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INFORMATION TECHNOLOGY AND THE JAPANESE ECONOMY

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ABSTRACT

In this paper we compare sources of economic growth in Japan and the United States from 1975 through 2003, focusing on the role of information technology (IT). We have adjusted Japanese data to conform to U.S. definitions in order to provide a rigorous comparison between the two economies. The adjusted data show that the share of the Japanese gross domestic product devoted to investment in computers, telecommunications equipment, and software rose sharply after 1995. The contribution of total factor productivity growth from the IT sector in Japan also increased, while the contributions of labor input and productivity growth from the Non-IT sector lagged far behind the United States. Our projection of potential economic growth in Japan from for the next decade is substantially below that in the United States, mainly due to slower growth of labor input. Our projections of labor productivity growth in the two economies are much more similar.

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Information Technology and the Japanese Economy

1. Introduction

Jorgenson (2002b) has shown that a substantial part of the American growth resurgence after 1995 can be attributed to information technology (IT). The rapid growth in U.S. labor productivity during the boom of the 1990's, the economic slowdown that began in 2001, and the subsequent recovery suggests that the potential growth of the U.S. economy has been considerably enhanced.[3] By contrast, the Japanese economy appears to be mired in the slump that followed the collapse of the "bubble economy" of the 1980's. This leads to the question, has the Japanese economy failed to benefit from advances in information technology?

There are many examples of cutting-edge businesses in the U.S., such as Dell and Wal-Mart, that produce and use information technology effectively. While it is often argued that major Japanese businesses do not fully utilize information systems, research conducted in Japan shows that the burgeoning levels of IT investment by businesses during the last half of the 1990's did contribute substantially to increased labor productivity growth.[4] It is clear that the impact of investment in IT on both the Japanese and U.S. economies has been very sizeable. But how does the impact of this investment differ between the two countries?

In order to compare the relationships between investment in information technology equipment and software and productivity growth in Japan and the United States, it is essential to lessen the differences in the treatment of IT in the official statistics. Under the United Nations System of National Accounts of 1993 (SNA93)[5] software is recognized as an investment in both countries, but the definitions are different. Second, prices of equipment and software must be measured in a consistent way, reflecting advances in information technology.

[3] Jorgenson, Ho, and Stiroh (2004) have analyzed the potential growth of the U.S. economy.
[4] See Economic Research Institute, Economic Planning Agency (2000).
[5] See United Nations (1993).

We have adopted the framework of Jorgenson (2002a) for analyzing the relationship between investment in IT and economic growth, encompassing the impact of IT investment by household and government sectors as well as the business sector. An important objective of this paper is to develop data for Japan that are comparable to the U.S. National Income and Product Accounts (NIPA). We have constructed new data on software investment for Japan and new IT price data to mitigate possible biases present in the Japanese national accounts. Exploiting this new information, we have constructed growth accounts for Japan between 1975 and 2003, and developed growth projections for the next 10 years.

In the following section we present an analytical framework introduced by Jorgenson (1995c), based on the production possibility frontier.[6] In Section 3 we describe the data on investment in information technology equipment and software for Japan and the U.S. and address possible upward biases in the official IT price data for Japan. In Section 4 we present the results of our analysis of the role of information technology in the growth of the Japanese and U.S. economies. Section 5 is devoted to economic growth projections from 2003 to 2013. Finally, we summarize our conclusions and outline the agenda for future research.

2. Theoretical Framework

(1) Role of Information Technology in Economic Growth

Moore's Law states that the density of semiconductor chips doubles every 18-24 months. Doubling in 18 months is equivalent to increasing the density of chips by 100 times every 10 years. The staggering rate of technical progress in the IT-producing industries -- semiconductors, computers, software, and telecommunications equipment – has led to a very rapid decline in IT prices. This price decline has stimulated a rapidly rising flow of investment into IT equipment and software by the IT-using industries in Japan and the United States.

[6] This framework is used by Jorgenson and Stiroh (2002), Jorgenson (2002), and Jorgenson, Ho, and Stiroh (2005).

For example, in 1990 a typical personal computer (PC) used Intel's 386 microprocessor with a clock speed of 20 megahertz (MHz) for the central processing unit. Intel's Pentium 4 processor, used in today's PCs, has a clock speed of 2.8 gigahertz (GHz) -- 140 times as fast. However, the price of a personal computer in Japan has changed very little, varying within a range of 200,000-500,000 yen. The technological progress in PC's can be observed in the rapid improvements in performance, rather than a decline in the price of a typical machine.

The key to capturing the rapid development of information technology is the construction of a price index for IT equipment and software that holds performance constant. Economic statisticians in Japan and the United States have used prices for matched models of IT products in overlapping time periods, as well as hedonic models of IT prices, to construct constant-quality price indexes. However, the methodology for price statistics differs between the two countries, making international comparisons problematical. We will return to this issue in the section on price data for Japan and the United States.

(2) Production Possibility Frontier

In order to capture the rapid pace of decline of IT prices, we employ the production possibility frontier introduced by Jorgenson (1995c).

$$Y(I_n, I_c, I_s, I_t, \mathrm{C}_{\mathrm{n}}, C_c) = A \cdot X(K_n, K_c, K_s, K_t, L) . \qquad (1)$$

Aggregate output Y consists of non-IT investment goods I_n, computer investment I_c, software investment I_s, investment in communications equipment I_t, consumption of non-IT goods and services C_{n}, and consumption of IT capital services by governments and households C_c. 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) or output per unit of input is denoted A.

The major advantage of this approach is the explicit role it provides for modeling the impacts of relative price changes on IT and non-IT outputs and inputs. For example, a constant-quality price index for computers is used in constructing computer investment data on the output side. In addition, the computer price index is included in the rental price of computer capital services on the input side and computer investment is incorporated into the estimate of the stock of computers used in production. These data are used on modeling the substitution between computers and other outputs, as well as the substitution between the services of computers and other productive inputs.

