

# The Role of ICT for Income Inequality: The Model and the Simulations

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**Abstract**—This paper is to clarify the relationship between ICT and income inequality. To do so, we develop the general equilibrium model with ICT investment, obtain the equilibrium solutions, and then simulate the model with these solutions for some OECD countries. As a result, generally, during the corresponding periods we confirm that the relationship between ICT investment and income inequality is positive. In this mode, the increment of the ratio of ICT investment to the aggregated investment in stock enhances the capital's share of income, and finally leads to income inequality such as the increase of the share of the top decile income. Although we confirm the positive relationship between ICT investment and income inequality, the upward trend for that relationship depends on the values of parameters for the making use of the simulations and these parameters are not deterministic in the magnitudes on the calculated results for the simulations.

**Keywords**—ICT, inequality, capital accumulation, technology.

## I. INTRODUCTION

AS IMF pointed out, owing to technology workers are earning a shrinking slice of the income pie, and rapid advance of information and communication technology has accelerated the automation of routine task and causes firms to substitute capital for workers in [15]. There are many researches about the relationship between ICT/technology and economic growth or the one between ICT/technology and income inequality [3]-[14].

Table I indicates the labor shares in income for some OECD countries (the United States of America, Japan, Canada, the United Kingdom, Germany, France, Italy, and Sweden). From this table, we see that the trend of the labor share in income have decreased for some countries since 2000.

The decrease of labor share in income means that the capital's share of income has increased and then wealth for capital owner also has increased through accumulation of capital. Behind this background, there is the development of information technology and communication (ICT), as mentioned above. More concretely, this reflects the inequality between the capital owner and non-capital owner, such as worker. Reference [8] shows the relationship between capital owner and income inequality with the model and simulation in the United States, and indicates the positive relationship between capital's share of income and the income inequality (the top quintile income share). Generally, capital is invested into many fields, especially, ICT industry. Reference [9] indicates that the effect of income inequality on economic growth is statistically significant on using the EHI2008 (EHII:

Estimated Household Income Inequality Data) measure of inequality.

TABLE I  
LABOUR SHARE IN INCOME [12]

	2000	2005	2007	2009	2011	2012
USA	71.1	68.5	69.7	69.9	67.0	66.8
Japan	72.1	67.9	66.7	71.5	70.5	69.7
Canada	70.7	68.1	68.9	73.9	70.0	71.2
UK	69.9	67.0	69.1	70.3	67.4	69.1
Germany	72.2	66.7	63.5	68.3	65.9	67.5
France	69.1	70.6	69.6	73.4	72.7	74.2
Italy	51.3	53.1	53.9	56.9	57.3	58.6
Sweden	70.6	69.4	66.2	73.6	69.8	72.4

Reference [2] pointed out that the growth for the productivity over employee and per hour was mostly higher in the United States of America over the period 1995-2006 than in other three countries (Japan, France and the United Kingdom), implying that the catching-up process had slowed or stopped. This result is due to higher growth in both ICT and non-ICT capital intensities and also in TFP in the United States of America. Furthermore, they mentioned that ICTs have had a positive and significant impact over the past two decades, via a sharp fall in price of ICT relative to the other capital goods and labor, and TFP gain by rapid technological progress in the different ICT-producing industries.

Fig. 1 shows the ratio of ICT investment to the aggregated investment in flow from 1990 to 2008. From this figure, we see that the share of ICT in investment for the United States of America, Japan and the United Kingdom have increased.

Fig. 2 shows the share of ICT in investment in stock by using the perpetual inventory method for flow investment, and the transition of the share of ICT to the all investment in stock. The perpetual inventory method estimates the initial ICT stock by discounting the initial investment as the sum of average investment growth rate and the depreciation rate, and then continuously accumulating ICT stock according to the ICT change formula<sup>1</sup>. The transition of the share of ICT investment to all investment in stock for four countries are upward as a trend. This trend is the opposite one of labor share in income shown in Table I for the corresponding countries.

The same trends of Figs. 1 and 2 also can be seen in [2]. That is, the contribution of ICT capital to productivity growth per hour is greater than that of non-ICT capital in the United States of America but less than that of non-ICT capital in other three countries. And the investment ratio is roughly the same

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<sup>1</sup>The initial value of ICT stock at  $t$  is specified as  $ICT_{i,t} = ic_{i,t}/(g_i + \delta)$ , where  $ic_{i,t}$  denotes ICT investment in flow at time  $t$  in country  $i$ . Then the ICT stock is equal to  $ICT_{i,t+1} = ic_{i,t} + (1 - \delta)ICT_{i,t}$ .

in the United Kingdom and the United States of America, and the contribution of ICT to productivity growth is also the same. And these results confirm the positive impact of the share of the population having completed higher education and the negative impact of market rigidities on ICT diffusion.

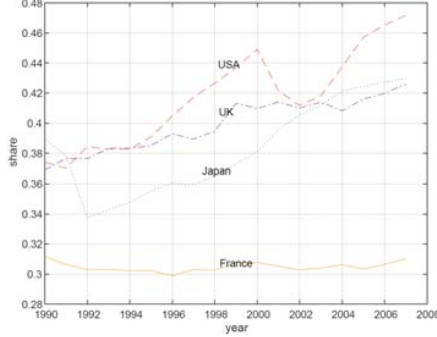


Fig. 1 Ratio of ICT-investment/Investment (flow)

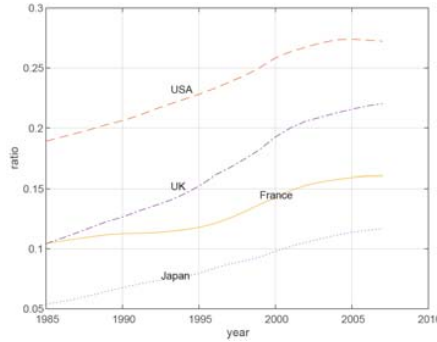


Fig. 2 Ratio of ICT-investment/Investment (stock)

Fig. 3 shows the share of the top decile income for four countries and this indicates the income inequality. Except France, all other countries show upward slop as a trend. For the United States, between 2000 and 2004, the share of the top decile income decreased due to September 11 attacks at 2001 and the burst of Internet Bubble from 2000 to 2002.

As mentioned at the beginning in this section, this suggests that upward slop of the ratio of ICT investment to all investment in stock relates the increase of the income inequality. Therefore, we confirm the relationship between ICT and income inequality in this study. This study comprises the model of general equilibrium system in Section II, in Section III the simulation with the results in the aforementioned section, and conclusion in Section IV.

## II. THE MODEL

This model is the general equilibrium one and is based on [8]. This economy consists of workers, capital owners, competitive firms, and government. The number of worker is  $n$  times of the one of capital owner, and number of capital owner is normalized as one. The firms are owned by the capital owners.

