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Macro Dynamics and Labor-Saving Innovation: US vs. Japan

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MACRO DYNAMICS AND LABOR-SAVING INNOVATION: US VS. JAPAN

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Abstract

This article deals with the empirical analyses of the growth for the United States and Japan from 1970 to 2005. Following our analysis in “Quantity or Quality: The Impact of Labor-saving Innovation on US and Japanese Growth Rates, 1960–2004” (March 2007), we applied the same method to a different data series in order to confirm our previous findings. As with the previous paper, the results shown in this paper support our view that Japan’s declining population can be compensated for by additional quality improvement of the existing labor force.

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1. Introduction

1. The contrast between the population changes in the United States (US) and Japan has recently become more distinct: Japanese population growth has slowed and is expected to continuously decline, while the population in the US reached 3 billion in 2006 and is expected to continue to expand due to subsequent immigration.

2. A recent study by Sato and Morita (2007), (hereinafter "previous paper") attempted to explain whether population changes severely affect economic growth. Extracting the "labor-saving innovation" from the economic growth led to the conclusion that it is not the "quantity," but "quality" of growth that matters. By dividing conventional total factor productivity (TFP) into "labor efficiency" and "capital efficiency," we pointed out that improved labor efficiency would compensate for the shrinking of the labor force in the near future.

3. We begin by reviewing the previous paper's key points through several excerpts.

> (1) The novel contribution of [the] paper, accruing from those of Sato and Ramachandran (1987) and Sato (1970), is that we analyze not only how the TFP has increased or decreased, but also analyze separately the efficiency of capital and the efficiency of labor. The result of this analysis will allow us to make a policy proposal that in order to raise TFP growth, we have to consider how and how much the efficiency of either or both of capital and labor must be increased. Merely knowing TFP is generally considered sufficient for economic analysis. However, our comparison of the two countries will show that because each country's composition of TFP is fundamentally different, knowing only total efficiency does not suffice. (p. 5)
>
> (2) In order to analyze the efficiency of capital and labor, we need to know the production function or the elasticity of (factor) substitution, which is the summary index of production function. In general terms, elasticity of substitution is a technology index. As Sato

and Beckmann (1968) and Rose (1968) discovered, elasticity of substitution plays a critical role in the analysis of the efficiency of each input factor. Our growth analysis uses the concept of elasticity of substitution and applies the concept to the data of the two countries. (pp. 5–6)

(3) We contrast the difference in the economic structures of Japan and the United States (US) by comparing the rate of factor-augmenting technical progress. Our investigation reveals that whether or not the capital and labor are efficiently used has a strong impact on economic growth. (p. 6)

(4) After the theoretical explanations …, we conducted the estimation using both countries' macro data. The data were taken from 1960 to 2004 and then divided into two periods: Period I (1960–1989) and Period II (1990–2004). Period II for Japan includes the lost decade, while that for the United States is often described as the new economy. The analysis on Period II was particularly effective in highlighting the characteristics of each economy. (p. 39)

(5) Concisely stated, the source of Japan's economic growth was quality improvement—rather than quantity increase—of population and labor force. In contrast, for the US, what supported its economic growth was quantity increase—rather than quality improvement—of population and labor force. (p. 39)

(6) Overall, we discovered that Japan's high growth in Period I was not so much due to the increase of the population, but to improved labor efficiency. Japan's stagnation, too, was not explained by the population decrease or shortage of effective demands, but by the slowdown of the improvement of labor efficiency.… Broadly defined innovation has been and will be the engine of the development and growth of the Japanese economy. Thus, Japan does not have to be pessimistic about the declining birth rate. (p. 40)

(7) We test the equilibrium condition … to determine each economy's performance.… In Japan, [the actual value of output per

> effective labor] is much higher than [the equilibrium value of output per effective labor]. Japanese capital stock has grown very fast, but it was not utilized to increase the economy's total income (GDP). In Period I, especially before the first oil crisis in 1973, an extremely high rate of investment accumulated Japanese physical stock at a very rapid pace, which supported the country's miraculous economic growth.… As for the US, [the actual value of output per effective labor] is very close to [the equilibrium value of output per effective labor] …, and the actual output in [each period] was just below the optimal output …. The growth rate of effective capital and effective labor, and the economic growth rate were balanced in both Period I and Period II. (p. 33)

4. In this paper, we apply the same methods to more specific data on the US and Japan in order to confirm the characteristics of the countries' macro-dynamics described in the previous paper. This time, the production series Y is represented by net domestic product (NDP) instead of gross domestic product (GDP), which was used in the previous paper. This change allows us to more directly find the income shares of capital and labor, and enables us to omit the effect of "consumption of fixed capital," which amounts to as much as about 20 percent of Japan's GDP and about 10 percent of US GDP. We selected strictly "private-nonagricultural" sectors for all the series, including Japan's net stock. Because of data constraints, we use data from a slightly shorter range of years (1970–2005).

2. The Data

5. The major differences between the data used here and that used in the previous paper are:

(1) as a series of an economy's output, Y, the real net domestic product, is taken instead of the real gross domestic product;

(2) the public sector and the agricultural sector are excluded from all the series; and
(3) instead of OECD data, each country's official data are carefully selected and adjusted to improve comparability between the US and Japan.

We implemented the first change because we needed a more income-oriented value of the shares of capital and labor—the estimation of biased technical progress depends largely upon them. In addition, omitting "consumption of fixed capital" helped us to observe how new value is added to each economy. Due to these changes in the data, mostly influenced by the first change, the series Y of each country is generally lower than that in the previous paper, as is depicted in Figure 1a (Japan) and Figure 1b (US).

