Information Technology and Economic Growth: A Comparison between Japan and Korea

Kazuyuki Motohashi and Takahito Kanamori*

In this paper we compare sources of economic growth in Japan and Korea from 1985 to 2004, focusing on the role of information technology (IT), based on the framework of Jorgenson and Motohashi (2005). In both countries, the information technology industry is an important source of economic and productivity growth from the output side. In addition, active IT investments are supposed to lead to substantial IT capital service contribution to economic growth from the input side.

Keywords: Information technology, Productivity, Japan, Korea

JEL Classification: O30, O47, O53

I. Introduction

Due to the declining birthrate in Japan, the labor contribution to the GDP growth rate is expected to be negative in the long term, and productivity growth is the only one driving force of the Japanese economy. Therefore, increasing the TFP growth rate has become one of the top priority policy goals in the Japanese government. As the role of information technology in economic growth becomes larger

* Professor, Department of Technology Management for Innovation, Graduate School of Engineering, University of Tokyo, 7-3-1 Hongo, Bunkyou-ku, Tokyo 113-8656, Japan, (Tel) +81-3-5841-1828, (Fax) +81-3-5841-1829, (E-mail) motohashi-kazuyuki@tmi.t.u-tokyo.ac.jp; Ph.D., Department of Advanced Interdisciplinary Studies, Graduate School of Engineering, University of Tokyo, respectively. We would like to thank Mr. Changsik Shin at the Bank of Korea for his kind support about Korean input and output tables and IT price data. The data series in this paper will be provided by authors upon request.
[**Seoul Journal of Economics** 2008, Vol. 21, No. 4]

and larger, promoting IT investments and facilitating effective use of IT systems are important not only for improving the competitiveness of Japanese industries, but also for the long term macroeconomic growth of the Japanese economy.

In this paper, the impact of information technology on the macro level economic growth rate is investigated by using a growth accounting framework from 1985 to 2004. This paper is based on the theoretical framework in Jorgenson (2001), and the methodology in Jorgenson and Motohashi (2005) is used for empirical treatments of Japanese data. The growth decomposition results in Jorgenson and Motohashi (2005) until 2003 are extended to those of until 2004, which enables us to look at the situation after 2000.

In this paper, the growth decomposition results in Japan are compared to those of Korea as well. Both Japan and Korea are major IT producing countries. The total revenue of the Samsung group is now larger than Matsushita and Sony, and Hynix Semiconductor, a spinout from the Hyundai Group is the second largest DRAM producer after Samsung Electronics. Therefore, it is interesting to compare the contribution of IT in the output side of GDP.

In terms of the input side story, IT contributes to GDP growth by IT capital services as well as TFP growth by the IT-producing sector. It is found that the growing IT capital contribution does not lead to TFP growth in the IT using industries in Japan (Jorgenson and Motohashi 2005). Slower decision-making and rigid organizational structure may be culprits of under-utilization of IT systems at Japanese firms (Motohashi 2007). In contrast, decision-making at Korean firms may be faster due to a top down system.

There are a number of studies that have been conducted by Pyo and his co-authors in analyzing the sources of productivity growth in Korea. Pyo *et al.* (2006) have analyzed the determinants of productivity using industry-level data for 33 industries. However, since this is a part of an international comparison project of RIETI, IT assets are not taken into account separately in this study to conduct a comparison with all other countries participating in this project.

There are some past studies that have estimated the economic growth contribution of IT capital and production in Korea as well. Ha and Pyo (2004) have rigorously estimated the effects of IT on economic growth using industry-level data, which sheds light on factors such as resource allocation between the industries, since they can trace back the growth account to the industry-level. In addition, Fukao *et al.* (2007) shows comparative results of growth decomposition for OECD countries including Korea, based on EU-KLEMS datasets. This paper also discusses about IT investments and capital for both Korea and Japan.

Although the methodology of their analysis is sound, it is not possible to compare the impact of IT on economic growth in Japan and Korea, due to the differences in methodology and definitions of IT assets used in different studies. For example, our definition of IT follows that of Jorgenson and Motohashi (2005), including computers, communications equipment, and three types of software assets, whereas Ha and Pyo's (2004) study includes assets such as office and accounting machinery as IT assets and excludes software assets. In Fukao *et al.* (2007), the definition of IT investment is not fully compatible between Korea and Japan, either. In contrast, this paper harmonizes these differences in methodology and definitions to conduct an analysis which enables us to make a rigorous comparison between the sources of economic growth in Japan and Korea.

This paper is organized as follows. The next section provides a brief introduction of the analytical framework and compares the data between Japan and Korea. It is important to make sure that both datasets are comparable, because it is found that differences in the definition and methodology in software investments and IT prices lead to significant bias to international comparisons (Jorgenson and Motohashi 2005). Then, the sizes of IT investment, capital stock, and rental services in Japan and Korea are provided in the following section. In this section, the levels and speed of informatization of the two countries are compared. Next, a section of the growth decomposition results follows. Since significant differences in IT prices are found, a sensitivity analysis of IT prices is also provided. Finally, this paper concludes with a summary of observations and next steps.