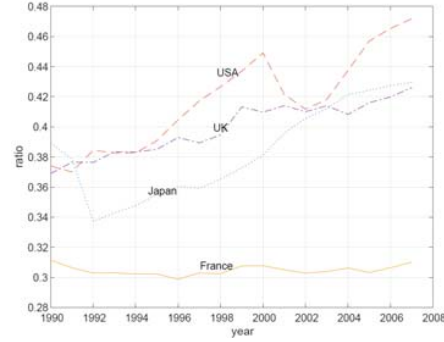


Fig. 3 Income Top 10%

### A. Household

1) *Workers*: Workers belong to the layer excluding the one for the top decile of income. They earn the income from only wage they work for firm to get. Also they obtain the redistributive transfer from their government. We assume that each worker maximizes the following utility

$$\sum_{t=0}^{\infty} \beta^t \log(c_t^w), \quad (1)$$

subject to the budget constraint

$$c_t^w = (1 - \tau_t^w)w_t^w l_t^w + \frac{T_t}{n}, \quad (2)$$

where  $\beta$  is the subjective time discount factor,  $c_t^w$  is the individual worker's consumption at time  $t$ ,  $\tau_t^w$  is the tax rate at time  $t$  for workers,  $w_t^w$  is the wage rate at time  $t$  for workers,  $l_t^w$  is the constant supply of labor for workers and  $T_t$  is aggregate redistributive transfers.

2) *Capital Owners*: Capital owners represent the top decile of income. We assume that they maximize the following utility,

$$\sum_{t=0}^{\infty} \beta^t \log(c_t^c), \quad (3)$$

subject to the budget constraint

$$c_t^c + i_t = (1 - \tau_t^c)(w_t^c + r_t), \quad (4)$$

where  $c_t^c$  is the individual capital owner's consumption at time  $t$ ,  $i_t$  is the investment at time  $t$ ,  $\tau_t^c$  is the tax rate at time  $t$  for capital owners,  $w_t^c$  is the wage rate at time  $t$  for capital owners, and  $l_t^c$  is the constant supply of labor for capital owners.

The capital is accumulated as:

$$k_{t+1} = i_t + (1 - \delta)k_t. \quad (5)$$

We denote capital stock at time  $t$  as  $k_t$ , and the depreciation rate as  $\delta$ .

3) *Firms*: Identical competitive firms are owned by the capital owners and goods  $y_t$  are produced according to the following technology.

$$y_t = Ak_t^\theta \left( l_t^c \right)^{\alpha_t} \left( n l_t^w \right)^{1-\alpha_t} \right)^{1-\theta}, \quad (6)$$

$$\theta_t = \theta_{t-1} + \eta \left( \omega g_{\psi t} + (1-\omega)(g_{\psi t} - g_{\psi t-1}) \right), \quad (7)$$

$$g_{\psi t} = \frac{\psi_t - \psi_{t-1}}{\psi_{t-1}}, \quad (8)$$

$$\psi_t = \frac{ict_t}{k_t}, \quad (9)$$

where  $A$  denotes the technology and  $ict_t$  the stock of ICT at time  $t$ ,  $\alpha$  the capital owner's share of labor income at time  $t$ .

4) *Government*: The government collect tax revenue to finance expenditures on public expenditure and redistributive transfers. We assume that the government's budget constraint is balanced at time  $t$ , as given by

$$g_t + T_t = n\tau_t^w w_t^w l^w + \tau_t^c (w_t^c l^c + r_t k_t), \quad (10)$$

where  $g_t$  is public consumption.

Regarding the income taxation, we introduce the following formulation which is revised from [1] and [8].

$$\tau_t^i = 1 - \lambda \left( \frac{y_t^i}{\bar{y}_t} \right)^{-\kappa}, \quad (11)$$

$$\bar{y}_t = \frac{y_t}{n+1}, \quad (12)$$

where  $0 < \lambda < 1$  indicates the parameter for income level, and  $\kappa \geq 0$  governs the slope of the tax schedule.

### B. Equilibrium

Based on the aforementioned model, we examine the equilibrium.

At first from the maximization problem of utility for capital owner, we obtain the evolution of consumption for capital owner.

$$\frac{c_{t+1}^c}{c_t^c} = \beta \left( (1-\tau_t) r_t + 1 - \delta \right). \quad (13)$$

Next, from profit maximization for firm we obtain the following results.

$$r_t = \theta \frac{y_t}{k_t}, \quad (14)$$

$$w_t^w = (1-\theta_t)(1-\alpha_t) \frac{y_t}{n l^w}, \quad (15)$$

$$w_t^c = \alpha_t (1-\theta_t) \frac{y_t}{l^c}. \quad (16)$$

Regarding the tax at equilibrium, from (11), (12), (14), (15), and (16), we obtain

$$\tau_t^w = 1 - \lambda \left( \frac{n+1}{n} (1-\theta_t)(1-\alpha_t) \right)^{-\kappa}. \quad (17)$$

$$\tau_t^c = 1 - \lambda \left( (n+1)(\alpha_t(1-\theta_t) + \theta_t) \right)^{-\kappa}. \quad (18)$$

Finally, from (4), (14), and (16), we obtain the investment at equilibrium as follows.

$$i_t = (1-\tau_t^c)(\alpha_t(1-\theta_t) + \theta_t) y_t - c_t^c. \quad (19)$$

With the above results, we close this system. We prepare the data for  $\theta_t$ ,  $ict_t$ , and  $\alpha_t$ . The initial values are  $k_0$  and  $c_0^c$ . The parameters are  $\beta$ ,  $l^w$ ,  $l^c$ ,  $n$ ,  $A$ ,  $T_t$ ,  $g_t$ ,  $\phi_t$ ,  $\delta$ ,  $\omega$ , and  $\eta$ . The variables for this system are  $c_t^w$ ,  $c_t^c$ ,  $w_t^w$ ,  $w_t^c$ ,  $\tau_t^w$ ,  $\tau_t^c$ ,  $i_t$ ,  $r_t$ ,  $y_t$ ,  $\psi_t$ , and  $k_t$ . Therefore, from the data for  $ict_0$ , initial value of  $k_0$ , and the parameters  $\omega$  and  $\eta$ , we obtain  $\psi_0$  and  $\theta_0$  by (7)-(9). By these values and (6),  $y_0$  is determined. Then  $r_0$ ,  $w_0^w$ , and  $w_0^c$  are determined by (14)-(16). Furthermore,  $\tau_0^w$ ,  $\tau_0^c$ ,  $c_0^w$ , and  $i_0$  are determined by (17)-(18), (2). Finally, next period of  $k_1$  and  $c_1^c$  are determined by (5), (13) and initial value  $c_0^c$ .

