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Quality of Labor, Capital, and Productivity Growth in Japan: Effects of employee age, seniority, and capital vintage

SHINADA Naoki
Development Bank of Japan

Research Institute of Economy, Trade & Industry, IAA
The Research Institute of Economy, Trade and Industry
http://www.rieti.go.jp/en/

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Abstract

An aging population, low fertility rate, and suppressed corporate investment have left Japan with an older workforce and older vintages of fixed capital. To restore economic dynamism, Japan must encourage productivity growth.

Using panel data of listed Japanese firms in FY 1977–2008, this paper demonstrates how both employee age and capital vintage affect the quality of labor and capital that influence productivity. Our research contributes three significant findings. (1) The older the average age of a firm's employees or the longer their seniority, the higher the firm's productivity growth, but it is unclear if the effects peak at specific ages. (2) The positive effects of employees' increasing age and seniority and the negative effect of older capital on Japan's productivity growth have declined since the 1990s. (3) These effects have been larger among manufacturers than non-manufacturers.

Negative effects of increasing non-regular workers should be addressed, and it is further important for Japanese firms to organize and manage labor skills and enhance knowledge, rather than depend on technology accumulated over time.

Keywords: productivity, labor, capital, employee age, seniority, and capital vintage.

JEL classification: D24; E22; E23; E24; J24

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1. Introduction

Faced with a rapidly aging population and low fertility rate, Japan must enhance productivity growth to maintain economic dynamism. Previous literature has mentioned Japan's historical trends in productivity growth, and numerous empirical studies have suggested that deterioration in productivity growth is a factor in Japan's long-term recession and lower economic growth since the 1990s. Within the framework of growth accounting analysis, this means that contributions other than changes in quantities of production inputs such as labor, capital, and intermediate goods to overall growth in output—i.e., total factor productivity (TFP)—have weakened since the 1990s. Many previous studies examined the problem of lower productivity growth, and some attribute its causes to slowdowns in technological progress, declining quality of labor, and reduced performance of capital equipment.

Japan's aging population makes any decline in labor quality a greater detriment to productivity growth. Technology, skills, and job experience embodied in the labor force are related to employee productivity, and their contributions to productivity have changed due to aging of Japan's working population, revisions in Japan's traditional seniority system, and deregulation of contract employees. That results not only in more flexibility and mobility in labor force but also in changing the effects of labor input quality on corporate productivity.

Quality of capital inputs also influences productivity. Japan's economic slowdown has been prolonged, corporate fixed investment has been suppressed, and firms are reluctant to renew capital equipment. As a result, Japan's capital stock ages, and its contribution to productivity declines.

Changes in quality of labor and capital inputs are related to job experience, firm-specific skills, and fixed productive equipment. These factors are time dependent—they accumulate or decrease over time. Structural changes in Japan's economy have considerably influenced time-dependent labor and capital input quality and the relationship of changes in quality to productivity growth. This study aims to capture changes in quality of these production inputs by measuring employee age, seniority, and capital vintage and by examining their effects on productivity growth.

Previous studies have analyzed separate effects of changes in quality of labor and capital input, including the age of employees and capital, using macro-, industry-, and firm-level data. This study uses a single dataset compiled from financial statements for FY 1976–2008 of Japan's publicly listed manufacturing and non-manufacturing firms. It demonstrates the effects of changes in quality of labor and capital inputs, particularly average age and seniority of employees and capital vintage, on TFP growth. An advantage of this study is that a single dataset captures the comprehensive effects of quality changes relevant to employees' age and seniority, sampled period, and industry. Our findings extend the results and implications of previous literature.

This paper proceeds as follows. Section 2 reviews previous literature concerning the relationships among productivity and employee age, seniority, and capital vintage, focusing on firm-level empirical studies of Japanese firms. Section 3 defines specifications of the models we estimate for our sample panel data. Section 4 explains the data construction for estimating the models. Section 5 explains descriptive statistics and trends of variables used for the estimation. Section 6 demonstrates the estimation results of our panel data analysis. Section 7 concludes with a summary of our findings and comments on their implications.

2. Previous literature

2-1. Age- and seniority-productivity profiles

Influenced by the theoretical background of human capital that stems from Becker (1964), many economists have studied the relationship between employee age and productivity growth. Firms invest in job education and training of their employees, and the employees take time enough to acquire general or firm-specific skills and knowledge. They use their skills and knowledge to earn profits, and are able to increase profitability if they succeed in developing their skills and knowledge over time. Economists generally consider that higher wages reflect increased profitability generated by the skills and knowledge that employees develop. Mincer (1974) and related studies demonstrate a positive relationship between wages and the extent of education and job experience.

On the other hand, Hellerstein and Neumark (1995) considered the relationship between employees' age and productivity or wages rather than the direct relationship between wages and productivity. They estimated marginal productivity differentials between employees of different ages through a production function approach to firms' technologies. Using 1998 data from 933 Israeli firms, they demonstrated an upward slope in productivity profiles and earnings against age classes, which means that the relative marginal productivity of unskilled employees (age 35–54) is greater than that for younger skilled employees but less than that for employees 55 or older.

However, Hellerstein and Neumark (2004) used a larger individual-level dataset of 26,031 employees in the U.S. in 1990 to find that the estimated productivity and wage profiles are concave with respect to age, with the age-productivity profile peaking among employees aged 35–54 years. Using matched employer–employee data from Finnish manufacturers in 1988–1994, Ilmakunnas, Maliranta, and Vainiomäki (2004) examined the relationships of employees' age and seniority and plant characteristics to plant performance such as productivity and wages. They found that age-productivity and seniority-productivity profiles are concave with respect to age. The age-productivity profile peaks at 33 years, and the seniority-productivity profile peaks at 2.5 years.