II. Analytical Framework and Data

A. Framework

The performance of computer and communications equipments is improving at an astonishing speed. Such technological progress hinges on Moore's Law, which states that the density of semiconductor chips double every 18 months. Miniaturization of ICs enables faster speed of processing which enhances performance of information communication technology equipment. Due to this rapid performance improvement, constant quality IT output as well as investment grows much faster than its nominal values. In order to capture the size of IT output and input to the macro economy, we apply the production possibility frontier approach introduced by Jorgenson (1995), as follows.

$$Y(P_c,\ P_s,\ P_t,\ GDP_n) = A \cdot X(K_n,\ K_c,\ K_s,\ K_t,\ L). \tag{1}$$

Aggregate output Y consists of computer production P_c, software production P_s, communications equipment production P_t, and non-IT components of GDP_n.[1] Aggregate input X consists of non-IT capital services K_n, computer services K_c, software services K_s, communications equipment services K_t, and labor services L. Total factor productivity (TFP) is denoted A. This framework is almost the same as that of Jorgenson and Motohashi (2005), but we do not take into account consumer and government capital services in this paper due to data constraints in Korea.

Under the assumption that product and factor markets are competitive, producer equilibrium implies that the share-weighted growth of outputs is the sum of the share-weighted growth of inputs and total factor productivity growth:

$$\begin{aligned} &\bar{w}_{P,c}\,\Delta\ln P_c + \bar{w}_{P,s}\,\Delta\ln P_s + \bar{w}_{P,t}\,\Delta\ln P_t + \bar{w}_{GDP,n}\,\Delta\ln GDP_n = \\ &\bar{v}_{K,n}\,\Delta\ln K_n + \bar{v}_{K,c}\,\Delta\ln K_c + \bar{v}_{K,s}\,\Delta\ln K_s + \bar{v}_{K,t}\,\Delta\ln K_t + \bar{v}_L\,\Delta\ln L + \Delta\ln A \end{aligned} \tag{2}$$

where $\bar{w}$ and $\bar{v}$ denote average value shares of outputs and inputs, respectively, in adjacent time periods.

The shares of outputs and inputs add to one under the assumption of constant returns:

$$\bar{w}_{P,c} + \bar{w}_{P,s} + \bar{w}_{P,t} + \bar{w}_{GDP,n} = \bar{v}_{K.n} + \bar{v}_{K.c} + \bar{v}_{K.s} + \bar{v}_{K.t} + \bar{v}_L = 1 \tag{3}$$

In Equation (2), the growth rate of outputs is a weighted average of growth rate of investments and consumption goods outputs. Similarly, the growth rate of inputs is a weighted average of growth rates of capital and labor services inputs. The contribution of TFP is derived

[1] Here, the production of IT component does not include the amount of the IT component used as an intermediate input such as company use of prepackaged software not capitalized as an investment.

as the difference between the growth rates of output and input.

B. Output data

In Japan, the Economic Social Research Institute (ESRI) of the Cabinet Office publishes an official GDP series. We use this official GDP series for the macro level output of the economy as a point of departure for Japanese data. Recently, there are some notable changes in this data. First, it is revised in accordance with the recommendations on the System of National Accounts by the United Nations in 1993 (SNA93). Major changes in this revision include (1) treating custom-made software in business and public sectors as an investment, instead of intermediate inputs, and (2) adding the depreciation of public infrastructure to government consumption. Adding these new components to GDP makes about a 2% increase in its size. This change leads to an upward revision of GDP growth rate as well, because software investments grow faster than the aggregated economy. ESRI publishes this revised data series from 1980, so we can use 93SNA data for this paper.

Second, ESRI started to publish a chain-weighted index GDP in 2004. The official Japanese GDP is based on a fixed-weighted index by changing its bench mark year, every five years. However, fixed-weighted indexes do not take into account the structural change of output composition within the five years, and the growing role of IT in the aggregated economy may not be taken into account appropriately. Therefore, we use the chain-weighted GDP series in this paper. However, ESRI publishes historical data of chain weighted-indexes only after 1994, so that we have to rely on fixed-weighted index data for 1993 and earlier.

Another problem with Japanese data is that only custom-made software is treated as an investment in GDP. In the United States, not only custom-made software, but also prepackaged software and own account software are treated as an investment. Therefore, we estimated the amount of prepackaged and own account software as is the case in Jorgenson and Motohashi (2005). In the benchmark Input Output Table in 2000, the amount of prepackaged software capitalized in the balance sheet of enterprises is estimated and added to the gross capital formation column. We use the share of capitalized prepackaged software investment to the total in 2000 (40.6%) for the whole period, because there is no information available in the other years. As for own account software, we have applied a cost-based approach, taking into account own account software engineers' labor compensations and associated other types of inputs, following the U.S. methodology (Parker and Grimm 2000).

In this paper, IT output includes: (1) computer and peripherals, (2) communications equipment, and (3) all three types of software. The data for the IT sector is estimated based on benchmark input output tables every five years, as well as annual extension tables by the Ministry of Economy, Trade and Industry (METI).[2] Based on the data of these IT outputs and non-IT outputs (total GDP minus IT outputs), a divisia output index is estimated by Equation (2).

In Korea, the Bank of Korea provides official GDP data, which is used as the output data in this paper. The official GDP of Korea is also based on fixed-weighted indexes, and not chain-weighted indexes. Therefore, we have to use fixed-weighted GDP as a starting point. But one upside of the Korean GDP is that the official statistics has already taken into account all three kinds of software. Prepackaged software priced at more than 500,000 won is taken into account as an investment, and the amount of own account software is estimated by using a similar methodology to that of the U.S. (Bank of Korea 2003).

The Bank of Korea started to publish GDP data with software treatment after the 2000 benchmark series, and historical data back to 1990 are also available. Therefore, we use SNA93 data for the period of 1990 to 2004 and SNA68 data with no software treatment for 1989 and earlier.[3] IT output data are estimated by using the linked input output table of 1985-90-95 and 1990-95-2000. Interpolation within five years and extrapolation until 2004 are made by the data from the manufacturing census and survey, and trade statistics. Based on the total GDP as well as IT output data, a Divisia output index is calculated again by Equation (2).