### III. MODEL CALIBRATION:SIMULATION

In this section by using the equilibrium results, we simulate the model for Japan, USA, and UK. Before the description of the results of simulation, we briefly mention the outlines of economic situations for the corresponding countries between 1990 and 2008/2010. The periods of the decline of economic growth for Japan are 1992-1994, 1998, 1999, 2002, and 2008. Those periods for USA are 1991, 2001, 2007, and 2008, and the ones for UK are 1991, 1992, and 2008. During these periods, we suppose that the group for top decile of income (earner) went through the serious damage for the earnings from interest rate due to the recession.

Next, we show the values of parameters for the simulation in Table II. These values are adjusted to get the plausible value of interest rate. Through all figures of the simulations, for both ends on the horizontal axis (the first and the last years), we use the value of actual data in the computation, such as the actual capital's share in income  $\theta$  from the data of USA<sup>2</sup>. Therefore, we have to exclude explanation for the both ends of the year for the analysis of the simulation as mentioned below,

TABLE II  
VALUES OF PARAMETERS FOR SIMULATION

	Japan	USA	UK
A	100000.0	200000.0	100000.0
$\alpha$	0.303	0.302	0.316
$\beta$	0.898	0.898	0.898
$n$	9	9	9
$l^c$	0.5	1.5	0.3
$l^w$	5.0	15.0	3.0
$\kappa$	0.03	0.03	0.03
$\lambda$	0.85	0.85	0.85
$\theta_0$	0.325	0.35	0.396
$\eta_0$	1.0	0.6	1.0
$\delta$	0.2	0.2	0.2
$\beta$	0.9634	0.9634	0.9634
$\omega$	0.15	0.15	0.12
Tax transfer factor	6.35	6.35	6.0

#### A. Simulation for Japan

The results of simulation for Japan are shown in Figs. 4-15. In Fig. 4, the solid line indicates the capital's share of income to be computed by the ratio of ICT investment to all investment shown on Fig. 2 (henceforth, we call this situation "this model" in the figures) and the dotted one does the actual data  $\theta$  of the

<sup>2</sup>This attributes to the computation of the economic variables, such as the economic growth.

capital's share of income (henceforth, we call this situation "actual data" in the figures). From this figure we see that although the magnitude of the capital's share of income in this model is greater than the one in actual data, the transitions for both curves are upward as a trend.

Fig. 5 shows almost the same result as the one in Fig. 4.

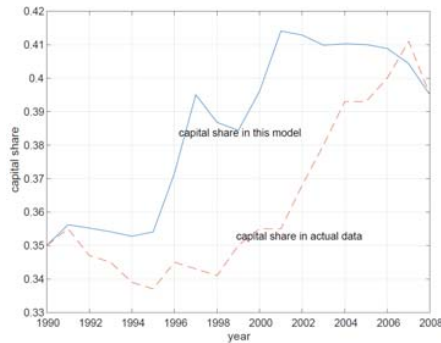


Fig. 4 Capital's Share of Income

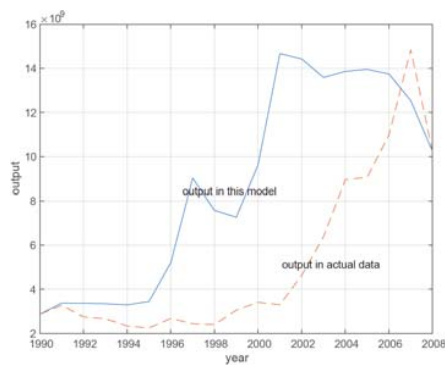


Fig. 5 Output

Fig. 6 shows the transitions of the interest rate. The solid and the dotted lines are the same definition in Fig. 4. This figure shows that the interest rates in 1997 and 2001 to be calculated with the equation in equilibrium are greater than the ones to be computed by the actual data of the capital share's of income. At these times Japanese economy was in recession. At the period between 1991 and 2001, the interest rates to be calculated by the actual data were still lower. This discrepancy implies that the investment of ICT increased in spite of the recession shown in Fig. 2, but actual interest rate kept lower due to the recession. Therefore, this discrepancy occurs as shown in Fig. 6.

Figs. 7 and 8 show the transitions of the wage rates for worker and capital owner. These figures indicate the same trends of the transitions like the ones in Fig. 6.

Fig. 9 indicates the ratio of the wage rate for capital owner to the one for worker. The trend of this ratio in this model increases up to 2001, and after 2001 the ratio decreases. Regarding the ratio in actual data increases up to 2007. The maximum ratio for both situations is about 6.8.

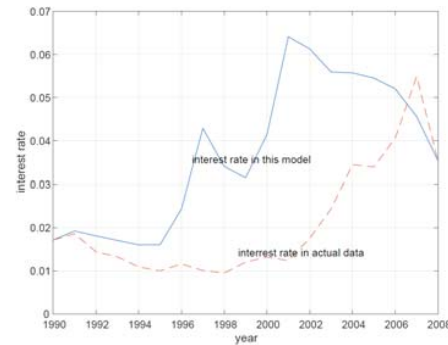


Fig. 6 Interest Rate

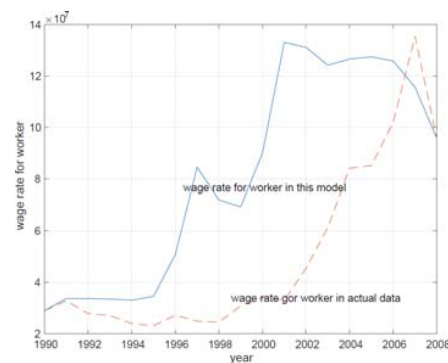


Fig. 7 Wage Rate for Worker

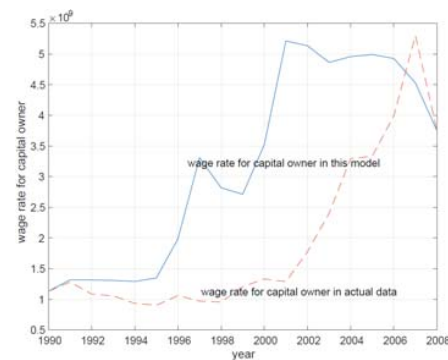


Fig. 8 Wage Rate for Capital Owner

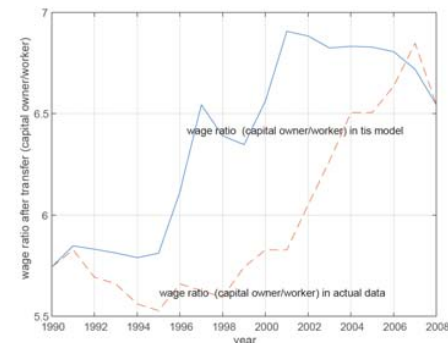


Fig. 9 Wage Ratio

Fig. 10 indicates the share of the top decile income. The solid line shows the share of the top decile income to be computed in this model, the dotted line the one to be computed with the actual data of  $\theta$ , and solid line with dotted one the real data of the share of top decile of income. Three lines in the figure indicate that the magnitudes of the share are different, the share in this model is the highest, the one with actual data of  $\theta$  is moderate and the one with real data of the share of the top decile income is the lowest. The discrepancy between the results in this model/actual data and real data stems from the recession, since during the recession the growth rate decreased and on the contrary ICT investment to all investment increased gradually, as shown in Fig. 2.

