transportation	0.593	1.348
77	Other transportation and packing	0.133	2.581
78	Telegraph and telephone	10.471	13.558
79	Mail	0.216	13.574
80	Education (private and non-profit)	0.128	1.323
81	Research (private)	0.130	2.717
82	Medical (private)	0.113	1.955
83	Hygiene (private and non-profit)	0.019	5.119
84	Other public services	0.049	6.747
85	Advertising	0.660	7.202
86	Rental of office equipment and goods	9.346	17.274
87	Automobile maintenance services	0.029	1.056
88	Other services for businesses	0.141	9.716
89	Entertainment	0.232	2.238
90	Broadcasting	2.588	7.509
91	Information services and internet-based services	0.394	15.518
92	Publishing	0.132	2.373
93	Video picture, sound information, character information production and distribution	0.024	1.942
94	Eating and drinking places	0.007	0.516
95	Accommodation	0.035	0.396
96	Laundry, beauty and bath services	0.009	1.000
97	Other services for individuals	0.038	1.819
98	Education (public)	0.057	0.997
99	Research (public)	0.433	1.904
100	Medical (public)	0.075	1.549
101	Hygiene (public)	0.038	2.785
102	Social insurance and social welfare (public)	0.086	3.841
103	Public administration	0.790	4.047
104	Medical (non-profit)	0.078	2.014
105	Social insurance and social welfare (non-profit)	0.045	3.414
106	Research (non-profit)	0.046	0.949
107	Other (non-profit)	0.089	3.046
108	Activities not elsewhere classified	0.214	2.741

5. The Case of Thailand[12]

We apply a new production function to the Thai economy in Stage 2 of the development ladder because time series data of real net IT capital stock are available, since the National Economic and Social Science Development Board (NESDB) has prepared Input-Output data. Although nominal gross output data series are available, real gross output data are not yet available. So, we use real GDP as a dependent variable instead of real gross output, though a production function of gross output is preferable than that of value added particularly for analyzing the IT revolution as well as oil crises. This is because IT input, like energy input, plays an important role as an intermediate input such as B2B. However, IT plays a more important role in TFP so we introduce IT variables to explain TFP in a value-added production function.

IT capital stock in the Thai economy consists of the following three investments:

- Office, computing and accounting machines.
- Radio, television and communication equipment and apparatus.
- Scientific, measuring, controlling equipment, n.e.c.

We estimate a traditional production function with TFP (Time) and a new production function with TFP (IT variables) and compare their simulation results to judge the effect of IT on the Thai economy. Time series data such as capacity utilization and work-hours are not available for the whole sample period. We had to assume constant returns to scale in order to obtain reasonable parameters.

Estimation Results for the Thai Economy:

Log(GDP) = -21.88939 + 0.489052*log(K) + (1-0.489052)*log(L)

(t=-2.0) (t=3.9) (constant returns to scale is assumed)

[12] We could obtain the time series data of real net IT capital stock only for Thailand. We thank Dr. SurapolSrihuang and Ms. WannapaKhlaisuan at NESDB for providing IT capital stock data.

+ 0.01186*Time - 0.045151*D9798 ……………………….………eq.3.18a

(t=2.1) (-2.2)

Sample: 1987-2009, D-W:2.02, R_2:0.99, ar(1,2)

Sum of Coefficients: 1.0

where

GDP: Real gross domestic product

K: Real Net capital stock

L: Employment

Time: a proxy of disembodied technical progress.

D9798: Financial crisis dummy (=1 for 1987 and 1988, 0 for else)

Log(GDP) = 2.388570 + 0.320615*log((K+K(-1))/2) + (1- 0.320615)*log(L) +

(t=3.5) (t=2.2) (constant returns to scale is assumed)

+ 0.247936*(KI)*(KQ)*(1-UR/100) – 0.058167*D9798 ……..eq. 3.18b

(t=2.7) (t=-3.4)

Sample: 1987-2009, D-W:1.83, R_2:0.99, ar(1,2)

Sum of Coefficients: 1.0

KI: IT capital intensity (= KIT / K)

KQ: Quality of capital (= KIT / K)

UR: Unemployment rate (%)

Findings:

- We tried to use (1-unemployment rate/100) as a proxy of capacity utilization when it worked.
- We assumed constant returns to scale because estimated parameters for labor or capital input often exceeded 1.0.
- Disembodied technical progress is 1.186% per year (Eq. 3.18a).
- Multiplier of IT capital intensity and Quality of capital explains TFP (eq. 3.18b).
- Output (GDP) elasticity w.r.t. IT capital stock is calculated from eq. 3.18b. This had an increasing trend in the 1990s but turned into a decreasing trend in the 2000s (graph 3.28). Its value, 0.8, in 2009 is still quite high, suggesting more significant effect of IT on the Thai economy than the Japanese economy.
- Output (GDP) elasticity w.r.t. IT capital stock (≡ela_GDP_KIT) will be precisely compared to output (gross output) elasticity w.r.t. IT capital stock (≡ela_G_KIT) as shown in eq.s 3.19a ~ 2.19c.