Figure 1a. Comparison of the Series *Y*: Japan

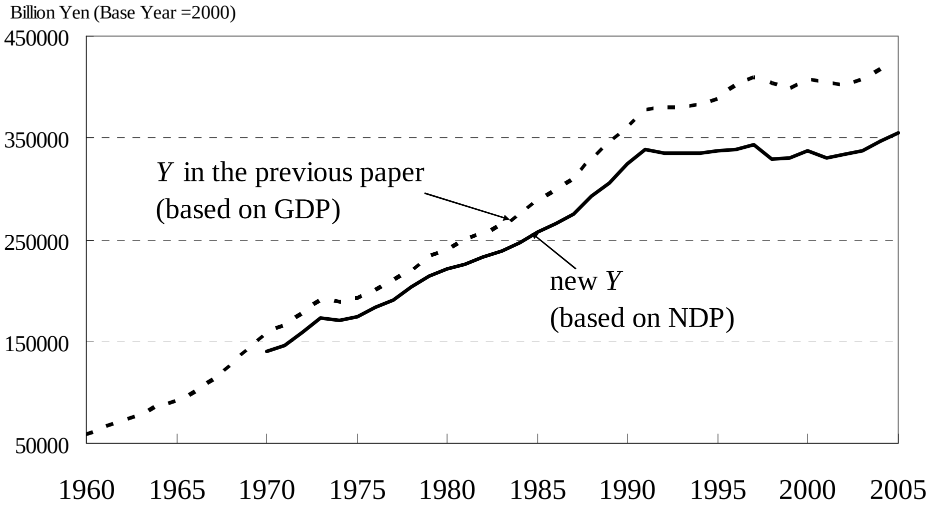
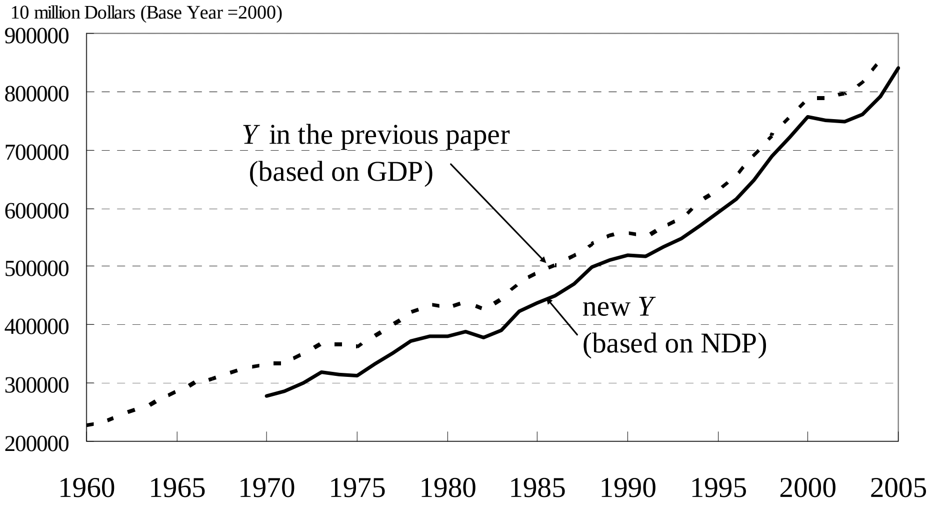


Figure 1b. Comparison of the Series *Y*: US



The average relative shares of capital and labor differed considerably as well, and the labor share is smaller here. For example, take average labor share α after 1990. In Japan, it was formerly 75.17%, but in the new series, it is calculated as 72.07%. In the US, it also declined from 67.61% to 61.97%. The new series describe more accurately how the newly added income each year is distributed to capital and labor. Precise comparison is shown in Table 1a (Japan) and Table 1b (US).

Table 1. Average Relative Share of Input Factors

a. Japan

	New Data			Previous Data		
	1970-2005	1970-1989	1990-2005	**1960-2004**	1960-1989	1990-2004
Average Relative Share of Capital α	**31.54%**	34.42%	27.93%	**29.34%**	31.60%	24.82%
Average Relative Share of Labor β	**68.46%**	65.58%	72.07%	**70.66%**	68.40%	75.17%
Total	**100%**	100%	100%	**100%**	100%	100%

b. US

	New Data			Previous Data		
	1970-2005	1970-1989	1990-2005	**1970-2005**	1970-1989	1990-2005
Average Relative Share of Capital α	**37.62%**	37.30%	38.03%	**31.33%**	30.80%	32.39%
Average Relative Share of Labor β	**62.38%**	62.70%	61.97%	**68.67%**	69.20%	67.61%
Total	**100%**	100%	100%	**100%**	100%	100%

Notes: α and β are calculated as period averages of $\alpha(t) = r(t)K(t)/Y(t)$ and $\beta(t) = w(t)L(t)/Y(t)$.

3. Neutrality Tests

6. Before estimating the production function using the new data, we have to confirm whether the selected series in both countries are appropriate for the analysis of the biased technical change.

The production function with biased technical change can be expressed as equation (1), in an aggregative economy under the neo-classical constant returns to scale technology, where at each year *t*, one output ($Y(t)$) is produced by two factor inputs, capital ($K(t)$) and labor ($L(t)$).

$$Y(t) = F\left[A(t)K(t),\, B(t)L(t)\right], \tag{1}$$

where $A(t)$ and $B(t)$ are efficiencies of capital and labor, respectively.

We followed the method used in the previous paper and conducted two tests: one on whether the elasticity of factor substitution is unity, and another on whether the production function is Hicks-neutral. The results are shown in Tables 2 and 3.

Table 2. Average Elasticity of Substitution Method Results

	Japan		United States	
$\bar{R}(z/w)$	**0.7036**	(1.1309)	**0.9467**	(1.2583)
$\bar{R}(y/r)$	**0.6691**	(0.7857)	**0.5688**	(0.9303)
$\bar{R}(x/\omega)$	**0.5643**	(0.8060)	**0.2544**	(1.2390)

Notes: Standard Deviation is in parentheses. Extreme 1–3 data are excluded in each series.