C. IT price data

It is found that the differences in the methodology in price indexes

[2] Details in IT output data are available in Motohashi (2002).

[3] For 1985-1989, software production is estimated assuming constant growth of software production during 1985-1990, using data from the 1985-1990-1995 linked input output table, and the official GDP has been adjusted during this period.

leads to substantial variations of IT price data across countries. In order to take into account fast performance improvements in computers, hedonic methods have become a common practice in statistical offices in OECD countries. The Bank of Japan started to publish hedonic price deflators for computers in the 1995 benchmark WPI (Wholesale Price Index), and has kept this methodology for the 2000 benchmark CGPI (Corporate Good Price Index) as well.[4] However, the Bank of Korea, which is in charge of the PPI (Producer Price Index), does not use the hedonic method for its computer deflators.

Another important issue for computer deflators is the index number methodology. Both the Bank of Japan and the Bank of Korea use Laspeyres price indexes as official statistics. However, it is found that fixed-weighted indexes give a substantial upward bias to computer prices, because a substantial shift from mainframe computers to personal computers can be seen in a broader category of computers (Nomura and Samuels 2004). In general, the price of PCs drops faster than that of mainframe computers, and fixed weight systems do not take into account the growing contribution of faster price declines of PCs to the aggregated computer price. After the 2000 benchmark CGPI, the Bank of Japan publishes chain-weighted indexes of computers as a reference series, which drop much faster than fixed-weighted indexes.

In Figure 1, computer prices are compared between Japan and Korea. For Japanese data, both fixed-weighted and hedonic ones are displayed. First, we cannot find a big difference in the overall size of price change between the two countries. Although the hedonic method is not used in the Bank of Korea, its price data seems to capture quality change of computers very well. Second, fixed-weighted deflators in Japan and Korea show similar trends; the price declines much faster after 2000. This can be explained by the increased weight of personal computers after the 2000 benchmark revision. On the other hand, the flexible weighted deflator in Japan moves more smoothly over the period from 1995 to 2004.

For communications equipment, the rate of price decline after 1995 is slightly higher in Korea than in Japan (Figure 2), when comparing official prices. In both countries, deflators of communications

[4] The Bank of Japan changed the name of index from WPI to CGPI in the 2000 benchmark revision, but the basic concept of the dataset does not change.