Since the production possibility frontier describes efficient combinations of outputs and inputs for the economy as a whole, external costs of adjustment in outputs and inputs are fully reflected in prices. For this reason the production possibility frontier is preferable to the principal competing methodology, the aggregate production function. The production function fails to treat relative price differences in outputs explicitly and does not incorporate costs of adjustment.[7]

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:

$$\begin{aligned} &\overline{w}_{I,n}\Delta\ln I_n + \overline{w}_{I,c}\Delta\ln I_c + \overline{w}_{I,s}\Delta\ln I_s + \overline{w}_{I,t}\Delta\ln I_t + \overline{w}_{c,n}\Delta\ln C_n + \overline{w}_{c,c}\Delta\ln C_c = \\ &\overline{v}_{K,n}\Delta\ln K_n + \overline{v}_{K,c}\Delta\ln K_c + \overline{v}_{K,s}\Delta\ln K_s + \overline{v}_{K,t}\Delta\ln K_t + \overline{v}_L\Delta\ln L + \Delta\ln A \end{aligned} \qquad (2)$$

where $\overline{w}$ and $\overline{v}$ 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:

$$\overline{w}_{I,n} + \overline{w}_{I,c} + \overline{w}_{I,s} + \overline{w}_{I,t} + \overline{w}_{C,n} + \overline{w}_{C,c} = \overline{v}_{K.n} + \overline{v}_{K.c} + \overline{v}_{K.s} + \overline{v}_{K.t} + \overline{v}_L = 1 \qquad (3)$$

7 See Jorgenson, Ho, and Stiroh (2005) for more detail on this point.

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 as the difference between growth rates of output and input.

(2) Theory of Capital Service Inputs

Data on output and labor input can be collected directly from transactions in product and labor markets. By contrast data for capital stock and capital service prices must be imputed from market transactions in investment goods. We next review the measurement of capital stock and capital service prices.[8] Since capital stock in the current time period K_t, is comprised of capital goods acquired in previous time periods $A_{t-\tau}$ and the efficiency of capital services d_τ varies with the vintage τ of capital goods, K_t may be expressed as follows:

$$K_t = \sum_{\tau=0}^{\infty} d_\tau A_{t-\tau} \tag{4}$$

If we define the mortality rate m_τ as the rate of decline in efficiency d_τ for each vintage, the difference in capital stock between two adjacent periods is:

$$K_t - K_{t-1} = A_t + \sum_{\tau=1}^{\infty}(d_\tau - d_{\tau-1})A_{t-\tau} = A_t - \sum_{\tau=1}^{\infty} m_\tau A_{t-\tau} = A_t - R_t \ , \tag{5}$$

where R_t represents the replacement requirement or the decrease in capital stock due to morality. If, in addition, efficiency declines at a constant rate δ, capital stock takes the form:

$$K_t = A_t + K_{t-1} - R_t = A_t + (1-\delta)K_{t-1} \tag{6}$$

Similarly, the price of capital services or the rental price of using a unit of capital stock for one time period is derived from the following capital-market non-arbitrage condition: the price of capital goods is the sum of future capital rentals. The price of capital goods can be

[8] Description of this section is based on the duality between investment and capital service prices developed by Jorgenson (1996b).

expressed by the following formula[9]:

$$q_{A,t} = \sum_{\tau=0}^{\infty} d_\tau q_{K,t+\tau+1} \quad , \tag{7}$$

where $q_{A,t}$ and $q_{K,t+\tau+1}$ are discounted prices for capital goods and capital services, respectively. Evaluating this expression at the current prices for capital goods and capital services, $p_{A,t}$ and $p_{K,t+\tau+1}$, and denoting the discount rate by r:

$$q_{K,t+\tau+1} = \left(\prod_{s=1}^{\tau+1} \frac{1}{1+r_{s+t}} \right) p_{K,t+\tau+1} \tag{8}$$

We can use formula (7) to express the differences in acquisition prices for capital goods over time:

$$q_{A,t} - q_{A,t-1} = -q_{K,t} - \sum_{\tau=1}^{\infty} (d_\tau - d_{\tau-1}) q_{K,t+\tau+1} = -q_{K,t} + \sum_{\tau=1}^{\infty} m_t q_{K,t+\tau+1} = -q_{K,t} + q_{D,t} \tag{9}$$

where $q_{D,t}$ represents the discounted price of depreciation of capital goods. If we express depreciation in terms of current prices, we obtain the following:

$$p_{K,t} = r_t p_{A,t-1} + p_{D,t} - (p_{A,t} - p_{A,t-1}) \tag{10}$$

The capital rental price $p_{K,t}$ is the sum of the cost of capital $r_t p_{A,t-1}$ and depreciation $p_{D,t}$, less capital gains on the capital good $p_{A,t} - p_{A,t-1}$. This is the non-arbitrage condition for the value of investment in capital goods and the rental value of capital services.

When the rate of depreciation on capital is constant ($p_{D,t} / p_{A,t-1} = \delta$)), the rental price reduces to:

$$p_{K,t} = (r_t + \delta - \tfrac{p_{A,t} - p_{A,t-1}}{p_{A,t-1}}) p_{A,t-1} \tag{11}$$

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[9] We first present the benchmark case with no taxation. The empirical estimates are based on a model that also takes into account the effects of taxation on capital income.

A higher rate of depreciation requires the recovery of investment over a shorter period of time and the capital rental cost increases. Similarly, if the price of a capital good is decreasing more rapidly, a greater future capital loss must be anticipated and the rental cost increases.

Even if the prices of two capital goods are the same, the rates of depreciation and rates of change in the prices of capital goods may differ, leading to different capital rental costs. Equation (11) is the formula we use for imputing the rental prices of capital services from the prices of investment goods. However, this formula must be modified possibility to incorporate taxes, as shown by Jorgenson and Yun (2001). The formulas used in this study will be described in a later section.

3. Data

(1) Output data

The data for Japan used in our analysis are comparable to the U.S. data presented in Jorgenson (2002b). We distinguish three sectors of the Japanese economy – businesses, governments, and households. The data structure is presented in Table 1.

(Table 1)

Output data are based on official estimates of the gross domestic product (GDP), published by the Economic and Social Research Institute (ESRI) of the Cabinet of Office of the Japanese Government.

In 2000 the Japanese System of National Accounts was revised to comply with United Nations (1993) System of National Accounts (SNA93). The major points of revision of the nominal value of GDP were (1) adding custom-made software to private and public investments and (2) adding depreciation of public infrastructure to government consumption. ESRI estimated that the impact of these accounting changes led to a 2.0% upward shift in the level of GDP in 1995 and an upward shift of 0.2% in the annual growth rate GDP in constant prices in 1998 and 1999.