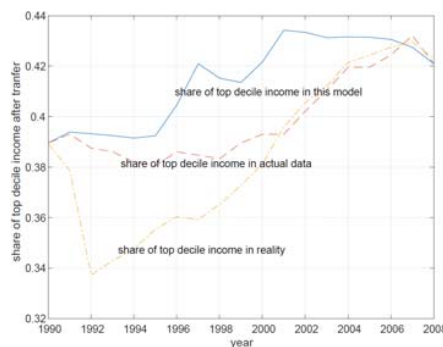


Fig. 10 Share of Top Decile Income

Fig. 11 shows the ratio of the income from the interest rate to the one from the wage rate for capital owner. The ratio is from about 1.8 to 2.3. Although its transition is fluctuating, the trend is upward. This implies that the income inequality relates to ICT investment, as [13] pointed out.

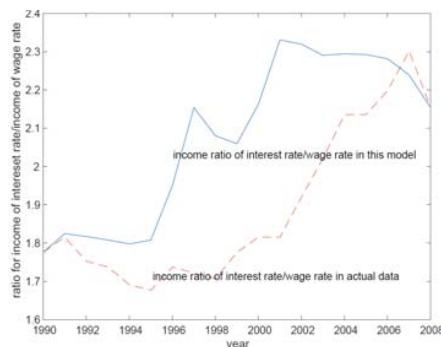


Fig. 11 Income Ratio of Interest Rate to Wage Rate

Fig. 12 indicates the tax ratio of capital owner to worker. The solid line indicates the results in this model and the dotted one does the results by using the actual data of the capital's share of income. This shows that the tax rate for capital owner is heavier than the one for worker, and its ratio is from around 1.45 to 1.5 in this model. Through our experience, this ratio is low and the ratio is contracting from 2001.

Fig. 13 shows the tax rates for worker and capital owner. Although the magnitude of the rates in this model are different

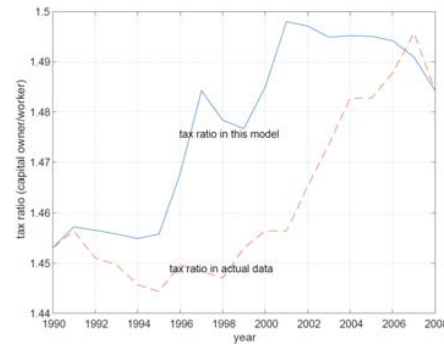


Fig. 12 Tax Ratio

from the ones in actual data of the capital's share of income, the transitions of these ratios are almost similar as a trend.

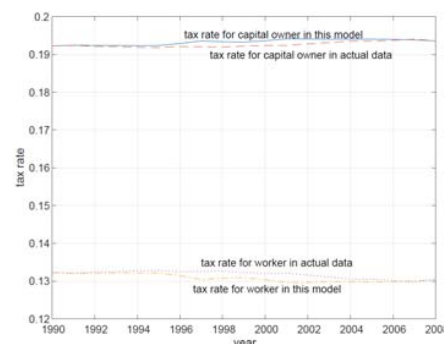


Fig. 13 Tax Rate

Fig. 14 shows the transitions of consumption for worker and capital owner. The consumption for capital owner in this model is similar to the one in the actual data of the capital's share of income. Although the magnitude of the consumption for worker in this model is different from the one in actual data of the capital's share of income, as a trend the transition of the consumption for worker in this model is similar to the one in the actual data of the capital's share of income.

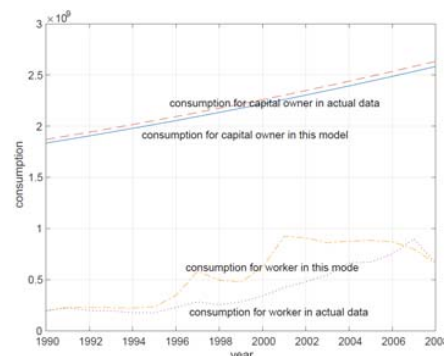


Fig. 14 Consumption

Fig. 15 shows the consumption ratio of capital owner to worker. The magnitude of the consumption ratio in the actual



data of the capital's share of income is greater than the one in this model, but both transitions are quite similar as a trend.

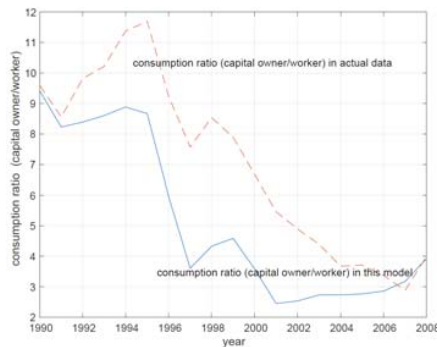


Fig. 15 Consumption Ratio

Fig. 16 shows the investments in this model and in the actual data of the capital's share of income. The magnitudes of investment are different between this model and the actual data of the capital's share of income, especially at the period between 1997 and 2001. However, both transitions are slightly similar as a trend.

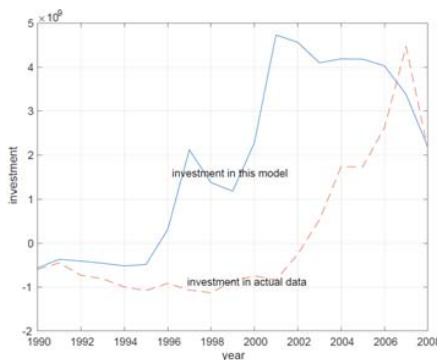


Fig. 16 Investment

### B. Simulation for USA

The results of simulation for USA are shown in Figs. 17- 29. In Fig. 17, the solid and the dotted lines indicates the same definition in Fig. 4. From Fig. 17, we see that although the movement of the capital's shares of income in this model is reverse to the one in actual data at 1992, 2001 and 2007 when the economic growth decreased, the trends of transitions for both curves are similar. Fig. 18 shows almost the same result as Fig. 17.