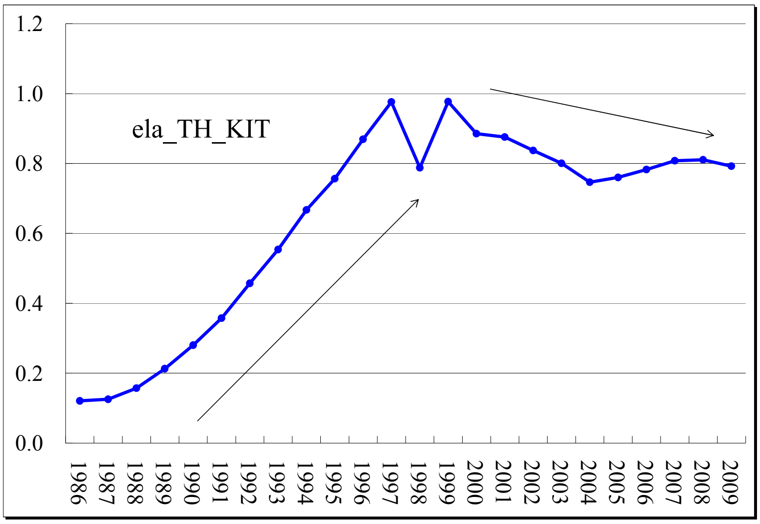
ela_G_KIT≡{d(G)/G}/ {d(KIT)/KIT} …………………………………. Eq. 3.19a

where G: gross output and KIT: IT capital stock.

ela_GDP_KIT≡{d(GDP)/GDP}/ {d(KIT)/KIT} ………………………. Eq. 3.19b

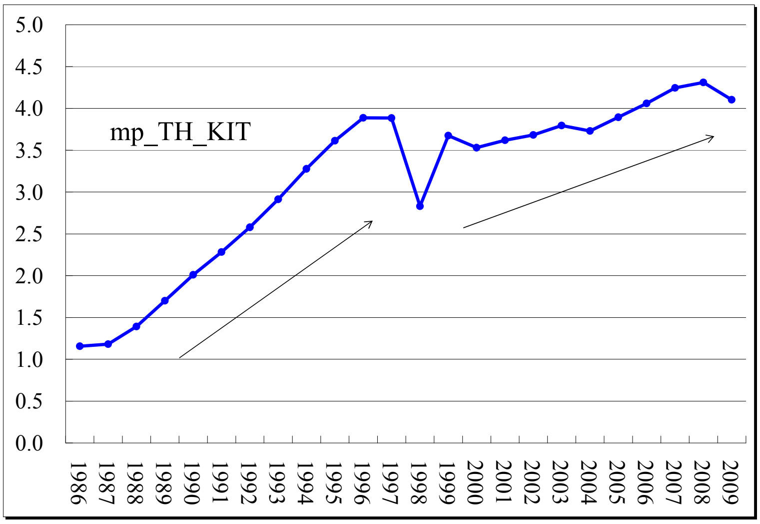
ela_GDP_KIT / ela_G_KIT = {d(GDP)/d(G)}*(G/GDP) ………………. Eq. 3.19c

Graph 3.28: Output (GDP) elasticity w.r.t. IT capital stock for Thai Economy



- The marginal product of IT capital stock enjoyed a sharp increasing trend before the financial crisis in 1997 and a moderately increasing trend in the 2000s (graph 3.29). Thai economy had much benefits from the IT revolution before the 1977 financial crisis than after that.

Graph 3.29: Marginal product (GDP) of IT capital stock for the Thai economy



<u>Simulation Studies for Real Output (GDP) Growth for the Thai Economy</u>

- Contribution to output growth by TFP (Time) is always 1.19% while that of TFP (KI*KQ) changes from 0.38% in the Pessimistic case to 6.17% in the Intensive IT investment case.
- A traditional production function shows only a 0.13% increase for output growth from the Standard case to the Intensive IT Investment case (table 3.15a) while a new production function shows a 3.05% increase for output growth from the Standard case to the Intensive IT investment case (table 3.15b). We assumed that KIT increased by 8.0% in the Standard case and by 12.0% in the Intensive IT Investment case. Namely, a traditional production function misses the effect of IT variables on output through TFP.
- If we apply the Peak-to-Peak approach to measure potential output, the potential output after the 1997-98 financial crisis is about 6% (graph 3.30).
- One of the most serious concerns about the recent Thai economy is the sharp decline in investment after the financial crisis. The average growth rate of IT capital stock fell from 17.4% during 1986-96 to 1.3% during 1997-2009 and that of non-IT capital stock from 10.2% to 2.5% for the same period.
- The simulation studies from the Standard case to the Intensive IT Investment case in table 3.15b illustrate how the Thai economy can maintain a potential output of much more than 6% by increasing IT investment.