Our study uses the SNA93 current price GDP for Japan as a point of departure[10]. We adjust these data to achieve comparability with U.S. data from the U.S. National Income and Product Accounts (NIPA). One major difference between the Japanese SNA93 and NIPA is in the treatment of software. In The Japanese SNA93 treats custom software as an investment, while the U.S. NIPA also includes prepackaged and own-account software in investment. Therefore, we have estimated investment in prepackaged and own-account software in Japan and added this to the official Japanese GDP.

Since households are included in the production sector, the capital service flow from consumer durables must be treated as both an output and input of households. In the Japanese SNA and the U.S. NIPA only capital services from owner-occupied housing are imputed and included in the GDP. We have treated other types of consumer durables, including information technology equipment and software, in the same way as housing. We have imputed the value of capital services for households and added this to GDP for Japan and the U.S., following Jorgenson (2002b).

The government is also included in the production sector, so that the capital services from government capital must be treated as an output and an input of governments. In the Japanese SNA and the U.S. NIPA only depreciation from government capital is included in the GDP. However, depreciation is only one component of the price of capital services (11), so that we must add the cost of capital and capital losses due to declines in asset prices to the value of government capital services. This makes the treatment of government capital symmetrical to business and household capital.

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[10] ESRI published historical SNA93 data back to 1980. Prior to 1980 only SNA68 data are available. Therefore, we extend SNA93 data backward by using growth rates of SNA68 data.

Table 2 compares output data for Japan in current prices of 2000 used in this study with the official Japanese GDP. The value of GDP in this study is about 534 trillion yen in 2000, which is about 23 trillion yen greater than the official GDP based on SNA93. About four trillion yen comes from adding prepackaged and own-account software investment in business, government, and household sectors and about 19 trillion yen comes from the capital service flow from consumer durables and government capital stock.

(Table 2)

We also note the differences between methods for deflating the current value of GDP to obtain GDP in constant prices in the Japanese SNA and the U.S. NIPA. In Japan, ESRI has recently published a chain weighted GDP index, as well as historical series back to 1994. We have to rely on fixed weight GDP index in Japan before 1993. By contrast the U.S. NIPA has incorporated a chain-weighted index for historical data on output and prices for some time. Since the share of information technology equipment and software in GDP is increasing rapidly, the role of IT investment in the Japanese economy will be under-estimated, relative to the U.S. In order to achieve greater comparability with U.S. data, we estimate IT and non-IT components separately for Japan and apply a flexible weighting scheme to estimate the rate of growth of output.

(2) Input data

(a) Investment in information technology equipment and software

In order to make comparisons of the impact of investment in IT equipment and software between the two countries, it is important to use a common definition of IT. The U.S. NIPA publishes both nominal and real values of investment by category of capital goods. Jorgenson (2002b) used the following categories of IT-related investment: computers and equipment, software, and communication equipment. In this study, we have defined IT investment for

Japan in the same way[11].

We have generated data on investment in IT equipment for Japan that is comparable to the U.S. NIPA by using Japanese input-output tables. However, as discussed in the previous section, the definition of software in the Japanese SNA is different from the U.S. definition. Japanese GDP data, based on SNA93, includes only custom-made software; prepackaged and own-account software are excluded. Therefore, we have estimated the software investments in these two categories in order to match the U.S. definition.

Although ESRI treats only custom-made software as an investment, the benchmark IO table for 2000, published by Japanese Statistical Bureau, has estimated the amount of prepackaged software to be treated as an investment. According to this table, the ratio of investment to total expenditure on prepackaged software is about 40%. Since the data are available only in 2000, we use this ratio for prepackaged software to adjust the annual expenditure data to generate an investment series. The Ministry of Economy, Trade, and Industry's (METI) Survey on Selected Service Industries provides annual data on investment in prepackaged and custom-made software. Therefore, we use this information as well as the benchmark input-output tables published every five years to estimate investment in custom-made and prepackaged software.

Neither Japan's input-output tables nor METI's Survey of Selected Service Industries includes investment in own-account software. We have estimated this investment using methods similar to those used for the U.S. NIPA, described in Parker and Grimm (2000). Specifically, we have estimated labor expenses for software development by employees in industries other than the IT sector, which produces custom-made and prepackaged software.

Finally, Jorgenson (2002b) used expenditures on computers and software from Private Consumption Expenditure (PCE) in NIPA to estimate investment in IT equipment and

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[11] Specifically, the categories for computers (1995 IO category: 3311011) and computer peripherals (3311021) correspond to "computers and equipment," and television and radio (3211021), video (3211031), cable communications devices (3321011), and wireless communications devices (3321021) correspond to "communications equipment."

software in the household sector[12]. Similarly, government expenditures on IT equipment and software were taken from NIPA. We have employed data from the Survey of Selected Service Industries as well as household and government consumption of software in the Japanese benchmark input-output tables to estimate investment in IT equipment and software in the household and government sectors.

(b) Capital services

In order to estimate capital services as precisely as possible, we have estimated capital stock and capital service prices by detailed category of investment goods. This enables us to take into account changes in the composition of capital stock. We have captured the improvement in the quality of capital associated with the substitution of investment goods with high marginal products, such as IT equipment and software, for goods with lower marginal products, such as non-IT investment goods.

Based on Japan's benchmark input-output tables, compiled every five years, as well as METI's annual extension tables with more than 500 commodity categories, we have estimated investment by 62 commodity groups for business and government sectors and 20 commodity groups for the household sector from 1970 to 2003. We have deflated this current price investment by the Wholesale Price Index constructed by the Bank of Japan for business and government investment and by the Consumer Price Index constructed by the Japanese Statistical Bureau for household durables. [13]

We have estimated capital stocks by the perpetual inventory method. Initial values of capital stock for 1973 are estimated by assuming that the real investment for each type of capital goods increased continuously in the past by the same growth rate as that for

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[12] The corresponding sectors of the Japanese input-output tables are those for computers (1995 IO category: 3311011), computer peripherals (3311021), cable communications devices (3321011), wireless communications devices (3321021), and software (8512011).

[13] The Japanese WPI and CPI are Laspeyres price indexes, with new benchmarks every five years. We constructed similar deflators for the period of our analysis. After the 2000 benchmark the WPI will be re-named as the CGPI (Corporate Goods Price Index).

the period 1970-1973.[14] We have used U.S. NIPA depreciation rates for each type of capital goods presented by Fraumeni (1997).