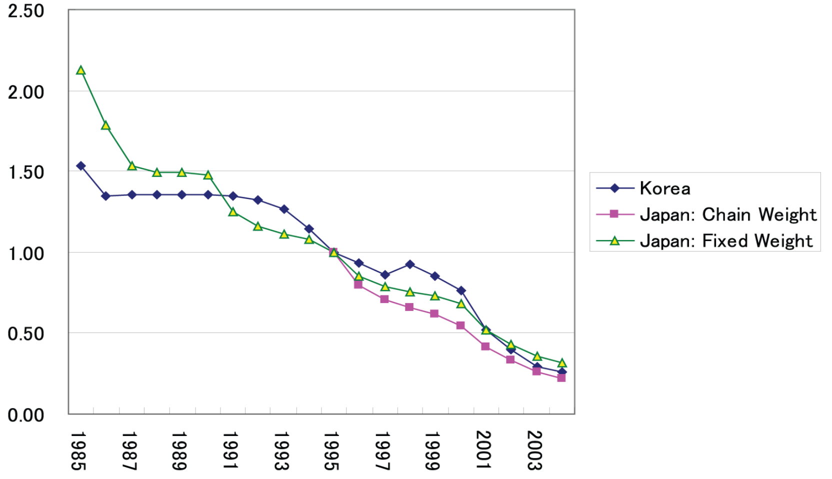

FIGURE 1
COMPUTER PRICE INDEXES

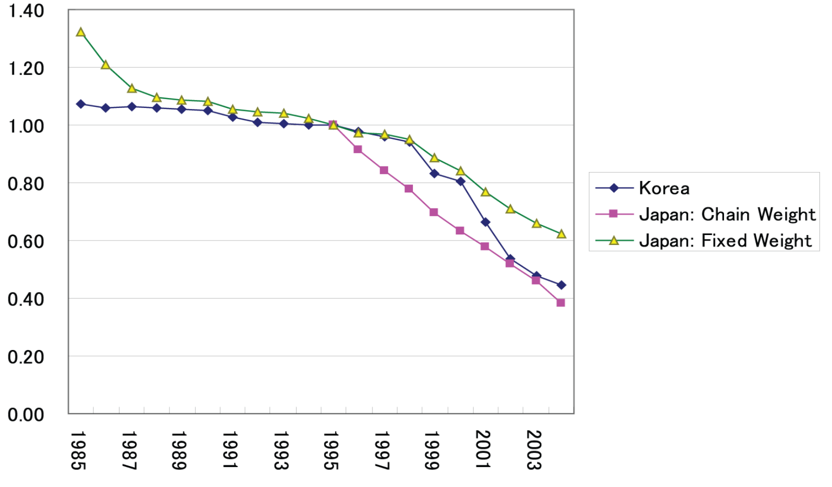

FIGURE 2
COMMUNICATIONS EQUIPMENT PRICE INDEXES

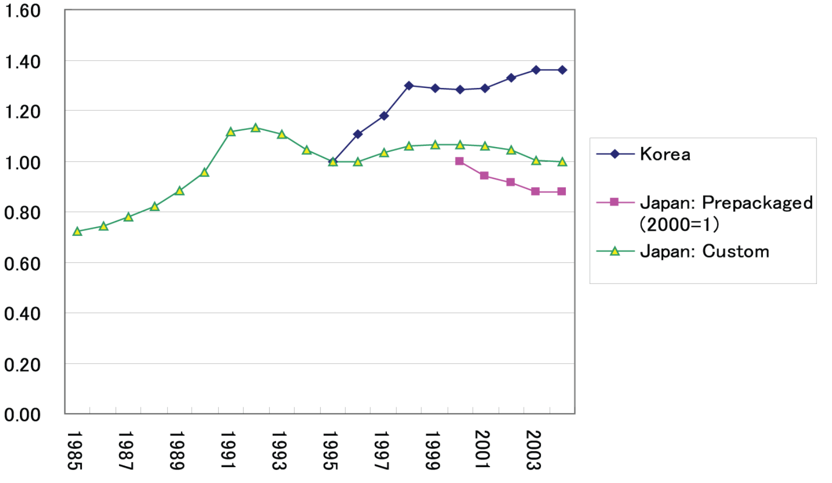

FIGURE 3
SOFTWARE PRICE INDEXES

equipment are based on a matched method, instead of a hedonic one, but are based on a very detailed category of items. Therefore, the quality change in communications equipment may be treated appropriately in both countries. As is the case for computer prices, the BOJ's official index for the flexible weighted deflator is available only from 1995. Therefore, the chain-weighted indexes incorporating the changing composition of items within the broad category of communications equipment are constructed before 1995, and used for the analysis of the Japanese part, as in Jorgenson and Motohashi (2005).

Finally, there are two types of deflators for software in the BOJ's CSPI (Company Service Price Index): *i.e.*, a cost based deflator for custom made software and a matched method one for prepackaged software. However, prepackaged software prices are available only after 2000, while the prices for custom-made software are available after 1980. In Korea, only the custom-made software deflator after 1995 is available, and this data is also estimated by a cost-based approach, which does not take into account productivity growth in the software industry.[5] Therefore, it is found that the price of

[5] In the growth account, the investment deflator of all assets by Pyo *et al.* (2006) is used as the software price index before 1995.

custom-made software has an upward trend in both countries, while the prepackaged software price is declining.

Since there are significant differences in IT price data between the two countries, we use “internationally harmonized prices” for estimating the output and input contributions to the macro economy, in addition to the results based on official prices. The harmonized price for Korea can be derived by the IT price data in Japan adjusted by the relative inflation rate of Korea to Japan. The original idea of this deflator was presented in Colecchia and Schreyer (2002), and it is used widely in internationally comparative studies (Jorgenson and Motohashi 2005; van Ark *et al.* 2002). As the benchmark Japanese data, we use chain-weighted price indexes for computer and communications equipment. As for prepackaged software, we use the BOJ’s CGPI data after 2000, and internationally harmonized data based on the U.S. BEA’s price data before 1999. The BOJ’s custom-made software prices are used for both custom-made and own account software.

D. Input Data

a) Capitals services

Capital service input in Japan is estimated by following the methodology in Jorgenson and Motohashi (2005). First, private and public investment data by 62 capital goods category is estimated from the Statistical Bureau’s benchmark input output tables as well as METI’s extension tables. Then, this investment series is used to estimate capital stock by the perpetual inventory method. Finally, capital service prices are derived by using Jorgenson’s rental service formula, taking into account tax structure by commodity type. Out of 62 capital goods categories, computer, communications equipment, and software are treated as IT sectors. Software investments include all three types, *i.e.*, custom-made, prepackaged, and own account software, as is mentioned in the Section 2 (1).

In Korea, a similar methodology is used. Input output tables by detailed commodity classification are available in 1985, 1988, 1990, 1993, 1995, 1998, and 2000. Interpolations and extrapolations until 2004 are conducted by using manufacturing census and survey data with trade statistics. Finally, we have private and public investment data by 39 capital goods categories. These data are used for capital stock and capital service input estimations. Out of 39 categories, computer, communications equipment and software are treated as IT sectors. In Korean data, all three kinds of software are estimated in the 1990-1995-2000 linked input output tables. Interpolations and extrapolations until 2004 can be done by using the data in the Information and Communication Industry Statistics Yearbook, but there is no software data before 1989. Data from the 1985-1990-1995 linked input output table is used to estimate software investment during 1985-1990, assuming constant growth during this period and no software investment before 1984.

Finally, it is important to take into account land capital contribution to make a fair comparison of Japan and Korea. In Japan, both land capital and price data are available in its SNA account. However, there is no official land stock data in Korea, so that we assume the share of the land stock to total capital stock in Japan to be the same for Korea in 1995, and the quality of the land stock in Korea improves by 1% every year.[6] In terms of land price data, we use the Korea National Statistical Office's (KNSO's) floating land price data with a five-year moving average operation to control for its short term fluctuations.

b) Labor

Our estimates of labor input are taken from the ICPA project of RIETI (Kuroda *et al.* 2006), originally derived from the KEO database (Keio Economic Observatory 1996) for Japan until 2000 and Pyo *et al.* (2006) for Korea until 2002. This is calculated by using the data of the number of workers, hours worked, and hourly wage rate cross-classified by sex, age, and education. Labor data for Japan has been extended using the population projection estimation complied by the National Institute of Population and Social Security Research. In Japan, data extension to 2004 is made by estimating labor quality improvement by using data from the KEO Database and official population projections up to 2050 (NIPSSR 2002) and total hours worked from the Monthly Labor Survey of the Ministry of Health, Labor and Welfare. For Korea, data from the Monthly Labor Survey of the Ministry of Labor was used to estimate the quality index and data on total hours worked from the KNSO's statistical database was

[6] In Japan, the quality of land stock improves by 1.07% from 1985 to 1990 and 0.98% from 1990 to 1995. This speed slows down after 1995 due to the slowdown of the Japanese economy. Therefore, we use 1% for Korea which has a substantially higher economic growth rate through out the period of the analysis.

