DYNAMIC ANALYSIS OF AGRICULTURAL INCOME IN JAPAN

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I *Inequality in growth rates*

There has been a marked inequality in growth rates among the sectors of industries in the development process of Japanese economy. The purposes of this paper are (1) to estimate the degree of such inequality in growth rates and then (2) to analyse the outstanding factors underlying this tendency.

Roughly speaking, the growth rate of primary industry for the prewar period had long been a little less than half of that of national economy as a whole. The same tendency is discernible in the behavior of real income of primary industry for the postwar period. While in the fiscal year of 1951 the income of primary industry occupied 25.0% of national income, this rate has declined to 18.3% in the fiscal year of 1957. This decline in importance clearly implies that the growth rate in primary industry has been comparatively low. Table 1 shows the index numbers describing the behaviors of real income of primary industry and national economy for the postwar period, 1951 through 1957. The base period of these index numbers are taken in 1928 through 1932.

Table 1 *Unequal development (Postwar)*

Fiscal years	Aggregate income		Income per worker	
	Primary industry	National income	Primary industry	National average
1951	145.42	123.81	133.4	101.3
1952	153.23	136.06	136.9	105.7
1953	148.91	143.65	125.7	107.1
1954	150.89	148.40	130.7	109.0
1955	173.92	163.92	145.9	115.6
1956	160.47	180.39	142.3	125.4
1957	168.13	194.81	151.6	132.9

(1) Index numbers of real income, taking the average income for 1928~32 as 100.0

(2) Income data are taken from the estimate by Economic Planning Agency, and the numbers of workers from the third estimate of Bureau of Planning, Ministry of Agriculture and Forestry.

(3) Deflators from those of Economic Planning Agency, the base period of which are shifted from 1934~36 to 1928~32.

Analysing the regression of real income of primary industry (Y_1) upon real national income (Y), we get the following equation:

$$\log Y_1 = 0.4705 \log Y + 1.1663 \qquad (1.1)$$
$$r^2 = 0.7529$$

The elasticity coefficient of Y_1 upon Y is 0.47, which indicates the degree of inequality in growth rates among Y_1 and Y.

Table 2 shows the index numbers describing the behaviors of real income in five years average for the prewar period, 1878 through 1942. The base period for these index numbers are also taken in 1928 through 1932. Analysing these data, we get the following equation:

Table 2 *Unequal development* (*Prewar*)

Years	Aggregate income		Income per worker	
	Primary industry	National income	Primary industry	National average
1878~82	35.4	11.6	32.8	17.2
1883~87	38.0	14.8	33.9	20.3
1888~92	44.8	17.7	38.5	23.0
1893~97	57.2	23.5	48.9	29.1
1898~1902	68.5	29.9	58.0	35.4
1903~07	69.8	32.1	60.3	36.8
1908~12	79.5	39.8	71.3	44.6
1913~17	78.9	45.9	74.1	50.6
1918~22	93.9	58.6	93.1	63.2
1923~27	98.0	75.1	97.7	77.2
1928~32	100.0	100.0	100.0	100.0
1933~37	111.6	120.5	112.1	114.5
1938~42	123.0	145.5	125.9	132.4

(1) Index numbers of real income, taking the average income for 1928~32 as 100.0
(3) Source: K. Ohkawa and others, *The Growth Rate of Japanese Economy*.

$$\log Y_1 = 0.4882 \log Y + 1.0668 \quad (1.2)$$
$$r^2 = 0.9476$$

The elasticity coefficient of Y_1 upon Y is 0.48, which almost equal to that of postwar period.