Graph 3.30 Potential Output (%) for Thai Economy by Peak-to-Peak

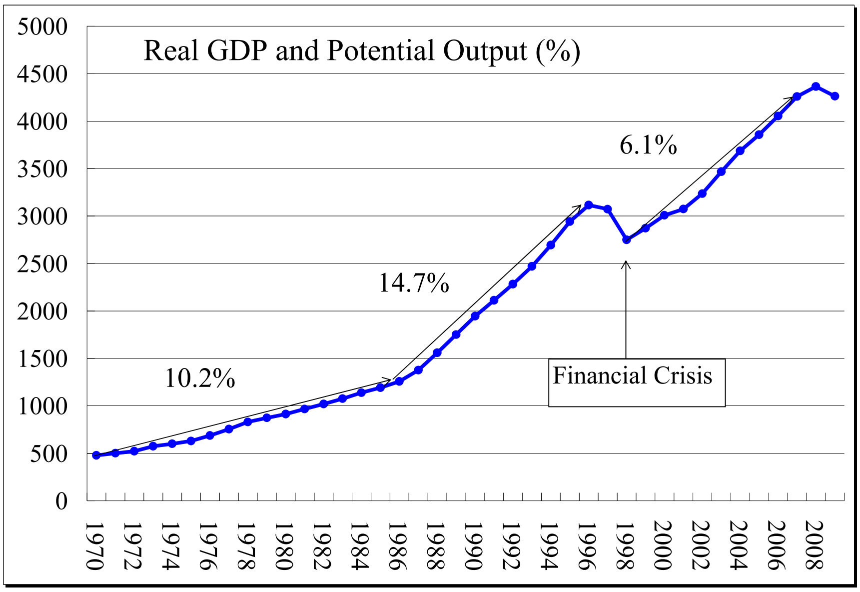


Table 3.15a: Simulation Studies for the Thai Economy: Case of TFP (Time)

History		GDP	KO	KIT	L	
Average Growth Rate	1986-2009	5.58	6.05	8.69	1.60	
	1986-1996	9.16	10.18	17.38	2.05	
	1997-2009	2.55	2.55	1.34	1.22	
Simulations						
Assumed Growth Rate (%) **Pessimistic Case**		GDP	KO	KIT	L	
			2.0	1.0	1.0	
Contribution to Growth Rate of Thai Economy			K(=KO+KIT)		L	TFP (Time)
		2.63	0.93		0.51	1.19
Assumed Growth Rate (%) **Standard Case**		GDP	KO	KIT	LH	
			6.0	8.0	1.5	
Contribution to Growth Rate of Thai Economy			K(=KO+KIT)		L	TFP (Time)
		4.86	2.92		0.76	1.19
Assumed Growth Rate (%) **Optimistic Case**		GDP	KO	KIT	L	
			8.0	10.0	2.0	
Contribution to Growth Rate of Thai Economy			K(=KO+KIT)		L(LH+L_Q)	TFP (Time)
		6.03	3.83		1.01	1.19
Assumed Growth Rate (%) **Intensive IT Investment Case**		GDP	KO	KIT	LH	
			6.0	12.0	1.5	
Contribution to Growth Rate of Thai Economy			K(=KO+KIT)		L	TFP (Time)
		4.99	3.05		0.76	1.19

Table 3.15b: Simulation Studies for the Thai Economy: Case of TFP (KI*KQ)

History		GDP	KO	KIT	L	KIT/LH(KI)	KIT/K(KQ)	UR
Average Growth Rate	1986-2009	5.58	6.05	8.69	1.60	6.97	2.19	2.19
	1986-1996	9.16	10.18	17.38	2.05	15.05	6.10	2.29
	1997-2009	2.55	2.55	1.34	1.22	0.13	-1.11	2.11
Simulations								
Assumed Growth Rate (%) **Pessimistic Case**		GDP	KO	KIT	L			
			2.0	1.0	1.0	1.0	0.0	2.0
Contribution to Growth Rate of Thai Economy			K(=KO+KIT)		L	TFP (KI*KQ)		
		1.76	0.7		0.68	0.38		
Assumed Growth Rate (%) **Standard Case**		GDP	KO	KIT	L			
			6.0	8.0	1.5	6.4	1.7	2.0
Contribution to Growth Rate of Thai Economy			K(=KO+KIT)		L	TFP (KI*KQ)		
		5.53	1.35		1.01	3.16		
Assumed Growth Rate (%) **Optimistic Case**		GDP	KO	KIT	L			
			8.0	10.0	2.0	7.8	1.7	2.0
Contribution to Growth Rate of Thai Economy			K(=KO+KIT)		L	TFP (KI*KQ)		
		6.70	1.66		1.35	3.71		
Assumed Growth Rate (%) **Intensive IT Investment Case**		GDP	KO	KIT	L			
			6.0	12.0	1.5	10.3	5.2	2.0
Contribution to Growth Rate of Thai Economy			K(=KO+KIT)		L	TFP (KI*KQ)		
		8.58	1.40		1.01	6.17		

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