In imputing capital service prices, Equation (11) has to be modified to incorporate the taxation of capital income for each type of investment good in each sector. For example, there is a special acquisition tax for automobiles and there is no corporate tax in government and household sectors. Nomura (2004) took these features of the Japanese tax system into account, as well as many others. In this paper, we have applied the formulas for capital service prices used by Nomura (2004) for business, government and household sectors, separately.[15]

(c) Labor input

Our estimates of labor input for Japan are taken from the ICPA project of RIETI[16], originally derived from KEIO database (Keio Economic Observatory, 1996). This is calculated by using the data of the number of workers, hours worked, and hourly wage rates, cross-classified by sex, age and education. As with data for capital services, the change in the quality of labor input associated with upgrading of the labor force can be captured by comparing the growth of hours worked with the growth of the labor input index.

(3) Prices for investment in IT equipment and software

We employ the production possibility frontier (1), explicitly measuring both outputs and inputs, so that prices of IT equipment and software affect both sides of our growth accounts. Since technological advances are so rapid and quality changes are so dramatic, a small change in methodology for measuring prices may result in significant differences in growth

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[14] In Japan, large-scale National Wealth Surveys were conducted several times prior to 1970. Although the results of these surveys are valuable for some purposes, for example, estimating war-time damages, they do not include detailed stock data on each type of investment good. For this reason, we have used the method described in the text to estimate initial values.

[15] Detailed formulas can be found in Appendix 3 of Motohashi (2002).

[16] Refer to RIETI (2004) for the ICPA project as well as classifications for this dataset.

accounting. We find that there is a considerable divergence between Japanese and U.S. IT prices, even after controlling for relative price differences in the two economies, as shown in Table 3.

(Table 3)

Although price indexes for computers in both countries are based on hedonic methods, a substantial difference can be found in movements of the price index for computers and peripherals. This index is a composite of personal computers, large-scale computers, and various kinds of computer peripherals. The differences can be explained by price differences at the commodity level, as well as the index number methodology. A major factor behind the price differences is that the Bank of Japan (BOJ)'s WPI/CGPI is based on a fixed-weight Laspeyres index with a base that is changed only every five years, while BEA employs a chain-weighted index.

Nomura and Samuels (2004) have found substantial fixed-weight bias in the Japanese WPI in the late 90's because personal computers with faster price declines gained output share. BOJ has recognized this problem and published chain-weighted price indexes as a reference series. We use the BOJ chain-weighted index for computers and peripherals from 1995 to 2003, instead of the fixed-weight Laspeyres price index employed in the Japanese national accounts. No chain-weighted price index for Japan is available before 1995, but differences between the two countries in the early 1990's can be partly explained by NEC's domination of the PC market condition in Japan, according to Nomura and Samuels.

For communications equipment the rate of price decline is slightly higher in the Bank of Japan's WPI/CGPI than in the U.S. NIPA index. Although both indexes use matched models, Japan's WPI is based on a more detailed list of items and may be more accurate. We use BOJ's chain-weighted price index for communications equipment, beginning in 1995. Since detailed commodity-level price information is available for 1985 to 1995, we employ a chain-weighted index for this period. as well.

Finally, the BOJ's price index for custom-made software by CSPI (company service price index) uses an estimate of costs that assumes no increase in labor productivity, while the U.S. NIPA price index uses a weighted average of costs for custom software and a hedonic price index for packaged software. BOJ publishes prepackaged software prices by CSPI after the 2000 benchmark year revision, so that we use them for 2000-2003 data. Before 2000, only the custom-made software price is available. Since it is unrealistic to assume no productivity growth in Japanese software industry, "internationally harmonized" prices, based on U.S. price indexes, are used for prepackaged software before 2000.

The basic idea of an internationally harmonized price index is to use U.S. prices of IT products relative to non-IT products to estimate prices of IT products relative to non-IT products in Japan. This approach was introduced in a series of OECD studies, for example, Colecchia and Schreyer (2002), and has been used in international comparisons by Van Ark et al. (2002). We use CGPI's price series for custom-made software as well as own-account software.[17] The adjusted price index used in this study is presented in Table 3.

4. Results

(1)Information technology and economic growth in Japan and the United States

Table 4 gives our estimates of the contribution of information technology to output and input of the Japanese economy, together with the corresponding results for the U.S., based on an update of Jorgenson (2002b). It is possible to compare the results between two countries from the middle 1970's. The results from 1980 are also displayed for Japan, since capital stock data in the 1970's may be less reliable. The contribution of information technology to Gross Domestic Product (GDP) includes investments in computers, software and communication

[17] In US national accounts, the deflator for custom-made software was formerly derived as a weighted average price of prepackaged and own-account software. However, after the 2002 benchmark revision of US national accounts, the same price index is used for custom and own-account software.

equipment by business, government, and household sectors. Capital service flows from IT equipment and software in government and household sectors are included in "contribution of non-IT", since they are output contributions from government or household sectors, instead of the IT sectors.

The growth rate of GDP in Japan dropped from about 4% in the 1980's to less than 2% in the 1990's. The contribution of IT to output growth in Japan after 1995 was 0.5%, which is comparable to that in the U.S. About two thirds of Japanese output growth from 1995 to 2003 can be attributed to IT production. The last half of the 1990's was the era of American growth resurgence. While IT played a significant role in this resurgence, about five sixths of output growth can be explained by the contributions of non-IT goods and services.

(Table 4)

Table 4 presents the sources of growth in the two countries. The growth rate of gross domestic income can be decomposed among the contributions of IT capital, non-IT capital, and labor services. The difference in growth rates between GDI and GDP is equal to the growth rate of total factor productivity (TFP). Our most striking finding on the sources of Japanese economic growth is the surge in the contribution of capital services from IT equipment and software from 1995, reflecting the sharp rise of IT investment.

The contribution of IT capital services in the U.S. rose steadily throughout the period 1973-2003. The contribution of IT capital in Japan declined during the first half of the 1990's, but rebounded strongly after 1995. The contribution of IT capital in Japan during this period was 0.54 percent per year, while the corresponding figure for the U.S. was 0.88 percent. Investment in IT capital rose rapidly in both countries.