Table 3. The Hicks-Neutrality Test Results

	Japan		United States	
Average $\dot{T}/T$	0.74%		1.07%	
α	0.3154		0.3762	
β	0.6846		0.6238	
Equation (2) Regression Results	$\frac{\dot{w}}{w} = -0.0008 \quad +0.6859 \frac{\dot{k}}{k}$ (−0.21) (11.18) Adj R^2=0.7849		$\frac{\dot{w}}{w} = 0.0166 \quad -0.1103 \frac{\dot{k}}{k}$ (6.24) (−1.00) Adj R^2=-0.0003	
	Estimated $\dot{T}/T$	-0.08%	Estimated $\dot{T}/T$	1.66%
	Estimated σ	0.4598	Estimated σ	-3.4107
Equation (3) Regression Results	$\frac{\dot{r}}{r} = 0.0160 \quad -1.044 \frac{\dot{k}}{k}$ (1.22) (−4.97) Adj R^2=0.4109		$\frac{\dot{r}}{r} = 0.0245 \quad -1.3241 \frac{\dot{k}}{k}$ (3.87) (−5.02) Adj R^2=0.4156	
	Estimated $\dot{T}/T$	1.60%	Estimated $\dot{T}/T$	2.45%
	Estimated σ	0.6557	Estimated σ	0.4711

In Table 2, if the three variables converge to one, i.e.,

$$\bar{R}(z/w) = \bar{R}(y/r) = \bar{R}(x/\omega) = 1,$$

where r = return to capital, w = wage rate of labor,

$x = L/K$, $y = Y/K$, $z = Y/L$, $\omega = r / w$, and $R(y/r) = (\dot{y}/y)/(\dot{r}/r)$,

the elasticity of factor substitution σ in equation (1) is on average equal to unity[1]. The results show that the three variables are not equal, and not even close to unity. Hence, the production functions cannot be Cobb-Douglas type.

Table 3 presents the results of the following regression:

$$\frac{\dot{w}}{w} = \frac{\dot{T}}{T} + \frac{\alpha}{\sigma}\frac{\dot{k}}{k} \qquad (2)$$

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[1] The reason is explained in Sato and Morita (2007).

$$\frac{\dot{r}}{r} = \frac{\dot{T}}{T} - \frac{\beta}{\sigma}\frac{\dot{k}}{k}. \tag{3}$$

T is the index of technical change in the production function with Hicks-neutral technical change ($Y(t) = T(t)F\left[K(t), L(t)\right]$), which is equivalent to TFP. If the relationships of equations (2) and (3) simultaneously hold, and $\dot{T}/T$ in the two equations are equal in each country, then the country's production function is Hicks-neutral. The results suggest, however, that the relationships hardly hold because the estimated variables are not significant, and the estimated two $\dot{T}/T$ differ greatly in each country. This leads to our judgment that the technical change in each country is not Hicks-neutral, and it should be estimated with biased technical change.

4. Estimates of Production Functions

4.1 Method

7. In accordance with the detailed explanation in Sato and Morita (2007), we take four steps in the estimation of the production functions with biased technical change for Japan and the US.

Step 1: Estimation of Hicks-neutral technical progress

First, we calculate $\dot{T}/T$ in each year *t*, using

$$\frac{\dot{T}(t)}{T(t)} = \frac{\dot{z}(t)}{z(t)} - \alpha(t)\frac{\dot{k}(t)}{k(t)}, \tag{4}$$

where $z = Y/L, \quad k = K/L$.

Step 2: Deriving average elasticity of substitution σ^N

Next, we estimate the average elasticity of substitution. In order to analyze the efficiency of capital and labor, we need to know the elasticity of (factor) substitution, which is the summary index of the production function. As Sato and Beckmann (1968) and Rose (1968) discovered, the elasticity of substitution plays a critical role in the analysis of the efficiency of each input factor. Here, we estimate it under the assumption of Hicks-neutral technical progress, σ^N , by the following definition:

$$\sigma^N(t) = \frac{d\left(\frac{K(t)}{L(t)}\right)\Big/\frac{K(t)}{L(t)}}{d\left(\frac{w(t)}{r(t)}\right)\Big/\left(\frac{w(t)}{r(t)}\right)} = \frac{\frac{\dot{K}(t)}{K(t)} - \frac{\dot{L}(t)}{L(t)}}{\frac{\dot{w}(t)}{w(t)} - \frac{\dot{r}(t)}{r(t)}}.$$

Step 3: Estimation of CES functions with Hicks-neutral technical change

Our data contains no trends of σ correlating with the values *k* or time *t*. Thus, we assume the constant elasticity of substitution (CES) production function and determine how σ^N fits the actual data. Before we directly estimate the production function with biased technical change, we estimate the function with Hicks-neutral technical change so that we can compare the fittedness of the two kinds of estimated production functions.

With Hicks-neutral technical change, the CES function should take the form of

$$Y^N(t) = T(t)\left[\alpha K(t)^{-\rho^N} + \beta L(t)^{-\rho^N}\right]^{-1/\rho^N}, \tag{5}$$

where σ^N =1/(1+ρ^N). *T*(*t*) is assumed to grow at a constant rate during a period, which is given as the average of each $\dot{T}(t)/T(t)$ estimated in equation (4). We also assume the income shares of factors α and β are constant throughout the period, and we apply period averages of observed α and β.