Fig. 19 shows the transitions of the interest rate. The solid and the dotted lines indicate the same definition in Fig. 17. This figure shows that at 1993 and 2001 the interest rates to be calculated with the equilibrium equations in this model are greater than the ones to be computed with the actual data of the capital's share of income. At these times USA economy was in recession. Between 1991 and 2004, the interest rates to be calculated with the actual data were still lower, and investment

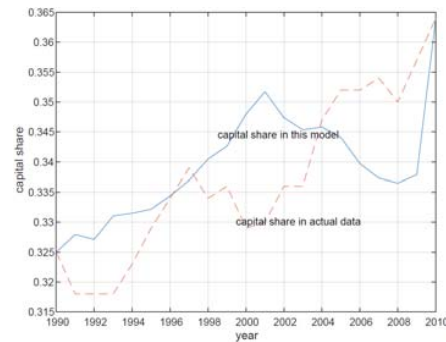


Fig. 17 Capital's Share of Income

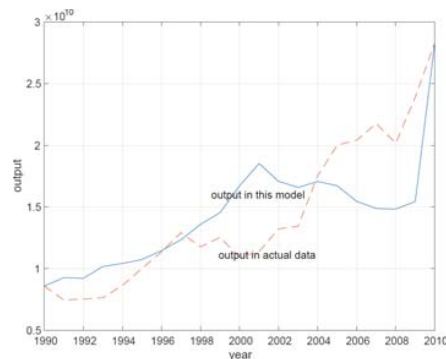


Fig. 18 Output

of ICT to all investment which we use in the computation of the capital's share of income increases as shown in Fig. 2. During this period the actual interest rate kept lower due to the recession, in comparison with the interest rate to be computed by using the ratio of ICT investment to all investment in this model. Between 2004 and 2009, the interest rate in the actual data is greater than the one in this model. The reason for this discrepancy is that the capital's share of income in this model decreases during these periods as shown in Fig. 17.

Figs. 20 and 21 show the transitions of the wage rates for worker and capital owner. These figures indicate the same trend as the ones in Fig. 19.

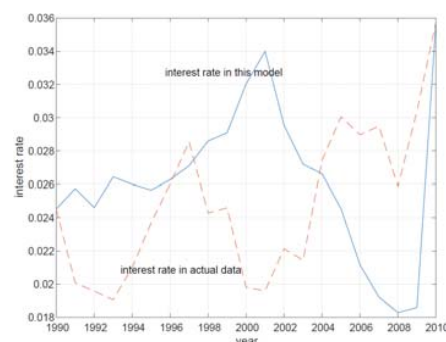


Fig. 19 Interest Rate

Fig. 22 indicates the ratio of the wage for capital owner

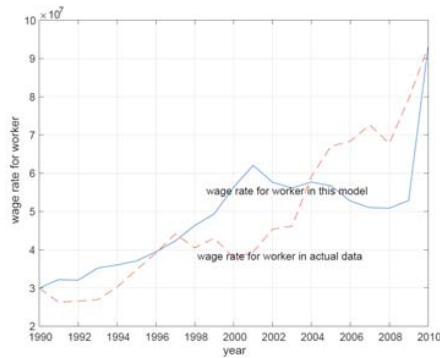


Fig. 20 Wage Rate for Worker

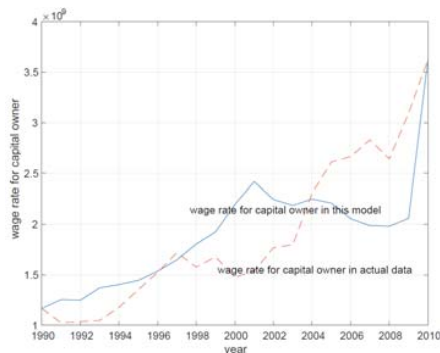


Fig. 21 Wage Rate for Capital Owner

to the one for worker. The trend of this ratio in this model increases up to 2001, and between 2001 and 2008 it decreases. On the contrary the ratio in actual data increases up to 2007. The maximum ratio in the curves to be computed by using the ratio of ICT investment to all investment in this model is about 5.8 at 2001 except 2010. This figure shows the slightly same trend for transition in Fig. 19.

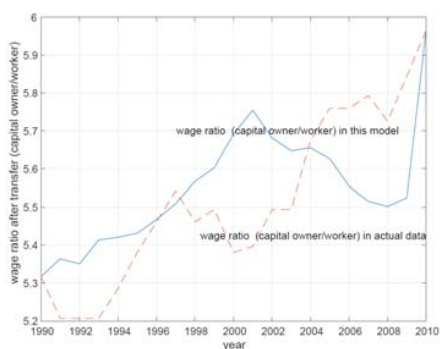


Fig. 22 Wage Ratio

Fig. 23 indicates the share of the top decile income. The solid line shows the share of the top decile income to be computed by using the ratio of ICT investment to all investment in this model, the dotted line the one to be computed with the actual data of the capital's share of income,

and solid line with the dotted one the real data of the share of the top decile income. Three lines in the figure indicate that the magnitudes of the shares are different, especially the share of the top decile income in real data. The real share is the highest through the periods, and the other lower two curves show almost the similar transition. The discrepancy between the real data and the ones in this model/the actual data stems from the factor except ICT investment, such as extortionate salary for executives, globalization of trade and so forth.

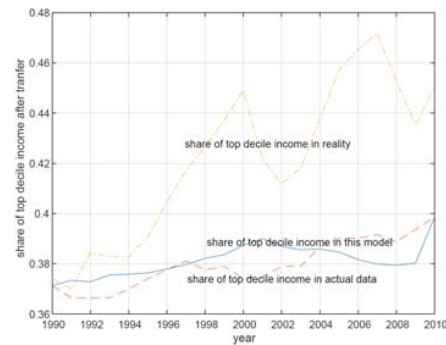


Fig. 23 Share of Top Decile Income

Fig. 24 shows the ratio of income from the interest rate to the one from wage rate for capital owner. The ratio is from about 1.55 to 1.9 which are lower than Japanese ones in Fig. 9. Usually we see that wage at top position in USA is higher than the one in Japan. This may relate to the results in Fig. 23, since in USA the share of the top decile income in this model is far lower than the real data and in Japan the difference for the two kinds of the share is not so much. Although both transitions in the figure are fluctuating, the trends are upward. This implies that the income inequality partially relates to ICT investment, taking into consideration the transition of the capital's share of income.

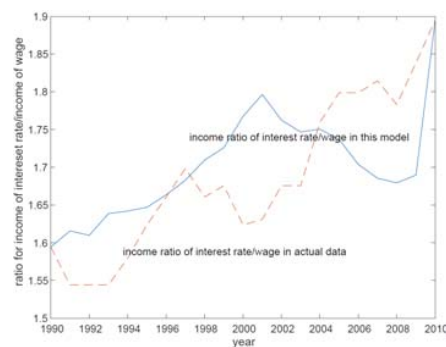


Fig. 24 Income Ratio of Interest Rate to Wage Rate

Fig. 25 indicates the ratio of tax for capital owner to the one for worker. The solid line is for the results in this model and the dotted one for the results by using the actual data of the capital's share of income. This shows that the tax rate for capital owner is heavier than the one for worker, and its ratio is from around 1.43 to 1.46. Through our experience, these

ratios are so low that the share of the top decile income in this model is lower than the real one in Fig. 23.