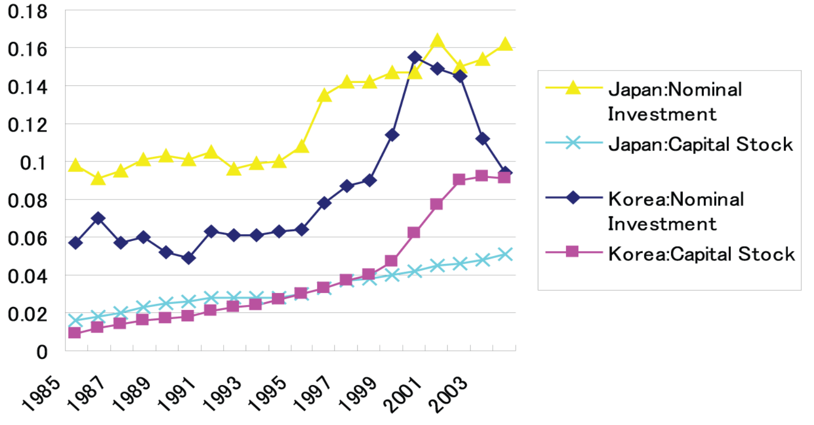

FIGURE 4
SHARE OF IT INVESTMENT AND STOCK

used as the labor quantity index.

E. Comparison of IT investments and stock

Figure 4 displays the percentage share of IT in nominal investment and capital stock in Japan and Korea. In both countries, there was a sharp increase in the share of IT investment during the late 1990s. The increase was particularly pronounced in Korea, where IT investment share more than doubled during 1995-2000. However, after 2000, Korea experienced a sharp decline in IT investment share, whereas Japan encountered a relatively moderate decline. In terms of the size of IT investment share in the two countries, Japan's share has been larger for most of the period examined.

Due to a surge of IT investment during the late 1990s, the share of IT capital stock increased in both countries during this period. Once again, the increase was particularly marked for Korea, where the share of IT capital stock almost doubled during the late 1990s. IT capital stock share was larger in Japan until 1999, but Korea's share has surpassed Japan's share since 2000.

Figure 5 reveals the composition of the 3 types of IT assets in Japan and Korea. A major difference in the composition of IT capital stock in Japan and Korea is the size of communications equipment capital stock. In Korea, communications equipment capital stock records

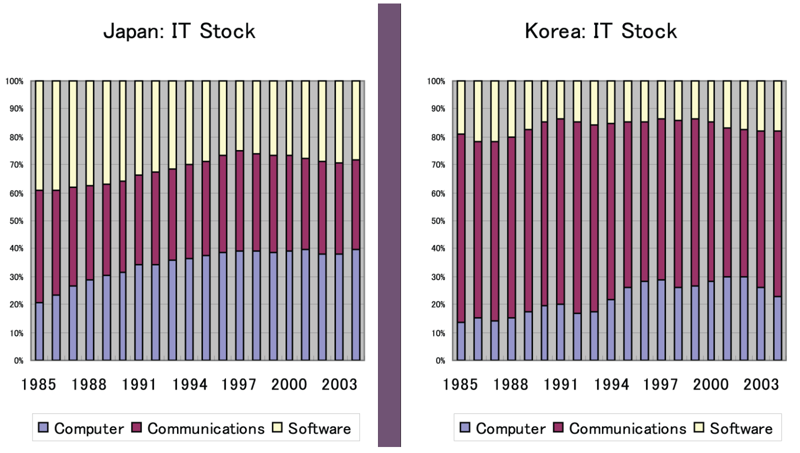

FIGURE 5
COMPOSITION OF IT STOCK

a share of over 50% of total IT capital stock during the entire period, whereas in Japan, the share of communications equipment is approximately one-third of total IT stock.

The share of computer capital stock generally exhibits an increasing trend in both countries during the entire period, although the size of the share in Japan is much higher. In contrast, the share of software capital in Japan dropped until the mid-1990s and started to increase its share thereafter, whereas in Korea, the share of software capital has generally been increasing since the early 1990s. Once again for software, the absolute size of the software share is considerably larger in Japan compared with Korea.

Figure 6 shows the breakdown of IT capital service value into the relative shares of the 3 types of IT assets. In terms of the share of IT capital service value, the share of software capital value has recently increased its share in both Japan and Korea. The increase is particularly sharp in Korea, where the value of software capital service has almost doubled in 2004 compared with 2000. The increase in the share of software capital service values in Japan and Korea indicates the increasing importance of software capital service input in the two countries.