Kawaguchi et al. (2006) constructed a Japanese employer–employee-matched dataset from 1993 to 2003. They also demonstrated that the seniority-productivity profile is concave, peaking at about 20 years of experience, corresponding to 40 years of age. They also demonstrated that the slope of the profile for 20 years or less is steeper than the slope for 20 years or more. Ochiai (2008) divided a dataset into two groups of employees—younger and older than age 40—to demonstrate that the older group has higher productivity. Shirakawa (2009) used industry-level data from the Japan Industrial Productivity (JIP) database compiled by RIETI and also found that TFP peaks at an average employee age of 45.8 years. Jinno (2009) conducted a similar industry-level study to show that employee maximum productivity is attained at age 35–54 years, the second-highest at age 55 years or older, and the lowest at age 35 years or younger.

Thus, empirical studies have adopted varying approaches toward age-productivity and seniority-productivity profiles, but the consensus is that productivity is concave with respect to age and that productivity peaks for employees in their thirties and forties.

2-2. Capital vintage

Previous literature has also investigated the effect of changes in quality of capital. Scholars are of the opinion that certain types of technological progress are embodied in capital and contribute to productivity growth. Among the popular frameworks for investigating embodied technological change is to capture decay of capital by estimating ages of production facilities. According to the concept of vintage capital proposed by Solow (1960) and Nelson (1964), an installation of new capital equipment increases productivity, and firm-level productivity will be higher as the average vintage of capital decreases.

Many industry- and firm-level studies have empirically examined relationships between vintages of capital and productivity. Sakellaris (2001) introduced a framework around Nelson's (1964) concept that negative effects of the average age of capital stock on productivity provide evidence of embodiment. Using a plant-level dataset from U.S. manufacturing plants in 1974–1988, he demonstrated that an increase in the average age of equipment stock, indicating the rate of embodied technological change, has a positive influence on economic growth. Similarly, Bahk and Gort (1993) used data of 2,150 U.S. plants in 1972–1986 to show that technical change embodied in capital as measured by average vintage is associated with a 2.5 to 3.5 percent change in output for each one-year change in average vintage.

Using the JIP and Japan Center for Economic Research (JCER) databases released by JCER, Miyagawa and Hamagata (2006) estimated vintages of Japanese capital at the industry level and demonstrated that a change in vintages of machinery has a larger positive elasticity versus a change in capital quality than that of buildings. Tokui, Inui, and Kim (2007) studied the relationship between decay of capital and vintages. Using Japan's firm-level panel data in 1997–2002 obtained from the Basic Survey of Japanese Business Structure and Activities by the Ministry of Economy, Trade and

Industry (METI), they estimated undecided capital for each vintage and the rate of technological progress embodied in equipment as 0.2–0.4 percent. Tokui, Inui, and Ochiai (2008) introduced a new dummy variable for capital decay, estimated from Japanese firm-level panel data about investment spikes generated by large-scale investment projects. They showed that the dummy variable for decay exposes a slowdown in productivity growth, but the negative effect is weakened three years after investment spikes.

3. Model specification

This study aims to capture the impact of changes in quality of labor and capital on productivity growth by measuring average employee age and capital vintage at the firm level. First, we define the concept of firm-level productivity that we seek to measure. OECD (2001) offers two ways to measure productivity: by gross output and by value added. Productivity is generally obtained from dividing gross output or value added by production inputs, and, especially for firm-level measurement, revenue is used for computing output basis. Value added is calculated from net profit and other items.

On the other hand, inputs such as labor, capital, and intermediate goods involve several types of productivity. Assuming a standard production function in which firms use multiple inputs to produce output, we obtain labor productivity, capital productivity, intermediate goods productivity, and other productivity that contribute to output. In the concept of growth accounting, other productivity is the Solow residual as TFP.

This study focuses on the effects of changes in quality of labor and capital on TFP growth because labor productivity is affected by factors such as capital quality and technological change included in TFP growth. In addition, output is calculated on a value-added basis to address data limitations and difficulties estimating the contribution of firm-level intermediate goods to output.

Assume the following Cobb–Douglas production function:

$$Y_t = A_t \cdot (Q_{L,t} L_t)^{\alpha} \cdot (Q_{K,t} K_t)^{1-\alpha} \tag{1}$$

Y: Output, L: Labor input, K: Capital input, Q_L: Quality of labor, Q_K: Quality of capital, α: Labor share.

To estimate effects of changes in employee age on productivity, previous literature, such as Shirakawa (2009) and Jinno (2009), used datasets of proportions by age cohort and applied them in Cobb–Douglas or general form production functions. However, due to data limitation, we obtain only average age and seniority in each year at a firm level, and we must define a single variable function that expresses quality of labor input.