Fig. 26 shows the tax rates for worker and capital owner. The rates for both agents in this model are quite similar to the ones in actual data.

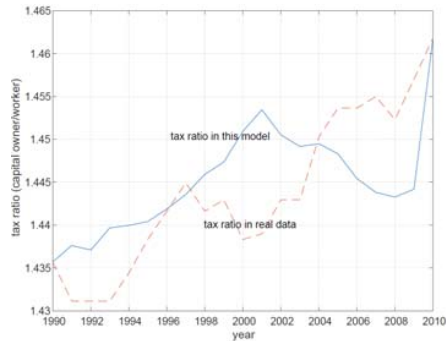


Fig. 25 Tax Ratio

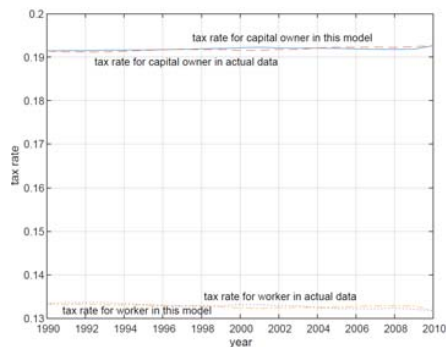


Fig. 26 Tax Rate

Fig. 27 shows the transitions of consumption for worker and capital owner. The consumption for capital owner in this model is similar to the one in the actual data of the capital's share of income. Although the magnitude of the consumption for worker is different from the one in actual data, the transitions of the consumption for worker in this model is similar to the one in the actual data.

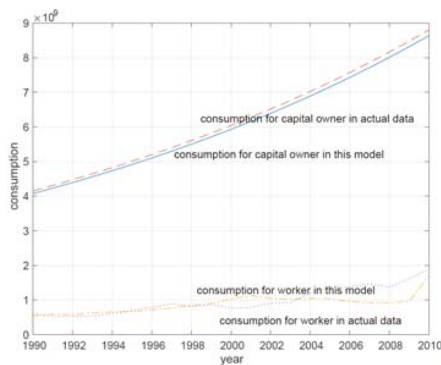


Fig. 27 Consumption

Fig. 28 shows the consumption ratio of capital owner to worker. The magnitude of the consumption ratio in the actual data of the capital's share of income is greater than the one in this model up to 2003, but both transitions are slightly similar as a trend.

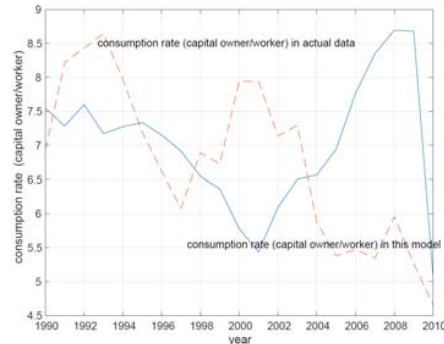


Fig. 28 Consumption Ratio

Fig. 29 shows the investments in this model and in the actual data of the capital's share of income. The magnitudes of investment are different between this model and the actual data, especially after 1997. However, both transitions are slightly similar.

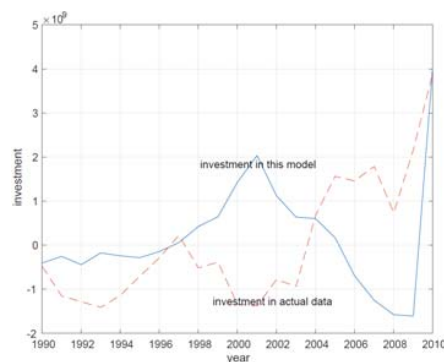


Fig. 29 Investment

### C. Simulation for UK

The results of simulation for UK are shown in from Figs. 30-42. In Fig. 30, the solid and the dotted lines indicate the same definition in Fig. 4. From Fig. 30, we see that the transition of the capital's shares of income in this model is reverse to the one in actual data at 1991 when economic growth decreased, and at 1998. However, the trends of transitions for both curves are lightly similar.

Fig. 31 shows the outputs in this model and in actual data. Between 1998 and 2007, the output to be computed in this model is quite different from the one to be computed with the actual data of the capital's share of income. This difference may stem from September 11 attacks and the burst of Internet Bubble, and the system in this model does not involve these impacts.



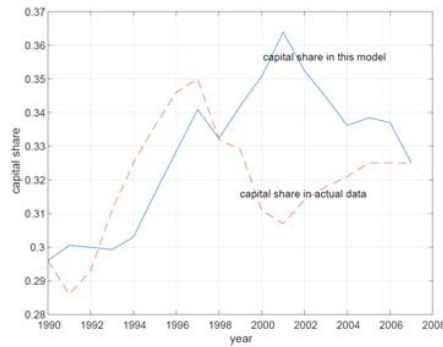


Fig. 30 Capital's Share of Income



Fig. 33 Wage Rate for Worker

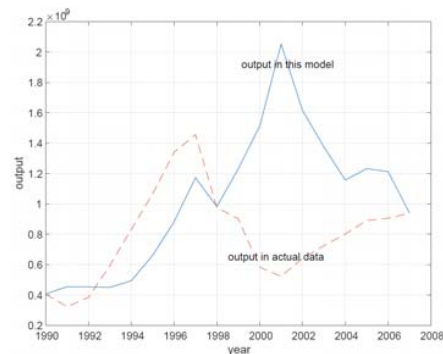


Fig. 31 Output

Fig. 32 shows the transitions of interest rate. The solid and the dotted lines indicate the same definition in Fig. 30. This figure shows that the interest rate to be calculated with the equilibrium equation in this model is greater than the one to be computed with the actual data of the capital's share of income from 1998 to 2007. This also attributes to the impacts of September 11 attacks and the burst of Internet Bubble.

Fig. 33 shows the transitions of wage rates for worker. This figure indicates the same transition as a trend in Fig. 32.

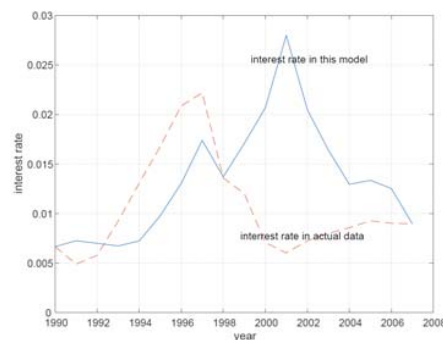


Fig. 32 Interest Rate

Fig. 34 shows the transitions of wage rates for capital owner. This figure indicates the same transition as a trend in Figs. 32 and 33.