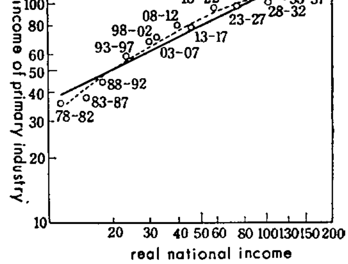

Fig. 1

However, as is clearly shown in Figure 1, a certain systematic bias is discernible among the dispersion of errors relating to the equation (1.2). The estimated values are lower than the observed ones for 1878~82 through 1888~92, then become higher for 1893~97 through 1923~27, and again decline lower for 1928~32 through 1938~42. It suggests the application of non-linear equation is preferable. The non-linear equation is estimated as follows:

$$\log Y_1 = 1.4940 \log Y - 0.3102 (\log Y)^2 + 0.2869 \quad (1.3)$$
$$r^2 = 0.9840$$

From this equation the said elasticity coefficient is estimated through the following equation:

$$EY_1/EY = 1.4940 - 0.6204 \log Y$$

This implies that the higher raises the level of national income, the lower declines the value of elasticity coefficient. In other words, as the national income develops, the degree of inequality in growth rates becomes larger. The average value of the coefficients is 0.49, which is almost equal to that obtained through the application of linear equation. However, the series of the values of coefficients clearly show downward tendency from the high value of 0.83 of 1878~82 towards the low value of 0.15 of 1938~42. Thus, we may state that the degree of inequality in growth rates in prewar period is not only considerably high in average, but growing through the course of economic development.

However, the inequality in growth rates among sectors of industries does not necessarily implies the growing income disparity among workers engaged in different sectors. If labor forces remove in adequate numbers from decling industries, the growing income disparity may possibly be held in check. It becomes our next problem to examine whether such possibility is realized or not.

While the average income per worker in primary industry was 0.554 of nation's average in the fiscal year of 1951, this rate has declined to 0.481 in the fiscal year of 1957. The disparity is clearly widening. Analysing the regression of the income per worker in primary industry (y_1) upon that of nation's average (y) for the postwar period, 1951 through 1957, we get the following equation:

$$\log y_1 = 0.6250 \log y + 0.8551 \qquad (1.4)$$
$$r^2 = 0.6250$$

The elasticity coefficient of y_1 upon y is 0.62, which is of course higher than that of Y_1 upon Y, but still lower than unity.

For the prewar period, 1878 through 1942, we get the following equation:

$$\log y_1 = 0.6713 \log y + 0.7018 \qquad (1.5)$$
$$r^2 = 0.9683$$

This equation is described as a straight regression line in Figure 2. Herein also discernible are the same sort of systematic errors, such as we noticed in Figure 1. In order to amend these systematic errors the non-linear equation needs to be applied. The result is as follows:

$$\log y_1 = 1.9569 \log y - 0.3816(\log y)^2 - 0.3508 \qquad (1.6)$$
$$R^2 = 0.9873$$

The elasticity coefficient is estimated through the following equation:

$$Ey_1/Ey = 1.9569 - 0.7632 \log y$$

The average value of elasticity coefficients is estimated 0.68, which is almost equal to 0.67 of the linear equation. However, the values of the coefficients show clearly downward tendency from the high value of 1.01 of 1878~82 towards the low value of 0.33 of 1938~42.

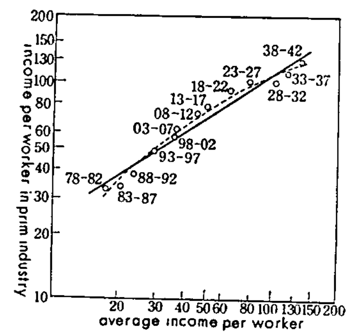

Fig. 2

The same sort of tendency will be discernible also in the behavior of agricultural income. We will try to estimate the degree of inequality in growth rates relating to agricultural income and analyse some strategic factors underlying the formation of agricultural income.

II *Dynamic analysis of agricultural income*

As the first step of our approach to the problem of unbalanced growth, we will compare the growth process of agricultural income to that of national income, and interprete the inequality in growth rates in terms of the comparative values of some strategic variables which play the important role in determining the growth rate of each process.