Step 4: Estimation of CES functions with biased technical change

Finally, we estimate the CES function with biased technical change. Sato (1970) argued that theoretically, the elasticity of substitution of biased technical change has to be stated as equation (6)

$$\sigma^B = \frac{d\left(\frac{AK}{BL}\right)\Big/\frac{AK}{BL}}{d\left(\frac{\partial F/\partial BL}{\partial F/\partial AK}\right)\Big/\frac{\partial F/\partial BL}{\partial F/\partial AK}}, \tag{6}$$

because when technical progress is nonneutral, the value of the elasticity itself is influenced by the efficiencies of capital and labor. However, because we cannot observe σ^B

directly, we use σ^N as a proxy of σ^B, and we substitute the estimates of elasticity σ^N into σ in equations (7) and (8) to derive $\dot{A}/A$ and $\dot{B}/B$ [2],

$$\frac{\dot{A}(t)}{A(t)} = \frac{\sigma(t)\dfrac{\dot{r}(t)}{r(t)} - \left(\dfrac{\dot{Y}(t)}{Y(t)} - \dfrac{\dot{K}(t)}{K(t)}\right)}{\sigma(t)-1} \tag{7}$$

$$\frac{\dot{B}(t)}{B(t)} = \frac{\sigma(t)\dfrac{\dot{w}(t)}{w(t)} - \left(\dfrac{\dot{Y}(t)}{Y(t)} - \dfrac{\dot{L}(t)}{L(t)}\right)}{\sigma(t)-1}. \tag{8}$$

Then, the production function becomes

$$Y^B(t) = \left[\alpha\left(A(t)K(t)\right)^{-\rho^N} + \beta\left(B(t)L(t)\right)^{-\rho^N}\right]^{-1/\rho^N}. \tag{9}$$

Estimated $Y^B(t)$ summarizes our model. It represents both the form of the production function and the biasedness of technical change.

4.2 Simulation Results

8. In this subsection, we present the estimated values of actual Y, Y^N and Y^B. In Figure 2 (Japan) and Figure 3 (US), CES production functions with Hicks-neutral technical change Y^N are plotted with thick gray lines. CES production functions with biased technical change Y^B are shown by thin lines with markers.

Estimated data from 1970 to 2005 are shown in Panel 1 of each Figure, and in Panel 2, the data are divided into two at the year 1990, so that Y^N and Y^B in 1990 start from the actual Y in the year. Generally, Y^N deviates from actual Y, and Y^B fit better than do Y^N. This supports our view that the economies of Japan and the US both experienced biased technical growth. It suggests that estimation of TFP does not suffice to diagnose economic performance or to prescribe any policy for either of these countries.

We should note one point here. In Figure 2, Panel 2, the Y^N and Y^B in period 1970–1989 seem to be very close. One may conjecture that this similarity occurs because

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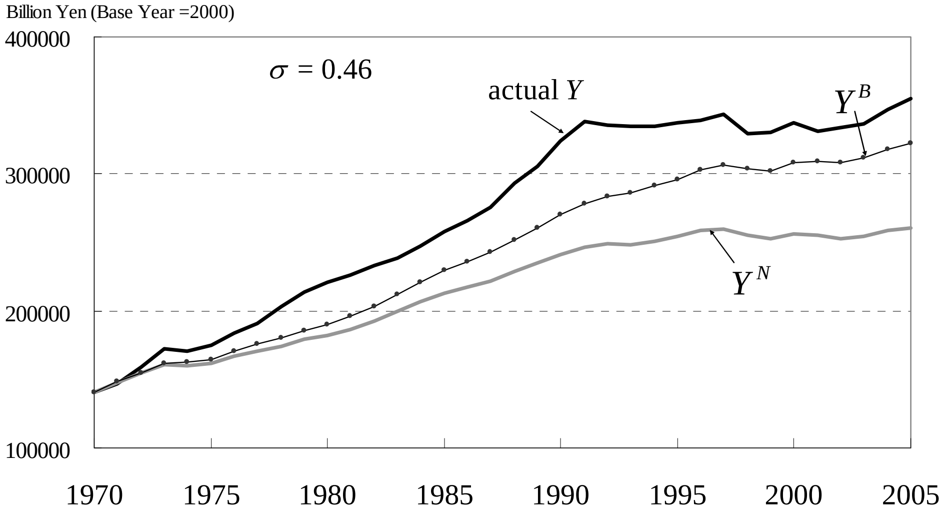
[2] Equations (7) and (8) are derived in Sato (1970).

$\dot{A}/A \simeq \dot{B}/B \simeq \dot{T}/T$. Actually, though, as shown in the next subsection, estimated capital efficiency growth $\dot{A}/A$ was negative, and labor efficiency growth $\dot{B}/B$ was positive, and was much larger than $\dot{T}/T$. In this case Y^N and Y^B coincidentally appeared to be close.