To express changes in vintage as quality of capital stock, Wolff (1996) and Miyagawa and Hamagata (2006) used an exponential function with vintage. We adopt this procedure for employee age on labor quality as well as for vintage of capital. Thus, Q_L and Q_K, including time-variant variables that indicate quality of labor and capital such as employees' ages or seniority (W) and capital vintage (V), are defined as follows:

$$Q_{L,t} = W_t^{p} \tag{2}$$

$$Q_{K,t} = V_t^{q} \tag{3}$$

$$A_t = A \cdot e^{gt} \tag{4}$$

Equation (1) is transformed as follows:

$$\ln Y_t = \ln A_t + \alpha \ln Q_{L,t} + \alpha \ln L_t + (1-\alpha)\ln Q_{K,t} + (1-\alpha)\ln K_t \qquad (5)$$

$$\ln \dot{A}_t = \ln A_t + \alpha \ln Q_{L,t} + (1-\alpha)\ln Q_{K,t} \qquad (6)$$

$$= \ln A_t + \alpha \cdot p \ln W_t + (1-\alpha) q \ln V_t \qquad (7)$$

A with a dot is TFP unadjusted by effects of quality changes of labor and capital. Considering assumption (4) and α, which is labor share directly calculated from corporate financial statements, a basic form for estimation is set as $\ln \dot{A}_t = C + \beta\, t + \gamma \ln W_t + \delta \ln V_t + \varepsilon$ (8).

4. Dataset and construction

4-1. Sampled firms

Our sample consists of listed Japanese companies in FY 1976–2008, financial statement data for which come from the Corporate Financial Databank of the Development Bank of Japan (DBJ). This database covers all listed Japanese firms, excluding financial institutions, from FY 1956, but our sample covers FY 1976–2008 due to limited availability of data pertinent to all variables in this study. As Table 1 shows, our unbalanced panel dataset includes 600–1,500 firms, enough to cover most listed firms.

4-2. Labor input

Labor input is calculated by multiplying firm-level numbers of employees and industry-level working hours per employee. Employees include full-time and part-time employees disclosed in the sampled firms' financial statements. Working hours, obtained from the Monthly Labour Survey by the Ministry of Health, Labour and Welfare (MHLW), include scheduled and non-scheduled hours worked.

4-3. Capital input

We estimate capital input by multiplying industry-level capacity utilization rates and firm-level real capital stock constructed from time-series data of fixed investment in non-residential buildings, structures, machinery, transportation equipment, and instruments and tools. For each asset, nominal gross investment is calculated as the change in book value of net capital stock plus accounting depreciation. Real investment is calculated by dividing nominal investment by the producer price index for the firm's industry.

Capital stock is calculated as follows:

$$K_t = (1-\delta)K_{t-1} + I_t \tag{9}$$

where K_t denotes real capital stock at the end of year t, I_t denotes real capital investment in year t, and δ denotes depreciation rates. According to the method suggested by Hayashi and Inoue (1991), we estimate real capital stock by considering physical depreciation rates suggested by Hulten and Wykoff (1981), then we calculate capital input by multiplying industry-level utilization rates and firm-level real capital stock.

Industry-level capacity utilization rates for manufacturing industries are obtained from *Reports on Industrial Production* by METI, and we adjust its industry-level categories to match the medium-level categories of the DBJ database. Non-manufacturing capacity utilization rates are estimated by the method proposed in Kamada and Masuda (2001). Their method uses production capacity given in the Business Survey Index, a diffusion index of sufficiency of equipment, in the *Business Outlook Survey* by the Ministry of Finance. Electricity power units for commercial power in non-manufacturing sectors are regressed on a linear trend and on the production capacity BSI, and utilization rates are obtained by removing the linear trend and residuals.

4-4. TFP

TFP, derived from the firm's production function, accounts for effects on total output other than those caused by inputs. A Cobb–Douglas-type firm production function is assumed as follows:

$$Y = \dot{A} \cdot L^{a} \cdot K^{1-a} \qquad (10)$$

Y denotes real output, K denotes capital input, and L denotes labor input. Real output is defined as a firm's nominal value added deflated by a wholesale price index for a corresponding industry. Because the DBJ database contains information on factor incomes from companies' financial statements, a measure of nominal value added at factor cost is constructed as the sum of expenditures on labor, rent, depreciation, operating profits before interest, taxes and public charges, and patent licensing fees.

Assuming constant returns of scale, we calculate labor share, α, as the average ratio of compensation in nominal value added during the sampled periods, and obtain TFP, $\dot{A}$. It should be noted that $\dot{A}$ could include changes in quality of labor and capital inputs other than those related to physical depreciation and changes in capacity utilization rates and working hours.

4-5. Age and seniority of employees

Data for age and seniority of employees are obtained from the DBJ database, which covers averages for age and seniority of each firm's employees in each fiscal year.

4-6. Capital vintage

Vintage of capital stock is estimated by the method proposed in Miyagawa and Hamagata (2006) as follows:

$$V_t = \left[(V_{t-1} + 1)\cdot(K_t - R_t) + 0.5 \times I_t\right] / K_t \tag{11}$$

V_t is vintage of capital at period t, and R_t is the amount of depreciation in year t. V_t is defined as a weighted average of years of undecayed capital stock from the previous year and one-half of capital investment made in a current year.

$V_{i,1}$, a benchmark for capital vintage of firm i, is calculated as

$$V_{i,1} = \ln RM_{i,1} / \ln(1 - DR_{i,1}) \tag{12}$$

$$RM_{i,1} = \frac{NK_{i,1}}{NK_{i,1} + CUM_{i,1}} \tag{13}$$

$$DR_{i,1} = \frac{DP_{i,1}}{DP_{i,1} + NK_{i,1}} \tag{14}$$

$RM_{i,1}$ denotes the rate of assets of firm *i* not yet depreciated in a benchmark year, DR_1 is a depreciation rate in the benchmark year, NK_1 is nominal assets in the benchmark year, CUM_1 is depreciated assets accumulated in the benchmark year, DP_1 is the amount of depreciated assets in the benchmark year. The benchmark year is the year a firm is listed; i.e., capital vintage in the benchmark year is an approximation based on accounting-based depreciation.