First, let us compare the actual rates of growth. Applying the logarithmic linear trend equation to the behavior of real national income for the fiscal years 1951 through 1957, we get the following equation:

$$\log Y = 3.74918 + 0.03102t$$

where t is year, taking 1954 as zero. From this equation the growth rate is estimated 7.40% per year. The trend equation for agricultural income is

$$\log Y_a = 2.88237 + 0.01095t$$

and its growth rate is 2.55%. And the behavior of agricultural income is related to that of national income through the equation:

$$\log Y_a = 0.3589 \log Y + 1.53679$$
$$r^2 = 0.7692$$

The elasticity coefficient of agricultural income upon national income is about 0.35. The correlation of this equation being weak, this coefficient has quite wide margin of errors, but we may safely state that the inequality in growth rates is quite substantial.

Then, we will explain the growth process of national income in terms of theoretical model of economic growth. The role of foreign trade being important, the growth process of Japanese economy cannot adequately be analysed through the application of the 'closed system' growth model of Harrod-Domar type. The growth model of ours must be that of 'open system'.

In the 'open system' the growth of national income depends not only upon the behavior of domestic investment, but also upon that of exports. The behavior of national income (Y) is related through the foreign trade multiplier process to the sum of domestic investment (V_d) and exports (X). The foreign trade multiplier equation is:

$$Y_t = k({}_dV_t + X_t) + h_1 \qquad (2.1)$$

where k is the foreign trade multiplier. If these explanatory variables, V_d and X, can be eliminated, the equation will be transformed into that of the growth behavior of national income.

Domestic investment (V_d) is related through the acceleration principle to the rate of increase in national income (ΔY). The acceleration equation is:

$$K_t = \beta Y_t + h_2 \qquad (2.2)$$

where K is national capital and β is accelerator. Therefore

$$\Delta K_t = \beta(Y_t - Y_{t-1})$$

${}_dV_t$ being equal to ΔK_t by definition, this equation is rewritten as follows:

$${}_dV_t = \beta(Y_t - Y_{t-1}) \qquad (2.3)$$

Next, exports (X) is related to imports (M) through the balance of trade equation, that is:

$$X_t = bM_t + h_3 \qquad (2.4)$$

And again M is related to Y through the import behavior equation:

$$M_t=\mu Y_t+h_4 \qquad (2.5)$$

where μ is the marginal propensity to import. Substituting the equation (2.5) for M in the equation (2.4), we get the equation explaining the behavior of X in terms of Y. That is:

$$X_t=b\mu Y_t+(h_3+bh_4) \qquad (2.6)$$

Substituting these equations, (2.3) and (2.6), for the explanatory variables in the equation (2.1), we get the following equation:

$$Y_t=\left[\frac{k\beta}{k(\beta+b\mu)-1}\right]Y_{t-1}-H \qquad (2.7)$$

which explains the growth behavior of national income. From this equation the average rate of growth will be estimated as:

$$\bar{G}_y=\left[\frac{1-kb\mu}{k(\beta+b\mu)-1}\right]-\frac{H}{\bar{Y}_{t-1}} \qquad (2.8)$$

These are the theoretical equations which we will try to apply to the economic data relating to the growth process of Japanese economy for the fiscal years 1951 through 1957.

Analysing the relevant economic data, as shown in Table 3, we get the following statistical equations, the values of which are expressed in units of million yen of prewar 1934~36 price level.

Table 3 *Growth process of national income*

Fiscal years	National capital	National income	Net capital formation	Exports	Imports
1951	33.798	15.423	3.623	2.072	1.853
1952	37.390	16.921	3.592	2.442	2.282
1953	41.099	17.866	3.709	2.695	3.174
1954	44.214	18.407	3.115	3.101	2.917
1955	48.288	20.564	4.074	3.584	3.377
1956	54.203	22.577	5.915	4.041	4.634
1957	60.841	24.169	6.638	3.839	3.996

(1) Unit: billion yen in the prewar price level of 1934~36.
(2) Net capital formation=gross capital formation−capital consumption allowances.
(3) National capital of 1955 is taken from Estimate of National Wealth by Economic Planning Agency. National capital of other years are estimated through adjusting the value of 1955 by the respective values of net capital formation.