Figure 2. Estimated Output of Japan

Panel 1. 1970–2005



Panel 2. 1970–1989 and 1990–2005

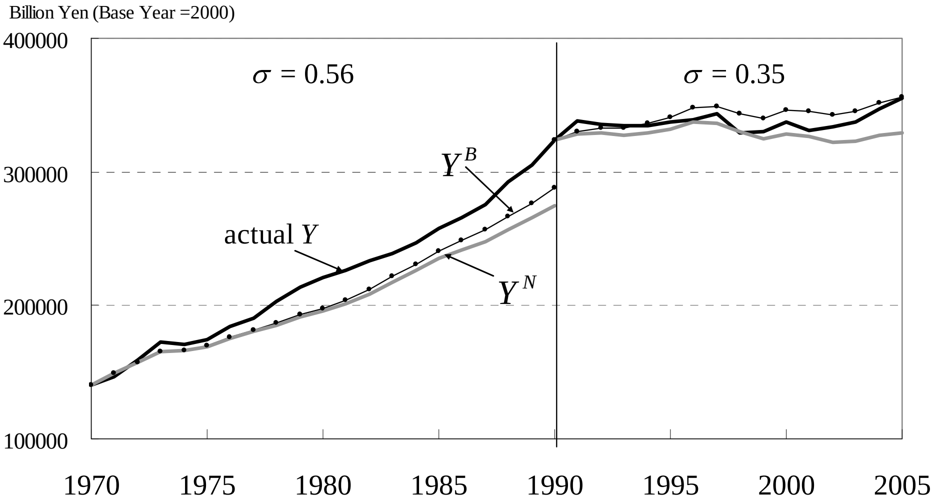
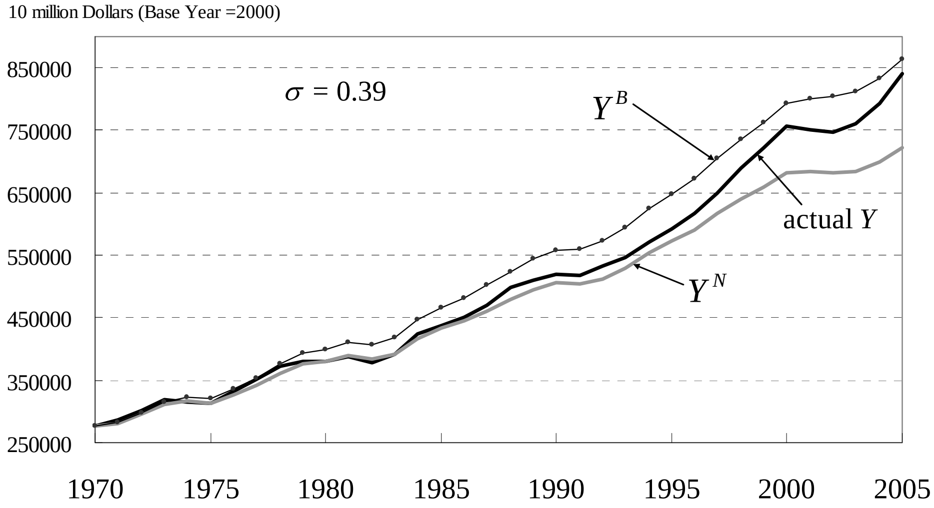
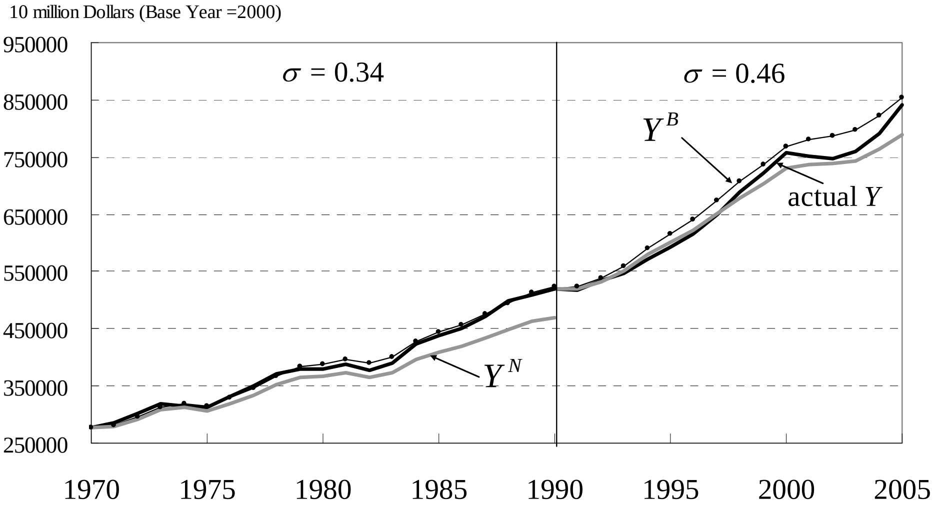


Figure 3. Estimated Output of the United States

Panel 1. 1970–2005



Panel 2. 1970–1989 and 1990–2005



4.3 Biased Technical Change of Japan and the United States

9. During the estimation process, in Step 1, we get some important values that explain economic dynamics of both countries. Table 4 lists the period average values for some of the variables.

Table 4. Growth Rate of Hicks-Neutral Technical Change and Other Factors

a. Japan

		New Data			Previous Data		
		1970-2005	1970-1989	1990-2005	**1960-2004**	1960-1989	1990-2004
Growth Rate of Output	$\dot{Y}/Y$	**2.72%**	4.20%	0.97%	**4.65%**	6.35%	1.03%
Growth Rate of Hicks Neutral Technical Change	$\dot{T}/T$	**0.74%**	0.99%	0.44%	**2.13%**	2.91%	0.45%
Growth Rate of Capital	$\dot{K}/K$	**5.15%**	7.45%	2.41%	**7.32%**	9.25%	3.18%
Growth Rate of Labor	$\dot{L}/L$	**0.35%**	0.86%	-0.27%	**0.28%**	0.56%	-0.31%
Growth Rate of Output Per Labor	$\dot{z}/z$	**2.36%**	3.31%	1.23%	**4.35%**	5.76%	1.34%

b. US

		New Data			Previous Data		
		1970-2005	1970-1989	1990-2005	**1960-2004**	1960-1989	1990-2004
Growth Rate of Output	$\dot{Y}/Y$	**3.25%**	3.29%	3.20%	**3.08%**	3.05%	3.13%
Growth Rate of Hicks Neutral Technical Change	$\dot{T}/T$	**1.07%**	0.76%	1.44%	**1.07%**	0.90%	1.43%
Growth Rate of Capital	$\dot{K}/K$	**3.11%**	3.55%	2.59%	**3.31%**	3.58%	2.72%
Growth Rate of Labor	$\dot{L}/L$	**1.58%**	1.88%	1.23%	**1.39%**	1.49%	1.19%
Growth Rate of Output Per Labor	$\dot{z}/z$	**1.64%**	1.38%	1.95%	**1.66%**	1.54%	1.92%

The table compares the new data with those in the previous paper, so we can observe not only the periodic change but also the effect of excluding “consumption of fixed capital” and of strictly selecting private-nonfarm sector.