Fig. 35 indicates the ratio of wage rate for capital owner

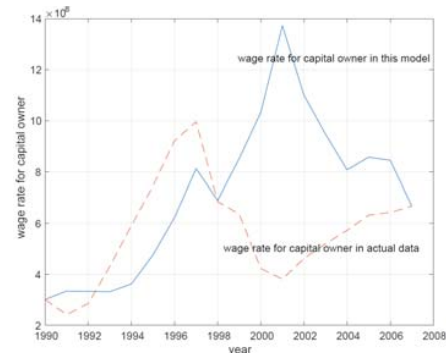


Fig. 34 Wage Rate for Capital Owner

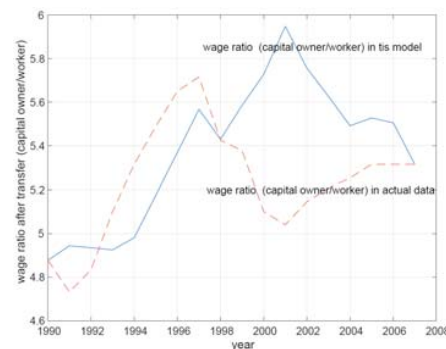


Fig. 35 Wage Ratio

Fig. 36 indicates the share of the top decile income. The solid line shows the share of the top decile income to be computed in this model, the dotted line the one to be computed with the actual data of the capital's share of income, and solid line with dotted one the real data of the share of the top decile income. Three lines in the figure indicate that the magnitudes

of the shares are different, especially the magnitude of the share of the top decile income in reality (the real data of the share of the top decile income). The real data is the highest among them, and all other lines are almost the similar transition. The discrepancy between the real data and the results in this model and the actual data stems from the factors except ICT investment, such as extortionate salary for executives.

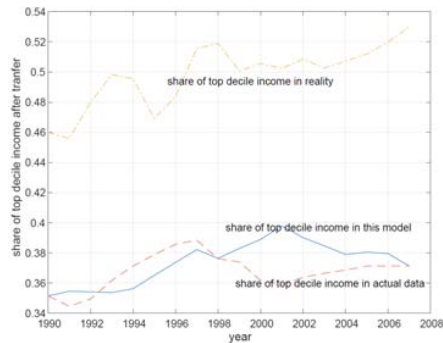


Fig. 36 Share of Top Decile Income

Fig. 37 shows the ratio of earnings from the interest rate to the one from the wage rate for capital owner, which is from about 1.28 to 1.8. This means that earnings from the interest rate is not so more than the one from the wage rates in this model and in the actual data of the capital's share of income. The ratio in this model is higher than the one in the actual data of capital's share of income after 1998. This may attribute to September 11 attacks and the burst of Internet Bubble. The ratio of ICT investment to all investment shown in Figure 2 does not include these impacts, since that ratio is consistently increasing in Fig. 2. Although the transitions are fluctuating, these are upward as a trend. This imply that the income inequality partially relates to ICT investment.

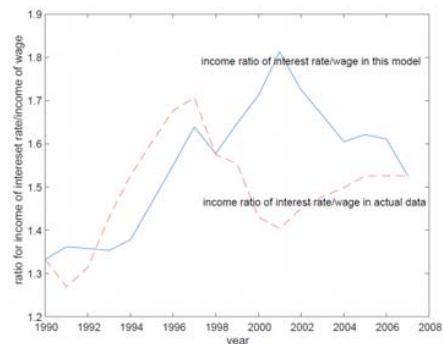


Fig. 37 Income Ratio of Interest Rate to Wage Rate

Fig. 38 indicates the ratio of tax for capital owner to the one for worker. The solid line is for the results in this model and the dotted one for the results by using the actual data of the capital's share of income. This shows that the tax rate for capital owner is heavier than the one for worker in both situations, and the ratios are from around 1.42 to 1.47. Through

our experience, these ratios are low and the two kinds of ratio are contracting after 2001.

Fig. 39 shows the tax rates for worker and capital owner. The tax rates in this model are almost same for the ones in the actual data of the capital's share of income, so that the transitions of these ratios are almost same.

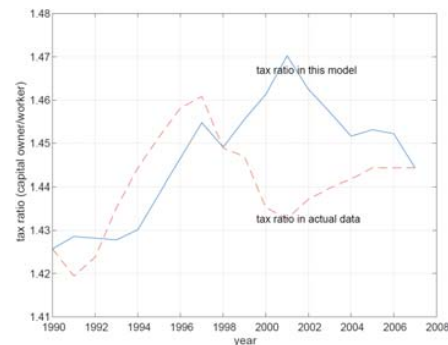


Fig. 38 Tax Ratio

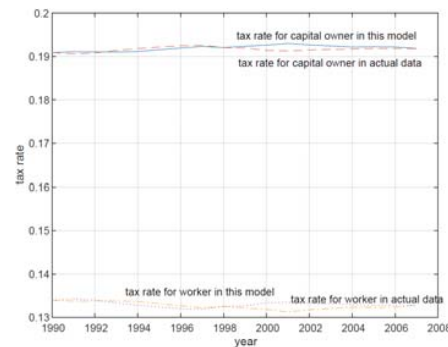


Fig. 39 Tax Rate

Fig. 40 shows the transitions of consumption for worker and capital owner. The consumption for capital owner in this model is similar to the ones in the actual data of the capital's share of income. Also the consumption of worker is similar to the one in the actual data, therefore, the transitions of the consumptions for capital owner and worker in this model are similar to the one in the actual data.

Fig. 41 shows the consumption ratio of capital owner to worker. The magnitude of the consumption ratio in the actual data of the capital's share of income is greater than the one in this model, but both transitions are quite similar as a trend.

Fig. 42 shows the investments in this model and in the actual data of the capital's share of income. The magnitudes of investments are different especially after 1998. However, the both transitions are slightly similar.

#### D. Summary of results

In the light of our purpose (to clarify the relationship between ICT investment and income inequality), we summarize the results for the above figures. To do so, we choose the four results of the simulation for each country ;

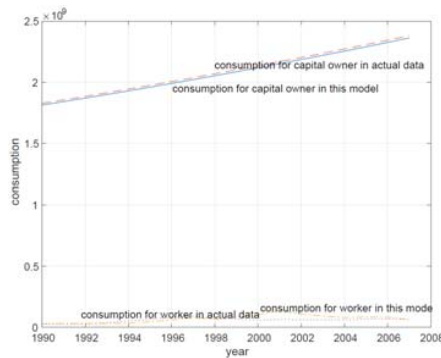


Fig. 40 Consumption

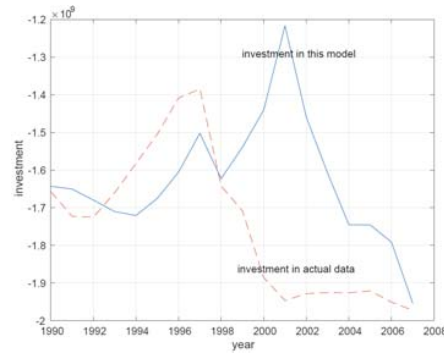


Fig. 42 Investment

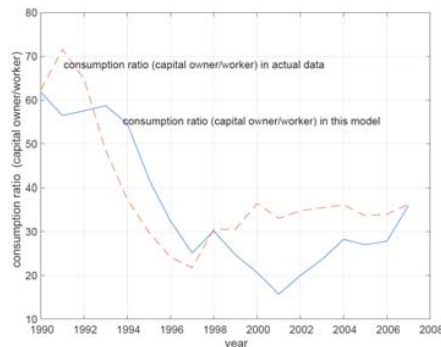


Fig. 41 Consumption Ratio

capital's share of income  $\theta$ , interest rate  $r$ , ratio of earnings from interest rate to the one from wage rate, and the share of the top decile income. In this study we assume that increase of ICT investment leads to increase of income inequality.