[foreign trade multiplier] $Y_t=1.5514({}_dV_t+X_t)+7{,}796$, $r^2=0.9388$

[acceleration principle] $K_t=3.0037Y_t-12{,}635$, $r^2=0.9898$

[balance of trade] $X_t=0.7397M_t+790$, $r^2=0.8948$

[import behavior] $M_t=0.2896Y_t-2{,}447$, $r^2=0.9145$

Combining these equations, we get

[economic growth] $Y_t=1.1672Y_{t-1}-1{,}544$

and the average rate of growth is estimated 8.13%. This theoretical value is considerably higher than that of actual growth rate 7.40%. Margin of error is rather large.

If we would apply the same growth model to the analysis of agricultural sector, we could explain adequately the inequality in growth rates in terms of the comparative values of some strategic variables. But, owing to the shortage of adequate data relating to this sector, the application becomes quite difficult. We have to apply more simplyfied formula, that is, Harrod type simple formula: $G\beta=s$, where s is the average rate of capital formation.

The relevant data are shown in Table 4. The values of agricultural capital are annual values, but those of agricultural income are expressed as three years· moving averages. The units for both series are 100 million yen of the price level of 1952.

Table 4 *Agricultural capital and income (Postwar)*

Fiscal years	Agricultural capital	Agricultural income
1951	14,534	7,668
1952	15,060	7,338
1953	15,353	7,187
1954	15,853	7,505
1955	16,901	7,988
1956	18,605	8,492
1957	19,150	8,497

(1) Unit: 100 million yen in the price level of fiscal year 1952.
(2) Source: data prepared for Agricultural Outlook Service by Bureau of Statistics and Research, Ministry of Agriculture and Forestry.

Analysing the regression of agricultural capital (K_a) upon agricultural income (Y_a), we get the following acceleration equation:

$$ {}_aK_t=3.0689{}_aY_t-7,476 $$
$$ r^2=0.9096 $$

From this equation the value of accelerator is estimated 3.0. However, the coefficient of determination being 0.9096, the correlation of this equation is not satisfactorily strong. The theoretical hypothesis underlying this regression equation is valid, but the observation errors are not to be ignored. These errors may probably make the value of accelerator lower than that of unbiased estimation. To amend this bias of underestimation, we will divide the value of accelerator by the coefficient of correlation. The adjusted acceleration equation is as follows:

$$ {}_aK_t=3.3739{}_aY_t-9,858 $$

The adjusted value of accelerator is 3.3.

Next, we will estimate the value of the average rate of capital formation. Applying the linear trend equation to the time series data of agricultural capital, we get the following equation:

$$ {}_aK_t=16,493+803t $$

where t is year, taking 1954 as zero. The value of agricultural capital formation is estimated 80.3 billion yen per year. The average annual value of agricultural income is 781 billion yen. Thus, the rate of capital formation is estimated 10.28%.

Dividing this value of the rate of capital formation by that of accelerator, we get the estimation of the growth rate of agricultural income. The result is 3.04% per year. Again this theoretical value of the growth rate is considerably higher than the actual one. And the growth rate of agricultural income, 3.04% is 0.37 of that of national income. The inequality in growth rates is quite substantial.

Comparing the results of these two estimations, we get the following informations of the factors underlying the inequality in growth rates. (1) The values of accelerators are almost same in these two estimations. The value of accelerator of national capital is 3.0, and that of agricultural capital is 3.3. While the accelerator is $\Delta K/\Delta Y$, the inverse of that value signifies the marginal productivity of capital. Thus, the sameness of accelerators implies the equality in the marginal productivity of capital between agriculture and national economy. (2) However, there is a marked difference in the rates of capital formation. Though we have not estimated directly the rate of capital formation in the dynamic analysis of national income, the value of this coefficient can be computed easily from the data of national capital and income. The average rate of national capital formation is 22.5%, which is much higher than that of agricultural capital. The latter is 0.45 of the former. This difference in the rates of capital formation is the strategic factor underlying the inequality in growth rates. Thus we have to make clear the reason why the rates of capital formation differ so much.