In Japan’s case, when we compare the new and previous data, the exclusion of the high growth decade (1960s) due to data constraints strongly affected the growth rate of output and other variables. Nevertheless, in comparisons from the 1990s on, the differences clearly show the effect of the change of data source. From the 1990s on, capital growth in the new data is 2.4% and 0.77 percentage point lower than that in the previous data. This explains how the consumption of fixed capital affected the Japanese economy.

Among those variables, there is a well-known and important relationship

$$\frac{\dot{Y}(t)}{Y(t)}=\frac{\dot{T}(t)}{T(t)}+\alpha(t)\frac{\dot{K}(t)}{K(t)}+\beta(t)\frac{\dot{L}(t)}{L(t)}, \tag{10}$$

which is equivalent to equation (4). Table 5 shows the period average values of each term in equation (10).

Table 5. Relative Contributions to Economic Growth by Technical Change and Factor Inputs

a. Japan

	New Data			Previous Data		
	1970-2005	1970-1989	1990-2005	**1960-2004**	1960-1989	1990-2004
$\frac{\dot{T}}{T}\Big/\frac{\dot{Y}}{Y}$	**27.11%**	23.55%	45.35%	**45.76%**	45.87%	44.30%
$\left(\alpha\frac{\dot{K}}{K}\right)\Big/\frac{\dot{Y}}{Y}$	**59.64%**	61.13%	69.32%	**46.14%**	46.05%	76.90%
$\left(\beta\frac{\dot{L}}{L}\right)\Big/\frac{\dot{Y}}{Y}$	**8.74%**	13.49%	-19.66%	**4.30%**	6.03%	-22.60%
Statistical Adjustment	**4.52%**	1.84%	4.99%	**3.80%**	2.05%	1.41%
Total	**100%**	100%	100%	**100%**	100%	100%

b. US

	New Data			Previous Data		
	1970-2005	1970-1989	1990-2005	**1960-2004**	1960-1989	1990-2004
$\frac{\dot{T}}{T}\Big/\frac{\dot{Y}}{Y}$	**32.87%**	23.09%	44.82%	**34.80%**	29.58%	45.69%
$\left(\alpha\frac{\dot{K}}{K}\right)\Big/\frac{\dot{Y}}{Y}$	**36.02%**	40.20%	30.81%	**33.65%**	36.11%	28.15%
$\left(\beta\frac{\dot{L}}{L}\right)\Big/\frac{\dot{Y}}{Y}$	**30.34%**	35.82%	23.71%	**31.09%**	33.73%	25.71%
Statistical Adjustment	**0.77%**	0.90%	0.65%	**0.46%**	0.58%	0.45%
Total	**100%**	100%	100%	**100%**	100%	100%

Notes: To apply actual data to the theory, we have to approximate differentiation by difference. Thus the weighted sum of the increase of each factor is not equal to the growth rate. We show such discrepancy as "Statistical Adjustment"

In Japan, capital ($\alpha\cdot\left(\dot{K}/K\right)$) contributed most to the economic growth. Capital investment, though excluding the consumption of fixed capital, still supported about 70 percent of economic growth during 1990–2005. In this period, capital and technical change compensated for the decline of labor ($\beta\cdot\left(\dot{L}/L\right)$).

In the US, the three terms contributed almost evenly to the growth on average. In the period 1990–2005, the TFP growth rate (1.44% per annum) explains about 45% of the growth, which suggests productivity improvement during the period.

10. Once σ is determined in Step 3, the growth rates of capital and labor efficiencies can be estimated in Step 4. The results are shown in Table 6. In both countries $\sigma < 1$ and $\dot{A}/A < \dot{B}/B$, so both countries are experiencing what Hicks (1932) originally defined as “labor-saving innovation[3].”

We should also mention here that T, A, and B are related as follows:

$$\frac{\dot{T}(t)}{T(t)} \equiv \alpha \frac{\dot{A}(t)}{A(t)} + \beta \frac{\dot{B}(t)}{B(t)}. \tag{11}$$

This is a simplified version of equation (13) in Sato and Morita (2007). The values of each item in equation (11) are presented in Table 7.

Table 6. Growth Rate of Biased Technical Change

a. Japan

		New Data			Previous Data		
		1970-2005	1970-1989	1990-2005	**1960-2004**	1960-1989	1990-2004
Growth Rate of Hicks Neutral Technical Change	$\dot{T}/T$	**0.74%**	0.99%	0.44%	**2.13%**	2.91%	0.45%
Estimated Elastisity of Substitution	σ_{AVG}^{N}	**0.46**	0.56	0.35	**0.57**	0.63	0.50
Growth Rate of Capital Efficiency	$\dot{A}/A$	**- 1.24%**	-1.04%	-0.93%	**-1.61%**	-1.63%	-1.36%
Growth Rate of Labor Efficiency	$\dot{B}/B$	**1.65%**	1.77%	1.00%	**3.86%**	5.11%	1.01%

b. US

		New Data			Previous Data		
		1970-2005	1970-1989	1990-2005	**1960-2004**	1960-1989	1990-2004
Growth Rate of Hicks Neutral Technical Change	$\dot{T}/T$	**1.07%**	0.76%	1.44%	**1.07%**	0.90%	1.43%
Estimated Elastisity of Substitution	σ_{AVG}^{N}	**0.39**	0.34	0.46	**0.46**	0.51	0.38
Growth Rate of Capital Efficiency	$\dot{A}/A$	**-0.04%**	-0.30%	0.20%	**-0.41%**	-0.59%	0.08%
Growth Rate of Labor Efficiency	$\dot{B}/B$	**1.74%**	1.40%	2.18%	**1.74%**	1.56%	1.97%

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[3] Definition of the labor-saving innovation also appears in Sato and Morita (2007).