As [13] pointed out that the rich earns from capital gain and wage rate, and the poor does from wage rate mainly, at first, we confirm the relationship between ICT investment and capital's share of income. Fig. 2 shows the ratio of ICT investment to all investment in stock, and these ratios are upward as a trend. From Figs. 4, 17 and 30, we confirm the upward trends of the capital's shares of income for Japan, USA and UK, in spite of the fluctuations of the capital's shares of income and the differences of magnitude of the shares.

Capital's share of income affects interest rate, so that we confirm the relationship between the capital's share of income and interest rates for each country through Figs. 6, 19, and 32. The transitions of interest rate for Japan and UK are similar at large; both trends are fluctuating but upward. Therefore, we confirm the positive relationship between the capital's share of income and interest rate in Japan and UK. On the contrary the transition of interest rate for USA is quite fluctuating, its maximum difference is 0.016 points (1.6%), and its trend is downward from 2001 to 2009<sup>3</sup>. Therefore, we cannot confirm the positive relationship between the capital's share of income and interest rate in USA.

<sup>3</sup>As pointed earlier, in the figure the value at beginning (1990) and end (2010) are taken the same value of actual data.

From Figs. 11, 24, and 37, the earnings from interest rate is higher than the ones from the wage rate, and these ratios range from 1.3 to 2.3. This means the support of [13]. The ratio of earnings from interest rate to the one from wage rate for Japan is the highest among three countries, and the next highest ratio is USA's, and the last is UK's. Under our assumption, this high ratio leads to income inequality, as mentioned before. Therefore we understand this as below.

From Figs. 10, 23, and 36, we confirm the extent of income equality. Through our simulations, the highest income inequality is Japan's, and next USA's, and the last UK's. This order corresponds to the order of the ratio of earnings from interest rate to the one from wage rate, as mentioned above. However regarding the actual order for income inequality, the highest one is UK's, the next USA's, and the last Japan's. This order difference may stem from the values of parameters which are used in computation with equilibrium equations for simulations. Regarding the relationship between the capital's share of income and the share of the top decile income, we confirm that the transitions of the share of the top decile income are upward as a trend, so that there is the positive relationship between the capital's share of income and the share of the top decile income. This means that progress of ICT investment leads to income inequality. However this may be said from the trend point of view and may not said in terms of magnitude of these values, since the parameters for simulation are not deterministic.

#### IV. CONCLUSION

In this study, to confirm the relationship between ICT investment and income inequality, we develop the general equilibrium model based on [8]. From this model, we obtain the equilibrium solutions, and then simulate these solutions.

As a result, generally, during the corresponding periods, the positive relationship between ICT investment and income inequality is confirmed. The cause of income inequality attributes to the earnings from interest rate of capital, especially for Japan. For USA and UK, in addition to the earnings from interest rate, the other causes such as globalization of trade, appearance of giant corporations like Apple and Amazon, etc., might be considered. In this model the accumulation of ICT investment enhances the share of

capital owner in income (the share of the top decile income) via interest rate and wage rate, and finally leads to income inequality. Although the relationship between ICT investment and income inequality is positive, it is just a trend on the transition of the simulation, not an extent of the one. Because our results for the simulations depend on the values of parameters which are not deterministic. Therefore, our further research might be to obtain the plausible values of parameters for fitting the real situation of the economies.

## REFERENCES

- [1] Cassou, S.P. and Lansing, K.J.(2004), "Growth Effects of Shifting from a Graduated-rate Tax System to a Flat Tax," *Economic Inquiry*,42(2),pp.194-213.
- [2] Cetté,Gilbert, Yusuf Kocoglu and Jacques Mairesse (2009), "Productivity Growth and Levels in France, Japan, the United Kingdom and the United States in Twentieth Century," *National Bureau of Economic Research*, Working Paper 15577.
- [3] Chinn,Menzie and Fairlie,Robert W.(2006), "ICT Use in the Developing World: An Analysis of Differences in Computer and Internet Penetration," *National Bureau of Economics Research*, Working Paper 12382.
- [4] Garicano,Luis (2000), "Hierarchies and the Organization of Knowledge in Production," *Journal of Political Economy*,108(5),pp.874-904.
- [5] Haacker,Markus(2010), "ICT Equipment Investment and Growth in Low-and Lower-Middle-Income Countries," *International Monetary Fund*, Working Paper WP/10/66.
- [6] Haller,Stefanie and Siedschlag,Lulia (2008), "Determinants of ICT Adaption: Evidence from Firm-Level Data," *Working Paper of Dynamic Regions*,No.29.
- [7] Jones,C.I., "Time Series Tests of Endogenous Growth Models," *Quarterly Journal of Economics*,110(1995),495-525.
- [8] Lansing,Kevin J. and Markiewicz,Agnieszka (2013), "Top Incomes, Rising Inequality, and Welfare," *Centre for Dynamic Macroeconomic Analysis (University of St. Andrews)*, Working Paper Series No.1304.
- [9] Malinen,Tuomas(2013), "Inequality and Growth: Another Look with a New Measure and Method," *Journal of International Development*, No.25,pp.122-138.
- [10] Nasab,Ebrahim H. and Aghaei,Majid(2009), "The Effect of ICT on Economic Growth: Further Evidence," *International Bulletin of Business Administration*, Issue 5,pp.46-56.
- [11] OECD(2011), "Divided We Stand: Why Inequality Keeps Rising," *OECD Income Distribution and Poverty Database*, [www.oecd.org/els/social/inequality](http://www.oecd.org/els/social/inequality) accessed on February 23,2015.
- [12] OECD Database(2017), <http://stats.oecd.org/> accessed on June 10,2017.
- [13] Piketty,Thomas (2014), *Capital in the Twenty-First Century*, Cambridge, MA:Harvard University Press.
- [14] Spiezia,Vincenzo(2012), "ICT Investments and Productivity: Measuring the Contribution of ICTS to Growth," *OECD Journal: Economic Studies*, Vol.2012/1,pp199-211.
- [15] URL of Bloomberg(2017),<https://www.bloomberg.com/news/articles/2017-04-10/technology-hits> accessed on April 10,2017.