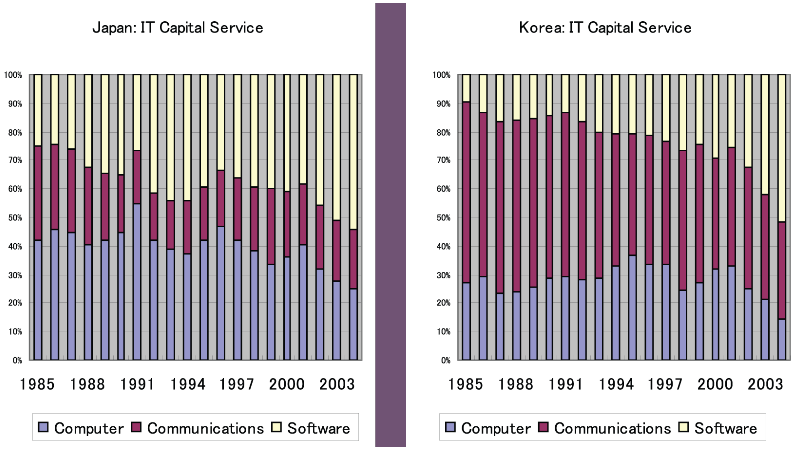

FIGURE 6
IT CAPITAL SERVICE BY TYPE OF ASSET

III. Results

As explained in Section 2, differences in IT price indexes could lead to differences in the estimates, so we first provide results adjusting for the differences in IT prices between Japan and Korea. Table 1 reports the results of the contribution of information technology to output and input growths, using internationally harmonized IT price indexes for Korea based on best estimate Japanese price indexes as the benchmark.[7] The GDP growth rate of Japan has plummeted since the early 1990s, whereas in Korea, a relatively high growth rate has been sustained during the entire period examined. In both countries, the output contribution of IT with respect to overall GDP growth is increasing its importance in recent years.

In terms of the contribution of the specific type of IT output, the contribution of computer and software accounts for a major portion of the increase in the IT output contribution in Japan, whereas in Korea, communications equipment output plays a dominant role. The increase in the contribution of communications equipment output to GDP growth is particularly marked during the early 2000s, reflecting

[7] The benchmark Japanese IT price indexes for computer and communications equipment are flexible weighted deflators, while that of software is based on harmonized indexes, based on U.S. prices.

TABLE 1

SOURCES OF GDP GROWTH USING BEST ESTIMATE AND HARMONIZED PRICES

(Japan)	1985-90	1990-95	1995-00	2000-04
	Outputs			
Gross Domestic Product	4.70	1.50	1.14	1.27
Contribution of Information Technology	0.48	0.10	0.56	0.39
Computers	0.27	0.10	0.16	0.28
Software	0.09	0.01	0.23	0.20
Communications Equipment	0.13	-0.01	0.17	-0.09
Contribution of Non-Information Technology	4.22	1.39	0.58	0.88
	Inputs			
Gross Domestic Income	2.96	0.63	0.48	0.28
Contribution of Information Technology Capital Services	0.43	0.19	0.39	0.34
Computers	0.26	0.13	0.18	0.14
Software	0.11	0.03	0.10	0.14
Communications Equipment	0.06	0.04	0.10	0.07
Contribution of Non-Information Technology Capital Services	1.23	0.68	0.37	0.07
Contribution of Labor Services	1.30	-0.24	-0.28	-0.13
Total Factor Productivity	1.74	0.87	0.66	0.99

(Korea)	1985-90	1990-95	1995-00	2000-04
	Outputs			
Gross Domestic Product	9.18	7.54	4.29	4.53
Contribution of Information Technology	0.72	0.50	1.51	1.06
Computers	0.25	0.21	0.56	0.02
Software	-0.02	0.09	0.24	0.20
Communications Equipment	0.49	0.21	0.71	0.85
Contribution of Non-Information Technology	8.46	7.03	2.78	3.47
	Inputs			
Gross Domestic Income	6.53	4.95	2.32	3.53
Contribution of Information Technology Capital Services	0.35	0.30	0.59	0.58
Computers	0.12	0.11	0.19	0.08
Software	0.05	0.08	0.15	0.29
Communications Equipment	0.19	0.11	0.24	0.21
Contribution of Non-Information Technology Capital Services	3.99	2.65	1.24	2.05
Contribution of Labor Services	2.19	2.00	0.49	0.89
Total Factor Productivity	2.66	2.58	1.97	1.00

the sharp increase in communications equipment production in Korea.

With regards to the input contribution, the contribution of IT capital services in Japan dropped temporarily during the early 1990s, but has increased again since the late 1990s, playing a crucial contribution to input growth of the Japanese economy in recent years. Similarly in Korea, the contribution of IT capital services has increased its contribution since the late 1990s, reflecting the rapid capital accumulation during this period.

In terms of the specific type of IT asset that contributed to GDP growth, one difference between Japan and Korea is the relative size of the contribution of communications equipment, as was the case for the output contribution. The relative size of the contribution of communications equipment capital services has been much higher in Korea, reflecting the large share of communications equipment capital with respect to total IT stock, as indicated in Section 3.

The major difference in the input contribution between Japan and Korea in recent years is due to the contribution of non-IT capital services and labor services. In Japan, labor input has been decreasing since the 1990s, contributing negatively to economic growth. In addition, the contribution of non-IT capital services has also been declining steadily, recording a close to 0 percentage point contribution during the early 2000s. In Korea, the contribution of non-IT and labor capital services still accounts for a major portion of input growth, in contrast to Japan.

Table 2 presents the results of the sources of TFP growth. In Japan, TFP growth in the IT sector accounts for more than 40% of overall TFP growth since the late 1990s. In particular, the contribution of TFP growth in the computer-producing sector is the dominant source of TFP growth. Similarly in Korea, the IT sector has contributed strongly to TFP growth, and the contribution of the IT sector to overall TFP growth is increasing importance. However, TFP growth in the non-IT sector has been declining in recent years. Out of the IT sectors, one feature of the source of Korean TFP growth is the large contribution of the communications equipment sector.