5. Descriptive statistics

5-1. TFP

Table 1 and Figure 1 show an average TFP growth rate of our sampled firms by year. The growth rate remains around 1.0–1.5 percent during the late 1970s, increases from the 1980s, and exceeds 2.0 percent in the late 1980s. After that, the rate starts to decline, although it remains at 1.0 percent until the bubble era in the early 1990s. It turns negative in the late 1990s following Japan's banking crisis. In the early 2000s, the growth rate recovers to around 1.0 percent, but it decreases again from the mid-2000s. The year-on-year growth rate turns negative again since 2007.

Previous literature measures TFP by various methods, and figures for growth rates depend on how they are measured. As one typical example, Jorgenson and Motohashi (2005) estimate Japan's macro-level TFP growth rate from 1975 to 2003. Their estimates are 1.57 percent of the average TFP growth rate in 1975–1990 and 0.59 percent in 1990–2003. Our estimates of 1.48 percent in 1977–1990 and 0.74 percent in

1990–2003, although based on a different micro-level approach, are similar to theirs.

5-2. Employee age and seniority

According to annual averages for our sampled firms in Figure 2, the average age of employees increased from around 34 years in the late 1970s to 36 years or older in the early 1980s. Average age remained stable until the early 1990s, although it declined during the bubble era from the late 1980s to early 1990s due to a surge in employment. During the recession of the late 1990s, average age increased to 37 or older, then continued to increase gradually, reaching approximately 38.5 years in 2008.

From the late 1970s to late 1990s, average seniority of employees displayed a trend similar to average age: seniority increased from around 10.5 years in the late 1970s to 13 years in the early 1980s. It slowed in the late 1980s and declined to 12.5 years during the bubble era. Afterward, however, the trend differs from the trend in average age. Until the mid-2000s, seniority generally remained unchanged, then it decreased since 2005.

As described in Figure 3, these average trends from our sampled firms are broadly consistent with macro-level trends obtained from the Basic Survey on Wage Structure by MHLW. The background of the characteristic trends in the 2000s was as follows: (a) Employment increased during the economic recovery phase. (b) Because Japan’s employment situation has been more flexible and mobile since the early 2000s, hiring of experienced mid-career employees has increased. (c) Non-regular employment has increased due to deregulation.

Figure 4 describes average ratios for the number of non-regular employees, including contract employees, versus all employees in our sampled firms and macro-level data from the Labour Force Survey by the Ministry of Internal Affairs and Communications. Both ratios trend upward from the 1980s; the ratio for the sampled firms greatly increased in the early 2000s. The worker dispatching law revised in 1999 allowed hiring of more dispatched workers. This could explain the trends in average age and seniority in our sample during the 2000s.

5-3. Capital vintage

Figure 5 shows that average capital vintage of our sampled firms increased from around 6.5 years in the late 1970s to 8 in the mid-1980s. Thereafter, as corporate fixed investment was encouraged, the vintage declined to around 6.5 years during the bubble era. Following the bubble's collapse in the early 1990s, the vintage of capital stock consistently increased while flow-based capital expenditures followed the pro-cyclical trend. The growth rate of investment continued to slow, and capital vintage reached approximately 11 years in 2008.

6. Estimation results

For estimating the basic form of Equation (8), we adopt the method of GMM estimation of dynamic panel models proposed by Arellano Bond (1991). The equation is transformed to the first-difference form as $\ln a_t = C + \gamma \ln w_t + \delta \ln v_t + \varepsilon$ (15), removing a time trend and time-invariant firm characteristics (fixed effects)[1], and $\ln a_{t-1}$ is included as an independent variable. According to Arellano and Bond (1991), we use $\ln a_{t-2}$, $\ln W_{t-2}$, and $\ln V_{t-2}$ as instrument variables.

Table 2 shows the estimation result of our full sample for all periods within

[1] In addition, industrial dummy variables are dropped because they have no significant effects on the dependent variable or show some collinearity.

FY 1977–2008. The estimated coefficient for average employee age is significantly positive, while that for average capital vintage is significantly negative. This means the TFP growth rate increases as average employee age rises, and the TFP growth rate decreases as capital vintage extends. These findings coincide with the hypothesis and empirical results of previous literature.

A similar significant relationship between average employee seniority and TFP growth appears in the table. In the full sample, changes in seniority have a similar positive effect on the productivity growth rate.

In terms of elasticity of changes in variables, it is estimated that the TFP growth rate rises about 0.5 percent as average employee age increases one percent.[2] TFP growth also rises about 0.13 percent as employees' average seniority increases one percent. On the other hand, TFP growth declines 0.04 percent as the vintage of capital increases one percent.

Next, we divide our sample into multiple groups according to employees' average age and seniority. In Table 3, the sample is divided into four age cohorts: <30, 30–40, 40–50, and >50 years. For the cohorts 30–40 and 40–50 years, the estimated coefficient for average age is significantly positive, and that for capital vintage is significantly negative. However, the results for employees <30 and >50 years indicate that average age has a positive but insignificant influence on productivity growth. This implies that employees <30 years had not accumulated job experience, knowledge, and skills sufficient to enhance productivity growth apart from increases in their labor input (such as hours worked). On the other hand, it could be more difficult for employees >50 to exercise their creativity in business, and their contribution from human capital to

[2] The elasticity is calculated assuming the overall average labor share in the full sample and the overall average age that rises by one percent.

productivity growth could diminish. Because we use data of average employee age, not detailed data for cohorts or individuals, the marginal effects of age on productivity growth are unclear. However, the trend of our results generally coincides with previous literature even though analytical approaches of previous studies differ from ours:[3] productivity peaks around age 40.