Our second finding is that the TFP growth rate in Japan fell after 1995, due to the slowdown of growth in TFP growth in the Non-IT sector. The TFP growth rate in Japan from 1995 to 2003 is about half of that of the U.S. However, it is important to note that the growth rate of TFP in Japan substantially exceeded that of the U.S. throughout the period 1973-2000.

An important part of the slowdown in economic growth in Japan during the 1990's is attributable to the drastic decline in the contribution of labor input analyzed by Hayashi and Prescott (2002). The labor input contribution dropped from 0.88 percent per year before 1990 to negative rate of -0.22 percent before 1995 and declined further to -0.32 percent after 1995. However, the contribution of Non-IT capital services also declined during the first half of the 1990's and continued to sink during the last half of the 1990's. The contribution of labor input in the U.S. fell only modestly during the first half of the 1990's and after 1995.

The Japanese economy grew at annual rates in the 3-5% range throughout the late 1970's and 1980's. In the 1990's growth rates dropped to the 1% range. Although more than 10 years have elapsed since the bursting of the "bubble economy", there is no sign of revival in the official statistics. Our estimates show that the contribution of IT to economic growth becomes larger throughout the period of economic slowdown.

(2) TFP decomposition between IT and non-IT

Jorgenson, Gollop and Fraumeni (1987) provide a model for tracing aggregate productivity growth to its sources at the level of individual industries. Productivity growth for each industry is weighted by the ratio of the gross output of the industry to GDP to obtain the industry's contribution to aggregate TFP growth. The price or "dual approach" to productivity measurement employed by Jorgenson (2002b) identifies productivity growth in different sectors from differences between output and input price changes.[18]

Since the price of output falls rapidly in the IT-producing industries, the change in IT prices relative to the aggregate price index can be used as a proxy for the TFP growth rate.[19] While

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[18] The dual approach must be carefully distinguished from aggregation over sectors. Jorgenson and Nomura (2005) have presented estimates based on aggregation over sectors. We rely on expenditure data from the Japanese national accounts, rather than data for individual industries.
A detailed comparison of these alternative methodologies is presented by Jorgenson, Ho, and Stiroh (2005).

[19] In an industry with rapid productivity growth, output price falls rapidly relative to the input price. TFP growth can be measured from relative change of the input price to the output price. In this sense, we assume differences of factor prices changes between IT and

an important part of the decline in IT prices can be attributed to the rapid decline of constant-quality prices for semiconductors, most semiconductors are used in the production of information technology equipment and other products. Accordingly, semiconductors appear as both an input and an output at the industry level and productivity growth in semiconductor production cancels out.

Table 5 shows the contribution of TFP in IT-production to TFP growth in Japan using the dual method, compared to the contribution for the U.S. The nominal share of IT production in GDP in the late 1990's was nearly the same for the two countries, a little more than 4%, and the IT contribution to the TFP growth rate was also very similar. The share of computers was higher in Japan than in the U.S. The relative price of computers fell faster than the prices of software or communication equipment in Japan, pushing up the contribution of IT to TFP growth.

(Table 5)

It should be noted that contribution of IT to total TFP growth increased after 1995, while the Non-IT contribution fell sharply. Compared to the U.S., the TFP growth rate in the Non-IT sector is greater in Japan for all periods except 1995 to 2003. As an explanation of this finding, Jorgenson (2003) has suggested that both Japan and the U.S. are close to the technology frontier in IT, while the level of Japanese technology continues to lag outside the IT-producing sectors. Investment in IT equipment and software has resulted in convergence of productivity toward U.S. levels.[20] However, the rate of convergence will gradually slow.

(3) Discussion

(a) Sensitivity of data adjustments

It is useful to compare our estimates of output in Japan with the official GDP data. As

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non-IT sector are negligible as compared to output price changes.

[20] This is consistent with the findings of the studies in Jorgenson (1995b), including the study of Jorgenson and Kuroda (1995).

described in section 3 (1), we have made adjustments in the scope of the official Japanese GDP data to achieve comparability with the U.S. The nominal value of GDP is adjusted by adding prepackaged and own-account software, excluded from the Japanese SNA93 concept of GDP, as well as rental services from consumer durables. In addition, we have adjusted IT prices in Japan in order to assess the impact of IT in the two countries.

Table 6 presents the same data as in Table 4 (Sources of Gross Domestic Product), using the official statistics for Japan. The price changes have significant impacts on both output and input data. This discrepancy becomes wider in recent years, due to the growing importance of IT in Japanese economy. The annual growth rate of output after 1995 falls by 0.14%; the largest difference comes from computers and software.

(Table 6)

Slower growth of input results from a lower pace of price decline, since the growth rate of capital stock decreases. In addition, since the capital service price falls with a lower rate of price decline in equation (11), the share of IT capital services also decreases. There effects are revealed in the fall of the contribution of IT capital services in Table 6. Slower growth in outputs and inputs cancels out, so that the effect on the TFP growth rate is small. The TFP growth rate in the late 1990's does not change.

The difference in the GDP growth rates in the 1990's comes from capital services from consumer durables and government capital, which are not included in the official GDP. Table 7 shows the differences between official GDP and our estimates. As the share of the IT sector increases, the impact of IT prices becomes larger. As for consumer durables and the government capital adjustment (CD and GOV), the contribution in the period 1975-1990 is negative, since the growth rate of official GDP is larger than that of CD and GOV, while it becomes positive after 1990.

(Table 7)

(b) Other issues in TFP estimation

Our TFP growth rate in the 1990's is very high by comparison with the Economic and Social Research Institute (2003) and Hayashi and Prescott (2002). Since these studies are based on the official price statistics, this is not surprising. In addition, we include land as a capital input, using six types of land data to take quality change into account, while the total volume of land is constant. Only capital services from depreciable assets are counted as capital inputs in the other studies. Including land in growth accounts reduces the positive contribution of capital services to GDP and pushes up the TFP growth rate. The shares of land rentals for periods 1975-90, 1990-95, and 1995-2003 are 23.2%, 45.9%, and 31.6%, respectively. If we eliminated land stock from our estimation, the annual TFP growth for each period would become smaller -- 1.14%, 0.44% and 0.37%, respectively.