To check for sensitivity in price adjustments, we present results using official price statistics of Japan and Korea in Table 3. In addition, we exclude land capital for the two countries to see the impact of land on the growth accounting estimates. The results for Japan show that both input and output contributions of IT decrease compared to the estimates using best price estimates. Since official

TABLE 2
DECOMPOSITION OF TFP GROWTH

(Japan)	**1985-90**	**1990-95**	**1995-00**	**2000-04**
Total Factor Productivity Growth	1.74	0.87	0.66	0.99
	Contributions to TFP Growth:			
Information Technology	0.36	0.25	0.30	0.47
Computers	0.19	0.16	0.17	0.27
Software	0.01	0.03	0.00	0.09
Communications Equipment	0.16	0.06	0.12	0.12
Non-Information Technology	1.38	0.62	0.36	0.51
	Relative Price Changes:			
Information Technology	-9.39	-6.31	-6.34	-7.78
Computers	-13.10	-10.52	-12.35	-23.10
Software	-0.94	-2.54	-0.14	-3.25
Communications Equipment	-10.00	-4.72	-9.41	-12.44
Non-Information Technology	-4.12	-1.65	-0.74	-1.01
	Average Nominal Shares:			
Information Technology	4.17	3.86	4.31	4.94
Computers	1.51	1.43	1.37	1.17
Software	1.04	1.18	1.62	2.85
Communications Equipment	1.62	1.25	1.32	0.91
Non-Information Technology	95.83	96.14	95.69	95.06
(Korea)	**1985-90**	**1990-95**	**1995-00**	**2000-04**
Total Factor Productivity Growth	2.66	2.58	1.97	1.00
	Contributions to TFP Growth:			
Information Technology	0.48	0.43	0.61	1.28
Computers	0.12	0.15	0.25	0.48
Software	0.03	0.04	0.02	0.11
Communications Equipment	0.33	0.25	0.35	0.69
Non-Information Technology	2.18	2.15	1.36	-0.28
	Relative Price Changes:			
Information Technology	-11.92	-11.23	-12.11	-12.71
Computers	-15.56	-15.39	-15.50	-26.42
Software	-10.63	-11.28	-3.44	-5.70
Communications Equipment	-12.47	-9.60	-12.56	-15.76
Non-Information Technology	-6.61	-6.53	-3.57	-3.64
	Average Nominal Shares:			
Information Technology	3.87	3.86	5.52	7.93
Computers	0.88	0.97	1.79	1.53
Software	0.27	0.33	0.79	1.97
Communications Equipment	2.73	2.56	2.94	4.44
Non-Information Technology	96.13	96.14	94.48	92.07

TABLE 3

SOURCES OF GDP USING OFFICIAL IT PRICES

(Japan)	1985-90	1990-95	1995-00	2000-04
	Outputs			
Gross Domestic Product	4.69	1.48	1.00	1.17
Contribution of Information Technology	0.47	0.09	0.41	0.30
Computers	0.27	0.10	0.10	0.23
Software	0.08	0.00	0.22	0.19
Communications Equipment	0.12	-0.02	0.10	-0.13
Contribution of Non-Information Technology	4.22	1.39	0.58	0.88
	Inputs			
Gross Domestic Income	3.37	0.94	0.41	0.16
Contribution of Information Technology Capital Services	0.46	0.20	0.31	0.27
Computers	0.28	0.14	0.14	0.09
Software	0.10	0.01	0.10	0.14
Communications Equipment	0.07	0.04	0.07	0.04
Contribution of Non-Information Technology Capital Services	1.61	0.98	0.38	0.02
Contribution of Labor Services	1.30	-0.24	-0.28	-0.13
Total Factor Productivity	1.32	0.54	0.58	1.01

(Korea)	1985-90	1990-95	1995-00	2000-04
	Outputs			
Gross Domestic Product	9.18	7.52	4.28	4.54
Contribution of Information Technology	0.77	0.69	1.44	1.52
Computers	0.26	0.26	0.52	0.19
Software	-0.03	0.07	0.24	0.21
Communications Equipment	0.54	0.36	0.68	1.12
Contribution of Non-Information Technology	8.41	6.83	2.84	3.02
	Inputs			
Gross Domestic Income	7.57	7.46	3.50	4.32
Contribution of Information Technology Capital Services	0.41	0.51	0.72	0.89
Computers	0.13	0.19	0.23	0.19
Software	0.04	0.08	0.16	0.32
Communications Equipment	0.24	0.24	0.33	0.38
Contribution of Non-Information Technology Capital Services	4.98	4.94	2.28	2.54
Contribution of Labor Services	2.19	2.00	0.49	0.89
Total Factor Productivity	1.60	0.06	0.79	0.22

price statistics of Japan do not use flexible weights for computers and communications equipment, the rapid decline in personal computers for example, is not captured accurately in the price indexes, resulting in a lower recorded contribution for both input and output growths. Similarly for software, the price index for prepackaged software in the official prices of Japan assumes no productivity growth in the software industry, and the results of the estimates using official prices decrease the input and output contributions of software. However, the sizes of the adjustments are relatively smaller in Japan.

The estimates for Korea using official price indexes indicate that the estimates using official price indexes generally increase the contribution of IT, compared with harmonized price estimates. Since the inflation rate is high in Korea and low (negative in recent years) in Japan, the price decline in IT prices using harmonized price indexes is not sharp compared to the baseline IT prices of Japan. Therefore, the price decline of IT generally drops more rapidly in the official price statistics compared with harmonized price indexes. The estimates using official price statistics of Korea provide further support for the strong contribution of IT for both output and input growths for the Korean economy.