Table 3 also shows subsamples for three seniority cohorts: <10, 10–20, and >20 years. Among all three cohorts, coefficients for average seniority are significantly positive, although the coefficient for the >20 cohort does not have the expected sign. The seniority is positively correlated with human capital accumulation that contributes to the productivity growth, unless mobility and flexibility of mid-career labor market is considered.

Compared with average employee age, seniority has a consistent positive influence on productivity over time. Numbers of contract employees have recently grown rapidly, and labor mobility has increased. These are plausible reasons why average seniority of sampled firms has been nearly flat or slightly declining in recent years. If it is assumed that length of seniority reflects accumulated knowledge and skills unique to a firm, a positive correlation between seniority and productivity growth would weaken as labor mobility increases. This might decrease the size of the coefficient for seniority in FY 1993–2008.

In Table 4, the sample is divided into two groups corresponding to business cycles: FY 1977–1993 and FY 1993–2008. Concerning the estimation involving average age and capital vintage, all coefficients of independent variables are significant

[3] Previous studies observe a U-shaped curve in the distribution of TFP growth rates and employee ages, but they do not demonstrate significant negative effects of the older ages on the productivity growth from the panel analysis. Similarly, our results do not show such a significant negative effect, but they demonstrate that the positive effect is not significant.

with the expected signs. The coefficient for age in FY 1977–1993 is larger than that in FY 1993–2008. This suggests that time-dependent human capital accumulation had greater influence on productivity growth before Japan's bubble than afterward. The same relationship holds between higher seniority and productivity growth. In addition, the effect of capital vintage on productivity growth after FY 1993 is smaller than before. In general, it is said that the marginal effects of time-dependent endowments in labor and capital become smaller.

The final sample is divided into two industry groups: manufacturing and non-manufacturing. In both estimations, all variables have significant coefficients, and signs are as expected. However, the coefficients are larger for manufacturing than for non-manufacturing industries, suggesting that time-dependent accumulations of human capital—job experience, knowledge, and skills—could be more easily embodied in manufacturers' capital equipment than among non-manufacturing industries. It also implies that the negative effect of capital vintage on productivity growth is larger for manufacturing industries, because manufacturers' capital stock includes a large share of machinery that depreciates quickly, while non-manufactures' capital stock includes a large share of buildings that depreciates slowly.

7. Conclusion

The estimation results are summarized as follows. Overall, a firm's productivity growth increases as its employees' average age or seniority increases. However, the relationship is unclear once average employee age exceeds a certain level. The positive effect of Japanese employees' increasing age and seniority and the negative effect of older capital on Japanese productivity growth have been smaller since the

1990s. These effects are greater on productivity growth among manufacturers than non-manufacturers.

Due to an aging population and low fertility rate, the average employee age in Japan should continue to rise. Our empirical results suggest that the positive effect of time-dependent human capital accumulation on productivity growth would wane, and firms must enhance productivity without depending on employees simply accumulating knowledge and skills over time.

The recent increase in numbers of contract employees challenges management to maintain and enhance productivity. We find that the positive effect of seniority on productivity growth is weaker among employees with less seniority, i.e., <10 years. Deregulation of non-regular employees, including contract employees, since 1999 has enhanced the flexibility of the labor market. In the short run, this presents firms with the advantage of adjusting employment faster during recessions. In the long run, however, it could be more difficult for firms to maintain some skills embodied in their labor force, and that would tend to constrain productivity growth. Our empirical findings suggest that the recent seniority effect is smaller than before. If the ratio of non-regular employees continues to increase, problems such as intergenerational technology transfer could spread over multiple industries.

It is also claimed that the number of younger non-regular employees has increased. Our study implies that contract employees' non-firm-specific knowledge and skills have been more important and/or that firm-specific skills are maintained by rehiring regular employees as contract employees. However, this situation presents difficulties if the share of less mature, inexperienced, non-regular employees becomes excessive. In the long run, policies are needed to handle these problems of non-regular employees and productivity growth.

Apart from policy measures, as working population declines and it becomes more difficult for firms to hire a younger labor force, firms should not depend excessively on time-dependent accumulated human capital, which is often firm-specific. Firms need to enhance productivity by organizing employees' knowledge and skills and managing them efficiently.

In addition, since the marginal positive effects of human capital accumulation weaken over time among older employees, firms must deal with less flexibility in the labor force. It is increasingly important for management to make optimal use of employee innovation.

Moreover, the empirical results suggest that older vintages of capital significantly decrease productivity growth. Therefore, efficient and effective investment is important if firms are to maintain technological progress that leads to productivity growth. According to our empirical findings, productivity growth in non-manufacturing industries is less influenced by changes in quality of production factors over time than manufacturing industries, so strategic investment is the key to enhancing productivity in non-manufacturing industries.

To spur productivity growth, Japanese firms must organize and manage enhanced labor skills and knowledge, not simply depend on technology accumulated over time, and select and concentrate on efficient investment projects.