Another issue is a level of classification of capital and labor inputs. In this study, capital and labor inputs are estimated from Divisia indexes incorporating detailed data, classified by type. Labor input has a larger share and a greater impact on the TFP estimate. The contributions of quality changes to economic growth are +0.93%, +0.58%, and +0.56% for periods 1975-90, 1990-95 and 1995-2003, respectively. It we eliminated these quality changes, estimated TFP would become larger -- 2.68%, 1.14% and 0.76%, respectively.

Finally, TFP is derived as a residual between the growth of output and the growth of input. Basu (1996) observes that TFP moves in the same direction as output and is pro-cyclical in the U.S.. He attributes this to the effects of market distortions. Since the Japanese economy experienced an economic surge in the late 1980's and a sharp decline in the beginning of 1990's, some caution is needed in interpreting the TFP growth rate in these periods. In this sense, TFP slowdown after 1995 may be partly explained by this business cycle effect.

5. Potential **Output Growth in Japan and the U.S.**

Table 8 gives growth projections for the U.S., using the methodology developed by Jorgenson, Ho and Stiroh (2004). The key assumptions are, first, that hours worked grows at the same rate as the working age population for the next decade, plus 0.1 percent per year to allow for elimination of slack in the labor market. The second key assumption is that reproducible capital stock – plant, equipment and software, and inventories – rises at the same rate as output. Land remains fixed in supply. These assumptions characterize growth in the U.S. over periods longer than a typical business cycle.

(Table 8)

We present three alternative growth scenarios for the U.S. – a base case, an optimistic case, and a pessimistic case. These three scenarios use a common set of assumptions for the growth of hours, the growth of labor quality, the share of capital in the national income, the share of IT output in the GDP, and the proportion of capital stock that is reproducible. The scenarios differ in assumptions about total factor productivity (TFP) growth in the IT-producing industries and the Non-IT industries. They also differ in assumptions about the growth of capital quality, defined as capital input per unit of capital stock. This reflects shifts in the composition of capital toward less durable assets like IT hardware and software.

The base case projection of potential output for the U.S. uses 1990-2003 averages of growth rates in IT and Non-IT total factor productivity and capital quality. This reflects the experience of the last half of the 1990s, dominated by the acceleration in TFP growth in the IT-producing industries, as well as the first half of the 1990s, before the acceleration took place. This is consistent with the International Technology Roadmap for Semiconductors (2004), which projects a continuation of a two-year product cycle through 2007 and resumption of the three-year cycle after that.

The optimistic case for the U.S. uses 1995-2003 averages of growth in productivity and capital quality for the decade 2003-2013. Jorgenson, Ho, and Stiroh (2004) have shown that this is in line with productivity growth in the U.S., since the recession of 2001. Even if this trend were to continue, U.S. growth would fall short of the historical growth rate of 4.05 percent per year during the period 1995-2000, when growth of hours worked of 1.99 percent was almost double the rate of labor force growth. For the U.S. the pessimistic case involves reversion to trends in productivity before 1995. This would imply a substantial slowdown in capital quality growth, reflecting the reduced impact of IT investment.

The base case projection of U.S. labor productivity growth is 2.21 percent per year. The drop in the projected growth of hours worked from 1.16 percent per year to 0.72 percent reduces the base case projection of U.S. GDP growth to 2.67 percent per year, well below the growth of 3.56 percent during 1995-2003. Output growth would be 3.55 percent per year in the optimistic case, essentially the same as the 1995-2003 growth rate. Finally, productivity growth in the pessimistic case would be only 1.01 percent per year, well below the level before 1995. The corresponding rate of growth of GDP would be only 1.73 percent per year.

Table 9 presents our projections of Japanese economic growth for the decade 2003-2013. We use the same methodology as for the U.S. However, hours are projected to decline at the same rate as the working age population – 0.63 percent per year, partly offset by a rise of 0.15 percent to allow for a decline in unemployment. Our base case for Japan uses 1990-2003 averages for IT and Non-IT productivity growth and the growth of capital quality. This was a period of very rapid productivity growth outside of the IT-producing industries and reflects Japan's continuing success in closing the productivity gap with other industrialized countries. However, Jorgenson (2003) shows that Japanese productivity was the lowest among the G7 nations in 2000, so that a sizable gap remains.

(Table 9)

Our optimistic case for Japan is based on the productivity averages of 1995-2003 for the IT-producing industries, just as for the U.S. These averages are combined with growth of Non-IT productivity and capital quality at the more rapid rates of 1990-1995. Finally, our pessimistic case is based on 1990-1995 averages for IT-producing industries – the beginning of the so-called "lost decade." These are combined with Non-IT productivity and capital quality growth at the slower rates of 1995-2003.

Our base projection of Japanese labor productivity is 1.97 percent per year, somewhat below the U.S. projection of 2.21 percent. The decline of hours worked in Japan will provide opportunities for capital deepening. In addition, the growth of TFP in IT-production and the Non-IT sector will remain lower in Japan than in the U.S. On the other hand, labor quality growth in Japan will continue at growth rates well above the U.S. rates. These three components, together with elimination of the unemployment gap, will enable Japanese productivity growth to maintain the levels of the 1990s. Our optimistic projection of

Japanese labor productivity growth is 2.37 percent per year, also below the U.S. projection of 2.83 percent per year. On the other hand, our pessimistic projection for Japan is 1.32 percent per year, above the projected U.S. growth rate of 1.01 percent.

We conclude that Japanese economic growth will continue to lag behind the U.S. This is implied by the projected decline in the working age population in Japan, even with a reduction in the unemployment rate and continued improvements in labor quality. Our optimistic growth projection for Japan is 1.88 percent per year for the period 2003-2013, substantially below the projection for the U.S. of 3.55 percent. Our pessimistic projection for Japan for the same period is 0.84 percent, also below the U.S. projection. Finally, our base case projection of Japanese GDP growth is 1.48 percent per year, well below the projected U.S. growth rate of 2.93 percent.

6. Conclusions

We have analyzed aggregate economic data for Japan and the U.S. to determine whether the increase in the rate of economic growth from surging IT investment in the U.S. in the late 1990's can also be observed in Japan. We have adjusted estimates of IT investments in Japan to achieve comparability with the U.S. estimates by Jorgenson (2002b). In order to make a rigorous comparison, we have constructed similar price deflators IT investment in Japan. We have also used the Japanese official statistics to assess the robustness of our results.