We have found substantial changes in TFP estimates for both countries due to smaller capital inputs without land stock. Since land input grows quite slowly compared to depreciable asset stocks, capital inputs without taking land into account are substantially over-biased, which leads to under-biased TFP estimates. This point should be noted because there are many studies which do not treat land as a capital input.

IV. Conclusion

In order to rigorously compare the economic growth contributions of Japan and Korea, focusing on the role of IT, we conducted growth accounting using the framework of Jorgenson and Motohashi (2005). To adjust for differences in IT data between the two countries, we have estimated annual investment series for computers, communications equipment, and three types of software assets, and to control for differences in the price indexes for IT, internationally harmonized price indexes were created for Korea, using Japanese price indexes as the benchmark.

From the output side, our results indicate that the contribution of

IT output has become a major source of GDP growth for Japan and Korea since the late 1990s. Similarly, growth contributions of IT to input growth, through the contribution of IT capital services, has also increased importance since the late 1990s.

The major difference in the sources of economic growth between Japan and Korea is due to the contribution of non-IT capital services and labor services. The contribution of labor in Japan has been negative since the early 1990s, and the contribution of non-IT capital services is also declining, recording close to a zero percentage point contribution in the early 2000s. In contrast, the contribution of labor and non-IT capital services is still a major source of input growth in Korea, although the level of contribution has dropped since the late 1990s.

In both countries, the IT-producing sector contributes significantly to TFP growth, and there is an increasing trend in the contribution, reflecting the increasing importance of the IT sector in these economies. The contribution of TFP growth of the IT sector in Korea has been higher than in Japan, and the gap is widening in recent years. However, the TFP growth rate of the non-IT sector in Korea has been decreasing, and in the early 2000s, the TFP growth rate of the non-IT sector was higher in Japan than in Korea.

However, IT is not the only factor to explain TFP. Innovation activities, regulatory environments, macro economic stability, and many other factors also have some impact on TFP. In order to investigate the relationship between IT investment and productivity, it is important to perform analyses at the micro level. In Japan, Motohashi (2007) uses firm level micro-data to analyze the impact of IT network use on productivity. Kanamori and Motohashi (2006) investigate the complementarities of organizational change (centralization and decentralization of decision right) and IT capital stock. We hope that similar studies will be conducted in Korea to understand the differences between the two countries in more detail.

(Received 21 April 2008; Revised 12 August 2008)

References

Bank of Korea. *2000 Input-Output Tables*. Bank of Korea, 2003.

Colecchia, A., and Schreyer, P. "ICT Investment and Economic Growth in the 1990s: Is the United States a Unique Case? A Comparative Study of Nine OECD Countries." *Review of Economic Dynamics* 5 (No. 2 April 2002): 408-42.

Fukao, K., Miyagawa, T., and Takizawa, M. Productivity Growth and Resource Reallocation in Japan, Hitotsubashi Hi-Stat Working Paper No. 224, November 2007.

Ha, B. C., and Pyo, H. K. "The Measurement of IT Contribution by Decomposed Dynamic Input-Output Tables in Korea (1980-2002)." *Seoul Journal of Economics* 17 (No. 4 2004): 511-46.

Jorgenson, D. W. "The Embodiment Hypothesis." In Postwar U.S. Economic Growth, *Productivity.* Chapter 2, Vol. 1, Cambridge: The MIT Press, 1995.

__________. "Information technology and the U.S. economy." *American Economic Review* 91 (No. 1 2001): 1-32.

Jorgenson, D. W., and Motohashi, K. "Information Technology and the Japanese Economy." *Journal of the Japanese and International Economies* 19 (No. 4 December 2005): 460-81.

Kanamori, T., and Motohashi, K. Centralization or Decentralization of Decision Rights? Impact on IT Performance of Firms. RIETI Discussion Paper Series 06-E-032, 2006.

Keio University Institute for Economic and Industry Studies (Keio Economic Observatory). KEO Database, Keio Economic Observatory Monograph Series No. 8, 1996.

Kuroda, M., Motohashi, K., and Shimpo, K. Investigating Productivity Slowdown in the 1990s by using KLEM Database in Japan. RIETI ICPA Project, 2006.

Motohashi, K. IT Investment and Productivity Growth of Japanese Economy and Comparison to the United States. RIETI Discussion Paper Series 02-J-018, 2002 (in Japanese).

__________. "Firm-level analysis of information network use and productivity in Japan." *Journal of the Japanese and International Economies* 21 (No. 1 March 2007): 121-37.

NIPSSR. *Population Projections for Japan: 2001-2050.* National Institute of Population and Social Security Research, January 2002.

Nomura, K., and Samuels, J. Can We Go Back to Data? Reconsideration of US Harmonized Computer Prices in Japan. Program on Technology and Economic Policy, Harvard University, 2004.

Parker, R., and Grimm, B. *Recognition of Business and Government Expenditures for Software as Investment: Methodology and Quantitative Impacts, 1959-98.* BEA, U.S.: Department of Commerce, 2000.

Pyo, H. K., Rhee, K. H., and Ha, B. Growth Accounting and Productivity Analysis by 33 Industrial Sectors in Korea (1984-2002). RIETI-ICPA Project, 2005, August 26, 2006.

Van Ark, B., Melka, J., Mulder, N., Timmer, M., and Ypma, G. ICT Investment and Growth Accounts for the European Union 1980-2000. Research Memorandum, University of Groningen, 2002.