Table 7. Relative Contributions to Hicks-Neutral Technical Change by Biased Technical Change

a. Japan

	New Data			Previous Data		
	1970-2005	1970-1989	1990-2005	**1960-2004**	1960-1989	1990-2004
$\left(\alpha\frac{\dot{A}}{A}\right)\Big/\frac{\dot{T}}{T}$	**-53.16%**	-36.33%	-59.03%	**-22.18%**	-17.67%	-74.09%
$\left(\beta\frac{\dot{B}}{B}\right)\Big/\frac{\dot{T}}{T}$	**153.48%**	117.29%	164.11%	**128.14%**	119.97%	167.09%
Statistical Adjustment	**-0.32%**	19.04%	-5.08%	**-5.95%**	-2.30%	7.00%
Total	**100%**	100%	100%	**100%**	100%	100%

b. US

	New Data			Previous Data		
	1970-2005	1970-1989	1990-2005	**1960-2004**	1960-1989	1990-2004
$\left(\alpha\frac{\dot{A}}{A}\right)\Big/\frac{\dot{T}}{T}$	**-1.33%**	-14.74%	5.22%	**-11.96%**	-20.18%	1.86%
$\left(\beta\frac{\dot{B}}{B}\right)\Big/\frac{\dot{T}}{T}$	**101.32%**	115.74%	94.14%	**111.44%**	119.80%	92.95%
Statistical Adjustment	**0.01%**	-1.00%	0.64%	**0.52%**	0.38%	5.19%
Total	**100%**	100%	100%	**100%**	100%	100%

Notes: See the notes of Table 5.

In Japan, the results in the previous paper showed the $\dot{A}/A$ to be on average negative throughout the period. Considering the results presented the previous paper, we presumed one of the reasons for this negative value could be a relatively large amount of "consumption of fixed capital" (approximately one fifth of the GDP). However, even when we excluded the factor, the results did not change significantly. The $\dot{A}/A$ in 1990–2005 is a scant 0.43 percentage point higher than the previous result, but still negative.

From 1990 on, despite the decline of labor (-0.27%, Table 4), the labor efficiency grew at 1% per annum (Table 6), which contributed 164.11% to TFP. In other words, the labor efficiency growth compensated for the decline of labor. We emphasized this point in the previous paper, and it is still persuasive with the new data.

In the US, both experiments showed the $\dot{A}/A$ to be slightly positive from the 1990s on. This change from that in the period 1970–1989, together with the s increase in $\dot{B}/B$, is a key to the rapid TFP growth in 1990–2005. We presume the possibility that it could be a structural change relating to the New Economy.

The contribution rate of capital efficiency growth $\alpha \cdot \left(\dot{A} / A \right)$ turned positive but remains low. It may be interesting to point out that if this contribution rate does not grow much in the future, we will be able to judge the US technical change to be more like Harrods-neutral.

4.4 Stability under Biased Technical Change

11. In the economy with biased technical change defined as equation (1), the stability condition should be as in equation (12).

$$\left(\frac{\dot{\overline{Y}}}{\overline{Y}} \right)^{*} = \left(\frac{\frac{d}{dt}(AK)}{AK} \right)^{*} = \left(\frac{\frac{d}{dt}(BL)}{BL} \right)^{*}, \tag{12}$$

where $\overline{Y}$ = output after technical change
AK = effective capital
BL = effective labor.

The precise explanation of equation (12) is presented in Sato and Morita (2007). Here we would like to determine whether the economies of Japan and the US satisfy this condition. We show the growth rate of *AK*, *BL*, and the economic growth rate in Table 8.

Table 8. Growth Rate of *AK*, *BL* and *Y*

a. Japan

		New Data			Previous Data		
		1970-2005	1970-1989	1990-2005	**1960-2004**	1960-1989	1990-2004
Growth Rate of Effective Capital	$\frac{\frac{d}{dt}(AK)}{AK}$	3.90%	6.41%	1.48%	5.71%	7.62%	1.82%
Growth Rate of Effective Labor	$\frac{\frac{d}{dt}(BL)}{BL}$	2.00%	2.63%	0.74%	4.14%	5.66%	0.70%
Growth Rate of Output	$\dot{Y}/Y$	2.72%	4.20%	0.97%	4.65%	6.35%	1.03%
$\frac{\dot{Y}}{Y}\Big/\frac{\frac{d}{dt}(AK)}{AK}$		**0.70**	0.65	0.66	**0.82**	0.83	0.56
$\frac{\dot{Y}}{Y}\Big/\frac{\frac{d}{dt}(BL)}{BL}$		**1.36**	1.60	1.32	**1.12**	1.12	1.46
$\frac{\frac{d}{dt}(AK)}{AK}\Big/\frac{\frac{d}{dt}(BL)}{BL}$		**1.95**	2.44	2.01	**1.38**	1.35	2.60

b. US

		New Data			Previous Data		
		1970-2005	1970-1989	1990-2005	**1960-2004**	1960-1989	1990-2004
Growth Rate of Effective Capital	$\frac{\frac{d}{dt}(AK)}{AK}$	3.08%	3.25%	2.79%	2.90%	2.99%	2.80%
Growth Rate of Effective Labor	$\frac{\frac{d}{dt}(BL)}{BL}$	3.32%	3.29%	3.41%	3.13%	3.05%	3.16%
Growth Rate of Output	$\dot{Y}/Y$	3.25%	3.29%	3.20%	3.08%	3.05%	3.13%
$\frac{\dot{Y}}{Y}\Big/\frac{\frac{d}{dt}(AK)}{AK}$		**1.06**	1.01	1.15	**1.06**	1.02	1.12
$\frac{\dot{Y}}{Y}\Big/\frac{\frac{d}{dt}(BL)}{BL}$		**0.98**	1.00	0.94	**0.98**	1.00	0.99
$\frac{\frac{d}{dt}(AK)}{AK}\Big/\frac{\frac{d}{dt}(BL)}{BL}$		**0.93**	0.99	0.82	**0.93**	0.98	0.89

We can see that in Japan, compared to the economic growth rate, the growth rate of effective capital was higher and that of effective labor was lower. Consequently, the effective capital growth is twice as high as the effective labor growth. Thus, the Japanese economy’s growth path is far from balanced. In contrast, in the US, the growth rate of each factor is almost even, especially during the period 1970–1989. By estimating the capital and labor efficiency, we can clearly observe how much Japan needs to raise its labor efficiency in the era of the shrinking labor force.