We have shown that the expansion of investment in IT equipment and software in the U.S. during the last half of the 1990's, accompanied by rising growth of TFP in the IT-producing sector, has a precise parallel in Japan. While this combination contributed to a sharp rise in the rate of economic growth in the U.S., it encountered a severely depressed economic environment in Japan. Growth rates of labor input plummeted in Japan during the 1990's, dragging down the rate of economic growth. However, the rising contribution of TFP in the IT sector after 1995 suggests that long-term prospects for the Japanese economy are less dismal than suggested by the official statistics.

The top priority for future research is to analyze relative levels of productivity in Japan and the U.S., following Jorgenson and Kuroda (1995) and Jorgenson and Nishimizu (1995). We believe that level comparisons will show that productivity in the IT-producing industries is similar in Japan and the United States. We anticipate that the IT-using industries in Japan lag behind their U.S. counterparts in the use of IT equipment and software, but will converge to U.S. levels. However, substantial parts of the Japanese economy are impervious to changes resulting from the adoption of IT and will continue to languish.

For economic policy it is very important whether TFP growth is concentrated in the IT-producing industries, as our results for the United States suggest. We have decomposed TFP growth in Japan between IT and non-IT sectors, using the decline in IT prices as a proxy for TFP growth in the IT-producing sectors. The growth of TFP in IT-using industries has been relatively strong in all periods except 1995-2003, which is consistent with persistence of opportunities to "catch up" to U.S. levels of technology in these industries.

In the analysis of individual industries, the effects of statistical issues arising from productivity measurements will be greater. For example, although productivity growth in service industries has been considered to be lower than that in manufacturing industries, this may be related to deficiencies in price deflators for service industry outputs. For example, the financial services industry shows particularly higher rates of investment in IT-related equipment and software,[21] but the output of this industry may be difficult to measure.

To avoid some of the statistical issues associated with the analysis of individual industries, analysis can also be conducted at a firm level. This would permit comparisons of the relationships of IT and productivity among businesses in the same industry. Brynjolfsson and Hitt (1995) conducted one of the first studies of the relationship between IT and productivity on a company level. More recently, the effects of IT investment on business organization have

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[21] Griliches (1994) discusses statistical issues in the measurement of service sector output as a source of under-estimation of the impact of IT investment.

been explored by Brynjolfsson and Hitt (2000). Finally, IT investment covers a wide range of different situations -- from applications of CAD/CAM technology in manufacturing to applications of ERP in business services. Motohashi (2003) has shown that the effects on productivity vary by application.

As illustrated by these examples, the economic analysis of investment in IT has made important progress in many areas. However, the rapid pace of technological advance is constantly generating new questions. It is vital that microeconomic analysis on a company level and macroeconomic analysis for the economy as a whole be properly aligned in order to clarify the mechanisms that underlie the structural changes resulting from the IT investments.

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Table 1: Variables used in growth factor analysis

	Business sector	Public sector	Household sector
Output	93SNA Official GDP + software adjustments	93SNA Official GDP + software adjustments	93SNA Official GDP + capital service from household
Capital Input	(Depreciable Assets) - Based on investment series by 62 types of asset (5 types of IT), capital stock and capital service are estimated. (Land) - Based on land stock data by 5 types of its category, consistent with SNA data. (Inventory) - Use SNA base aggregated inventory stock and price to estimate capital service		Based on investment series by 20 types of asset (3 types of IT), capital stock and capital service are estimated.
Labor	Number of workers, hours worked and per hour wage data by sex, age and education category		—

(Note) Refer to Motohashi (2002) for details in depreciable asset data

Table 2: Comparing current price output in 2000

	(in billion yen)
Official GDP: 93 SNA	511462
+Software Adjustment	3,704
+Consumer Durables Adjustment	19,049
Adjusted Output Data	534,215
Official GDP: 68SNA (reference)	490,518

Table 3: Comparison of IT prices

	WPI Laspeyres Index		US BEA Price		Price index for this study	
	1975-95	1995-03	1975-95	1995-03	1975-95	1995-03
Computer	-6.4%	-12.0%	-16.3%	-21.2%	-6.4%	-15.5%
Comm. Equipment	-1.4%	-5.1%	1.5%	-3.4%	-1.6%	-9.3%
Software	4.2%	-0.2%	-1.1%	-0.9%	-2.9%	-1.5%

Table 4: Sources of Gross Domestic Products

(JAPAN)

	1975-90	1980-90	1990-95	1995-03
Gross Domestic Product	4.03	3.97	1.64	1.28
Contribution of Information Technology	0.43	0.55	0.22	0.47
Computers	0.22	0.29	0.11	0.19
Software	0.13	0.18	0.08	0.22
Communications Equipment	0.08	0.09	0.03	0.06
Contribution of Non-Information Technology	3.61	3.42	1.41	0.81
Gross Domestic Income	2.46	2.71	0.84	0.83
Contribution of Information Technology Capital Services	0.36	0.44	0.29	0.54
Computers	0.18	0.21	0.13	0.22
Software	0.12	0.16	0.12	0.20
Communications Equipment	0.07	0.07	0.04	0.11
Contribution of Non-Information Technology Capital Services	1.01	1.08	0.77	0.62
Contribution of Labor Services	1.09	1.19	-0.22	-0.32
Total Factor Productivity	1.57	1.25	0.80	0.45

Notes: Average annual percentage rates of growth. The contribution of an output or input is the rate of growth, multiplied by the value share.