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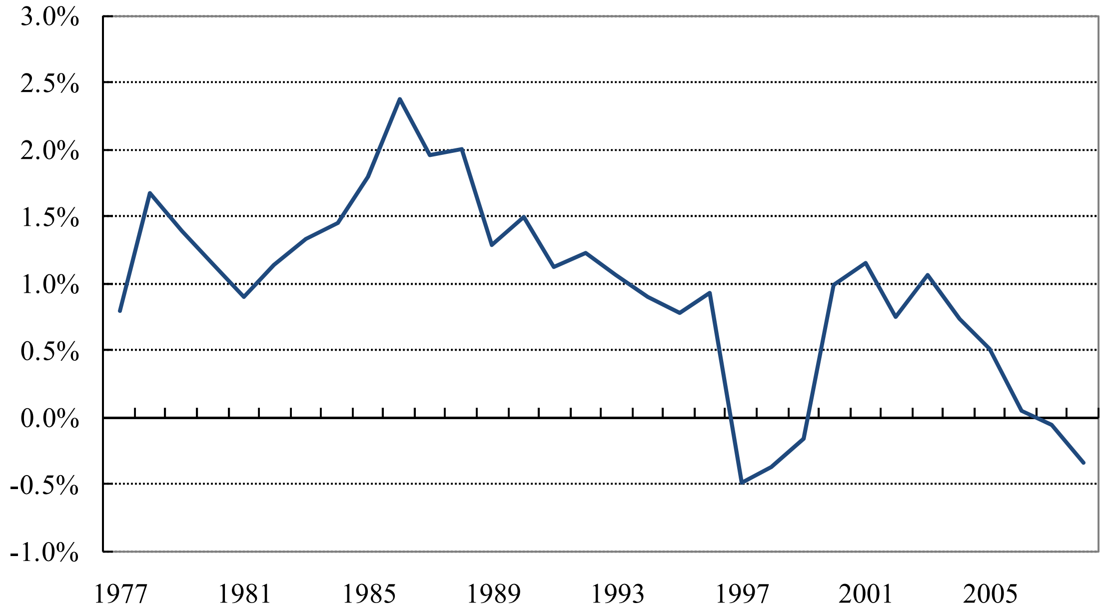

Figure 1: TFP growth rate, 3-year moving avg.
(Sample firms)

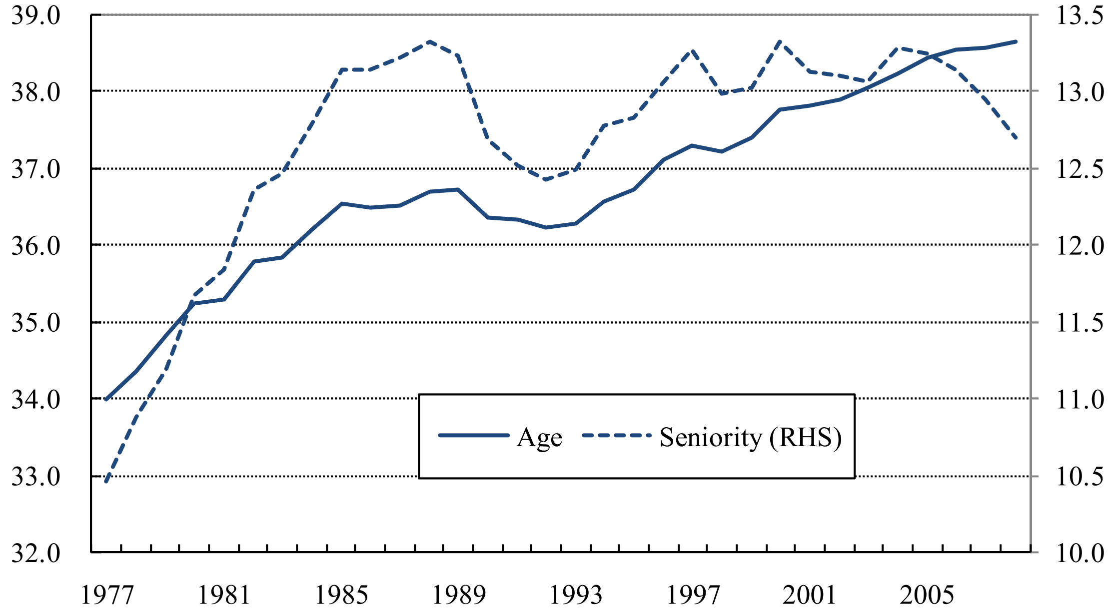

Figure 2: Average age and seniority of employees
(Sample firms, years)

Figure 3: Average age and seniority of employees
(Macro-level, years)