5. Summary and Conclusion

12. We have confirmed the findings in Sato and Morita (2007) by using more specific data—the nonfarm-private sector's net domestic product (NDP)—instead of gross domestic product (GDP). As our neutrality tests confirmed, the new series in both countries were also appropriate for the analysis of biased technical change. We illustrated that the estimations of production functions with biased technical change fit better to actual output than those with Hicks-neutral technical change.

13. To compare the new results with the previous results for Japan, the differences are as follows:

- The economic growth rate and some other new series during 1970–2005 and 1970–1989 are considerably different from the previous series. Most of the differences are explained by the exclusion of the data for the 1960s owing to data constraints. The strong influence of the data (or lack thereof) for the 1960s indicates that the extremely high growth in that decade too strongly affected the analysis of 1960–2004 or 1960–1989 in the previous paper.
- In 1990–2005, capital growth was lower in the new series, which suggests that the increase of "consumption of fixed capital" affected the growth rate. Excluding it, in the new data, growth rate of capital efficiency in 1990–2005 was still negative, but its degree is smaller. It follows that the contribution of effective capital to the economic growth went up with the better capital efficiency. The new data more clearly shows the role of newly accumulated capital.
- Estimated elasticity of substitution in 1990–2005 was lower in the new data.

The results common to the two studies on Japan are:

- Japanese growth rate was backed by both capital growth and growth of labor efficiency throughout the observation periods.
- The Japanese economy remains far from the steady-state. It is highly possible that the economy will autonomously adjust itself eventually.

For the US, there is just one major difference: the estimated elasticity of substitution was lower in 1970–1989, but higher in 1990–2005.

The results common to the two studies on the US are:

- Contrastive to Japan, no effects of exclusion of the 1960s data were found except the value of elasticity of substitution. The two studies in general showed closely corresponding results despite the difference in the period. The reason why only the elasticity differs should be investigated in future studies.
- Capital efficiency turned positive in 1990–2005, which hints that there may have been a technical change that may relate to the so-called New Economy.
- The US economy has been in the steady-state since the 1960s.

14. In conclusion, what has our application of the theory of biased technical change revealed? The US economy has been in the steady-state, but the Japanese economy is far from it. Since the ratio of the growth rate of effective capital to the growth rate of effective labor is too high in Japan, there will be two possible processes to reach the steady-state. One is negative adjustment—decline of effective capital, which may lower the level of steady-state growth rate. The other is positive adjustment—increase of effective labor, which may realize higher steady-state growth. According to our studies, Japan has continuously improved labor efficiency until it could compensate for the decline of labor. As its labor force continues to shrink, Japan should make a perpetual effort to raise labor efficiency with a view to avoiding the negative type of adjustment.

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Appendix

The data sources are as follows.

Japan

Y: “Net domestic product” excluding “agriculture, forestry and fishing, plus producers of government services,”
deflated by GDP Deflator
(Department of National Accounts, Economic and Social Research Institute, Cabinet Office, Government of Japan, *Annual Report on National Accounts*)

K: “Tangible fixed assets” excluding “dwellings” (net stock, real)
multiplied by
the ratio of “private sector” in “producing assets” (gross stock, nominal)
(Department of National Accounts, Economic and Social Research Institute, Cabinet Office, Government of Japan, *Annual Report on National Accounts*)
multiplied by
the ratio of “gross capital stock by industry, total minus agriculture, forestry and fishing.” (gross stock, real)
(Department of National Accounts, Economic and Social Research Institute, Cabinet Office, Government of Japan, *Annual Report on Gross Capital Stock of Private Enterprises*)

L: “Hours worked per employee”
multiplied by
“number of private employees” excluding “agriculture”
(The Japan Institute for Labour Policy and Training, *Roudou Toukei Deeta Kensaku Sisutemu* (Search System for Labour Statistics), http://stat.jil.go.jp/, and Statistics and Information Department, Ministry of Health, Labour and Welfare, *Monthly Labour Survey*)

w: “Compensation of employees” excluding “agriculture, forestry and fishing, and producers of government services”
deflated by GDP deflator
(Department of National Accounts, Economic and Social Research Institute, Cabinet Office, Government of Japan, *Annual Report on National Accounts*)
divided by
labor force (L)

United States

Y: “National income without capital consumption adjustment by industry, private” excluding “agriculture”
(National Income and Product Accounts Tables, Bureau of Economic Analysis, U.S. Department of Commerce, http://www.bea.gov/national/nipaweb/Index.asp).

K: “Current-cost net stock of private nonresidential fixed assets by industry group and legal form of organization, private” excluding “farms”
deflated by
“chain-type quantity indexes for net stock of private nonresidential fixed assets by industry group and legal form of organization”
(Fixed Asset Tables, Bureau of Economic Analysis, U.S. Department of Commerce, http://www.bea.gov/national/FA2004/SelectTable.asp#S6)

L: “Average weekly hours of production and nonsupervisory workers on private nonfarm payrolls”
multiplied by
“employees on private nonfarm payrolls”
multiplied by 52 weeks
(Employment, Hours, and Earnings from the Current Employment Statistics survey, Bureau of Labor Statistics, U.S. Department of Labor, http://www.bls.gov/ces/home.htm)

w: “Compensation of employees by industry, private industries” excluding “farms”
deflated by GDP deflator
divided by
labor force (L)