(US)

	1948-73	1973-89	1989-95	1995-03
		Outputs		
Gross Domestic Product	4.00	2.99	2.43	3.56
Contribution of Information Technology	0.11	0.35	0.37	0.59
Computers	0.03	0.18	0.15	0.32
Software	0.02	0.08	0.15	0.17
Communications Equipment	0.07	0.09	0.08	0.09
Contribution of Non-Information Technology	3.88	2.64	2.06	2.97
		Inputs		
Gross Domestic Income	3.07	2.68	2.13	2.56
Contribution of Information Technology Capital Services	0.16	0.38	0.49	0.88
Computers	0.04	0.20	0.22	0.49
Software	0.02	0.07	0.16	0.22
Communications Equipment	0.09	0.11	0.10	0.17
Contribution of Non-Information Technology Capital Services	1.80	1.11	0.71	1.01
Contribution of Labor Services	1.11	1.18	0.93	0.67
Total Factor Productivity	0.93	0.31	0.31	0.99

Table 5: Decomposition of TFP Growth

(JAPAN)

	1975-90	1990-95	1995-03
Total Factor Productivity Growth	1.57	0.80	0.45
	Contributions to TFP Growth:		
Information Technology	0.23	0.32	0.36
Computers	0.13	0.18	0.23
Software	0.05	0.10	0.04
Communications Equipment	0.05	0.04	0.09
Non-Information Technology	1.35	0.48	0.10
	Relative Price Changes:		
Information Technology	-9.18	-8.51	-7.35
Computers	-12.37	-10.21	-16.52
Software	-4.79	-8.59	-2.45
Communications Equipment	-7.52	-4.41	-9.40
Non-Information Technology	-1.31	-0.47	-0.09
	Average Nominal Shares:		
Information Technology	2.31	3.59	4.25
Computers	1.10	1.65	1.44
Software	0.58	1.16	1.92
Communications Equipment	0.63	0.78	0.90
Non-Information Technology	97.69	96.41	95.75

(US)

	1948-73	1973-89	1989-95	1995-03
Total Factor Productivity Growth	0.93	0.31	0.31	0.99
Information Technology	0.05	0.20	0.23	0.46
Computers	0.02	0.13	0.13	0.31
Software	0.00	0.03	0.06	0.06
Communications Equipment	0.03	0.05	0.04	0.08
Non-Information Technology	0.88	0.11	0.08	0.53
Information Technology	-4.3	-9.1	-7.5	-11.5
Computers	-21.9	-21.5	-15.2	-31.3
Software	-5.0	-5.1	-5.3	-3.9
Communications Equipment	-3.1	-4.7	-3.9	-6.7
Non-Information Technology	-0.9	-0.1	-0.1	-0.6
Information Technology	0.91	2.20	3.04	4.04
Computers	0.10	0.64	0.83	0.97
Software	0.07	0.49	1.12	1.78
Communications Equipment	0.74	1.07	1.08	1.28
Non-Information Technology	99.09	97.80	96.96	95.96

Table 6 Sources of GDP by using Official Price Data in Japan

	1975-90	1980-90	1990-95	1995-03
Gross Domestic Product	3.98	3.89	1.55	1.14
Contribution of Information Technology	0.37	0.47	0.14	0.34
Computers	0.22	0.29	0.11	0.14
Software	0.07	0.10	0.00	0.19
Communications Equipment	0.08	0.09	0.03	0.02
Contribution of Non-Information Technology	3.61	3.42	1.41	0.80
Gross Domestic Income	2.40	2.64	0.73	0.69
Contribution of Information Technology Capital Services	0.30	0.36	0.18	0.40
Computers	0.18	0.21	0.13	0.17
Software	0.06	0.09	0.01	0.16
Communications Equipment	0.07	0.07	0.04	0.07
Contribution of Non-Information Technology Capital Services	1.01	1.08	0.77	0.62
Contribution of Labor Services	1.09	1.19	-0.22	-0.32
Total Factor Productivity	1.57	1.25	0.82	0.45

Notes: Average annual percentage rates of growth. The contribution of an output or input is the rate of growth, multiplied by the value share.

Table 7: Comparison of output with official GDP in Japan

	1975-90	1990-95	1995-03
Official Statistics (93 SNA)	4.03%	1.53%	0.95%
+IT price adjustment	0.05%	0.09%	0.14%
+CD and GOV adjustment.	-0.05%	0.02%	0.19%
Final GDP growth rate	4.03%	1.64%	1.28%

Table 8: Growth Projections from 2003 to 2013 in United States

	Projections		
	Pessimistic	Base-case	Optimistic
		Projections	
Output Growth	1.73	2.93	3.55
ALP Growth	1.01	2.21	2.83
Effective Capital Stock	1.46	2.48	3.00
		Common Assumptions	
Hours Growth	0.723	0.723	0.723
Labor Quality Growth	0.087	0.087	0.087
Capital Share	0.410	0.410	0.410
IT Output Share	0.039	0.039	0.039
Reproducible Capital Stock Share	0.846	0.846	0.846
		Alternative Assumptions	
TFP Growth in IT	8.67	10.02	11.51
Implied IT-related TFP Contribution	0.21	0.37	0.45
Other TFP Contribution	0.10	0.38	0.54
Capital Quality Growth	0.84	1.66	2.08
Implied Capital Deepening Contribution	0.65	1.40	1.79

Notes: In all projections, hours growth and labor quality growth are from internal projections, capital share and reproducible capital stock shares are 1959-2003 averages, and IT output shares are for 1995-2003. Pessimistic case uses 1973-1995 average growth of capital quality, IT-related TFP growth, and non-IT TFP contribution. Base case uses 1990-2003 averages and optimistic cases uses 1995-2003 averages.

Table 9: Growth Projection from 2003 to 2013 in Japan

	Projections		
	Pessimistic	Base-case	Optimistic
		Projections	
Output Growth	0.84	1.48	1.88
ALP Growth	1.32	1.97	2.37
Effective Capital Stock	0.56	1.00	1.27
		Common Assumptions	
Hours Growth	-0.483	-0.483	-0.483
Labor Quality Growth	0.430	0.430	0.430
Capital Share	0.393	0.393	0.393
IT Output Share	0.043	0.043	0.043
Reproducible Capital Stock Share	0.674	0.674	0.674
		Alternative Assumptions	
TFP Growth in IT	7.53	8.11	8.47
Implied IT-related TFP Contribution	0.32	0.34	0.36
Other TFP Contribution	0.10	0.33	0.48
Capital Quality Growth	0.58	1.13	1.47
Implied Capital Deepening Contribution	0.64	1.03	1.27

Notes: Hours growth is from the Institute for Population and Social Security. Labor quality growth are from internal projections. Capital share and reproducible capital stock shares are 1975-2003 averages. IT output shares are for 1995-2003. Pessimistic case uses 1990-1995 average growth IT-related TFP growth, and 1995-2003 average non-IT TFP contribution and capital quality growth. Base case uses 1990-2003 averages for al l of them. Optimistic cases uses 1995-2003 averages for IT-related TFP growth and 1990-1995 non-IT TFP contribution and capital quality growth.