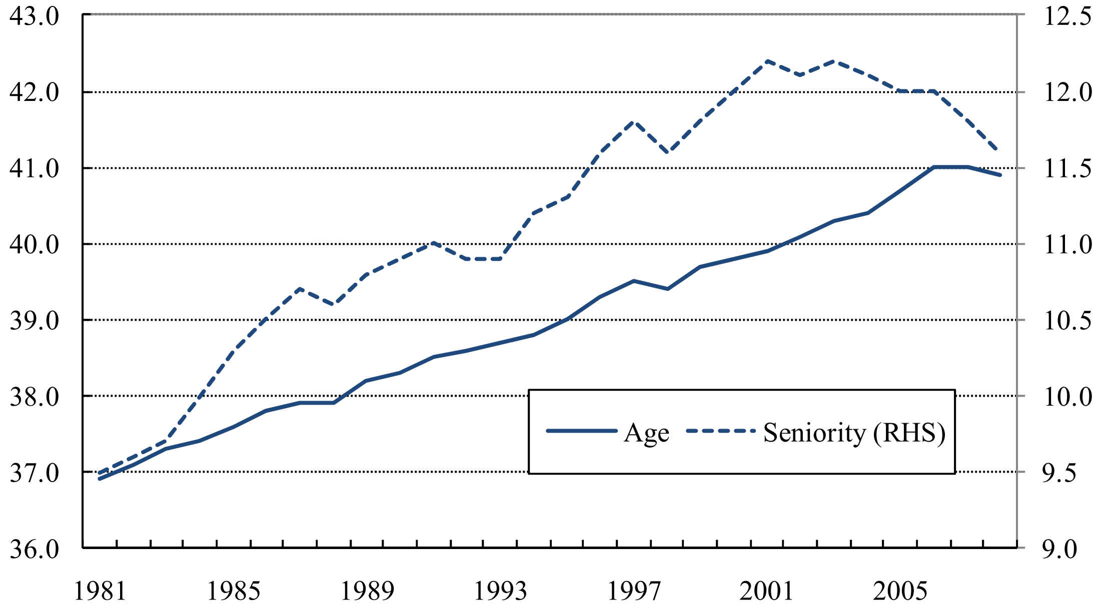

Figure 4: Non-regular employees ratio
(Sample firms & macro-level, percent)

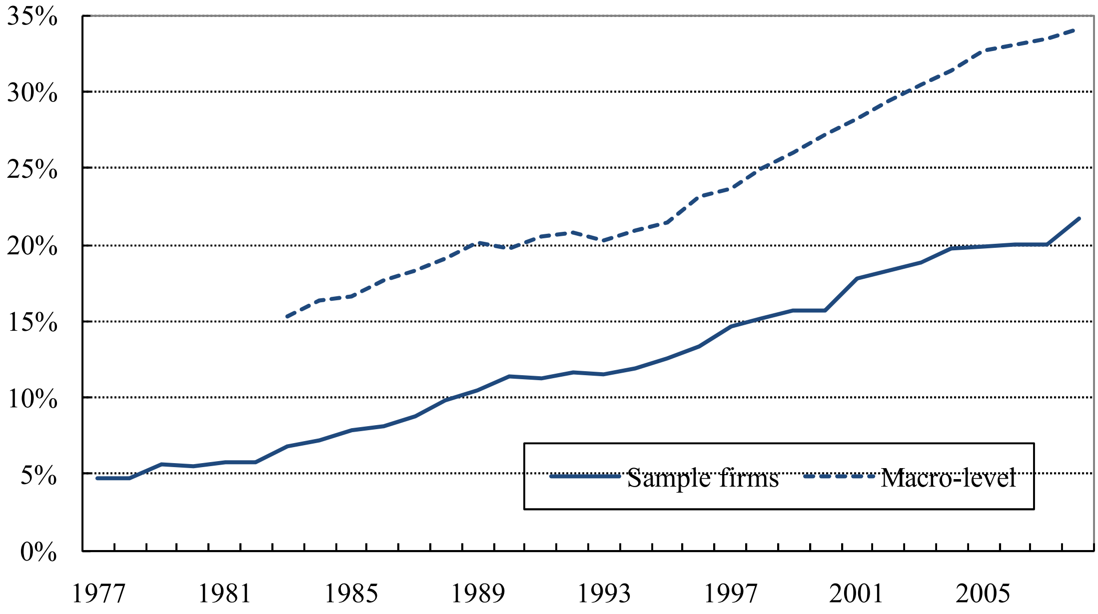

Figure 5: Average vintage of capital
(Sample firms, years)

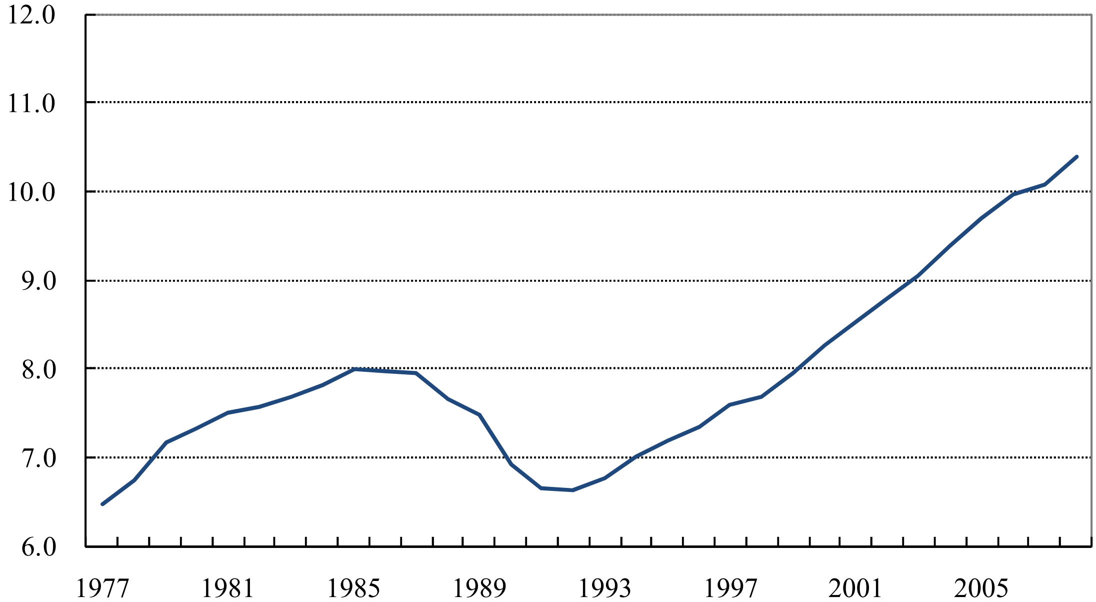

Table 1. Sample Mean Values of Variables

Year	Sample Firms	TFP Growth	Age	Seniority	Vintage
1977	603	0.8%	34.0	10.5	6.5
1978	660	2.5%	34.4	10.9	6.7
1979	662	0.8%	34.8	11.2	7.2
1980	708	0.1%	35.2	11.7	7.3
1981	717	1.8%	35.3	11.8	7.5
1982	712	1.6%	35.8	12.4	7.6
1983	750	0.7%	35.8	12.5	7.7
1984	762	2.1%	36.2	12.8	7.8
1985	829	2.6%	36.5	13.1	8.0
1986	793	2.4%	36.5	13.1	8.0
1987	810	0.9%	36.5	13.2	7.9
1988	863	2.7%	36.7	13.3	7.7
1989	997	0.3%	36.7	13.2	7.5
1990	1093	1.5%	36.4	12.7	6.9
1991	1176	1.6%	36.3	12.5	6.6
1992	1168	0.6%	36.2	12.4	6.6
1993	1222	1.0%	36.3	12.5	6.8
1994	1264	1.1%	36.6	12.8	7.0
1995	1343	0.2%	36.7	12.8	7.2
1996	1477	1.4%	37.1	13.1	7.3
1997	1359	-3.1%	37.3	13.3	7.6
1998	1518	0.6%	37.2	13.0	7.7
1999	1442	2.1%	37.4	13.0	7.9
2000	1462	0.3%	37.8	13.3	8.3
2001	1437	1.1%	37.8	13.1	8.5
2002	1521	0.9%	37.9	13.1	8.8
2003	1537	1.3%	38.0	13.1	9.0
2004	1506	0.1%	38.2	13.3	9.4
2005	1473	0.2%	38.4	13.2	9.7
2006	1466	-0.1%	38.5	13.1	10.0
2007	1439	-0.2%	38.6	12.9	10.1
2008	1137	-0.7%	38.6	12.7	10.4

Table 2. Estimation Results (1)

Period	Industry	Age/Seniority Class	Age	Seniority	Vintage	Lagged	cons
All	All	All	1.032 ***		-0.076 ***	0.210 ***	0.003 ***
			(0.043)		(0.007)	(0.008)	(0.000)
All	All	All		0.278 ***	-0.064 ***	0.252 ***	0.003 ***
				(0.012)	(0.007)	(0.007)	(0.000)

Note: *** denotes significant at 1% level, ** at 5% level, and * at 10% level.

Table 3. Estimation Results (2)

Period	Industry	Age/Seniority Class	Age	Seniority	Vintage	Lagged	cons
All	All	<30	0.016		0.014	0.055 **	0.021 ***
			(0.103)		(0.019)	(0.022)	(0.002)
		30-40	0.900 ***		-0.068 ***	0.224 ***	0.005 ***
			(0.049)		(0.009)	(0.010)	(0.000)
		40-50	0.781 ***		-0.044 ***	0.168 ***	-0.004 ***
			(0.082)		(0.013)	(0.013)	(0.000)
		>50	0.174		0.028	0.226 ***	0.006
			(0.307)		(0.031)	(0.047)	(0.006)
All	All	<10		0.127 ***	-0.042 ***	0.105 ***	0.017 ***
				(0.018)	(0.011)	(0.013)	(0.001)
		10-20		0.283 ***	-0.056 ***	0.284 ***	0.000 *
				(0.016)	(0.009)	(0.010)	(0.000)
		>20		0.236 ***	0.041 *	0.147 ***	0.000 *
				(0.049)	(0.025)	(0.025)	(0.000)

Note: *** denotes significant at 1% level, ** at 5% level, and * at 10% level.

Table 4. Estimation Results (3)

Period	Industry	Age/Seniority Class	Age		Seniority		Vintage		Lagged		cons	
1977-1993	All	All	1.201	***			-0.071	***	0.324	***	-0.001	**
			(0.070)				(0.016)		(0.014)		(0.000)	
1993-2008			0.507	***			-0.030	***	0.128	***	0.006	***
			(0.058)				(0.009)		(0.009)		(0.000)	
1977-1993	All	All			0.396	***	-0.149	***	0.357	***	-0.001	*
					(0.023)		(0.021)		(0.014)		(0.000)	
1993-2008					0.127	***	-0.014	*	0.147	***	0.006	***
					(0.016)		(0.008)		(0.009)		(0.000)	

Note: *** denotes significant at 1% level, ** at 5% level, and * at 10% level.

Table 5. Estimation Results (4)

Period	Industry	Age/Seniority Class	Age		Seniority		Vintage		Lagged		cons	
All	Manufacturing	All	1.115	***			-0.062	***	0.239	***	-0.002	***
			(0.056)				(0.011)		(0.009)		(0.000)	
	Non-manufacturing		0.741	***			-0.065	***	0.143	***	0.008	***
			(0.056)				(0.009)		(0.011)		(0.000)	
All	Manufacturing	All			0.360	***	-0.072	***	0.253	***	-0.001	***
					(0.018)		(0.011)		(0.009)		(0.000)	
	Non-manufacturing				0.165	***	-0.041	***	0.176	***	0.008	***
					(0.015)		(0.008)		(0.011)		(0.000)	

Note: *** denotes significant at 1% level, ** at 5% level, and * at 10% level.