III *Capital formation and technical progress*

Having analysed the behavior of agricultural income during the postwar years 1951 through 1957, we obtain the estimated value of the growth rate, 3.04% per year, which is much lower than that of national income. However, this wide difference in growth rates does not imply that the production conditions of agriculture have been quite unfavorable and the technological level remains stationary through these years. Contrary is the truth. Conditions are rather favorable and technical progress is considerably rapid during these years. We will make clear these facts through the comparison with the development of agriculture in prewar years.

Picking out the years 1921 through 1932 as a sample of the prewar period, we will apply the same procedure of analysis to the data relating to the behavior of agricultural in-

Table 5 *Agricultural capital and income (Prewar)*

Years	Agricultural capital	Agricultural income
1921～23	4,999	1,825
1922～24	5,020	1,768
1923～25	5,207	1,841
1924～26	5,602	1,865
1925～27	5,962	1,879
1926～28	6,164	1,924
1927～29	5,937	2,160
1928～30	6,233	2,137
1929～31	6,671	2,160
1930～32	6,942	2,021

(1) Unit: million yen in the price level of 1928～32.
(2) Agricultural capital from the estimate of Mr. Noda. Agricultural income from Ohkawa and others, *The Growth Rate of Japanese Economy.*

come during these years. These years lie between the termination of the First World War and the Great Depression. During these years the economic conditions are stable. The relevant data are shown in Table 5. The values of agricultural capital and income are both expressed in the three years moving average. The unit for these values is million yen of the price level of 1928 through 1932.

Analysing the regression of agricultural capital (K_a) upon agricultural income (Y_a), we get the following acceleration equation:

$$_aK_t=3.3333_aY_t-652.9$$
$$r^2=0.6572$$

The value of accelerator is estimated 3.3. However, the coefficient of determination is 0.6572 and the correlation is rather weak. Using the same procedure of adjustment, we will divide the value of accelerator by the coefficient of correlation. The adjusted acceleration equation is:

$$_aK_t=4.1121_aY_t-2,177.7$$

And the revised value of accelerator is 4.1, which is considerably higher than that of postwar 3.3. This may suggest that the marginal productivity of capital is lower in prewar years than in postwar years.

Applying the linear trend equation to the series of agricultural capital data, we get the equation:

$$_aK_t=5,766.5+214.4t$$

where t is year, taking 1925~27 as zero. The annual value of capital formation is estimated 214.4 million yen. Dividing this value by the average annual value of agricultural income, 1,985 million yen, we get easily the estimation of the average rate of capital formation, the result of which is 10.94%. This seems a little higher than that of postwar period. However, we must be careful over such a comparison. The prewar data of agricultural capital have upward bias. They estimated the length of life considerably longer in prewar period than that of the same type of capital goods of postwar period. And they underestimated the amount of depreciation.

From these values of accelerator (β) and the average rate of capital formation (s), we can easily estimate the value of growth rate (G). G is 2.66%. This value of G is considerably higher than the result of estimation obtained directly from the application of logarithmic linear trend equation.

The logarithmic linear trend equation for the series of agricultural income during the same period is:

$$\log {_aY_t}=3.28604+0.00929t$$

where t is year, taking 1925~27 as zero. From this equation the actual rate of growth is estimated 2.16%, which is 0.50% smaller than the theoretical value of 2.66%.

Comparing the results of the analysis of the prewar data to that of the postwar data, we get the following informations. (1) The growth rate of prewar period is slightly lower than that of postwar period. (2) The accelerator of the former is considerably higher than that of the latter. (3) The rate of capital formation of the former is a little higher than that of the latter. So far we may conclude that the difference in the values of accelerator is the strategic factor which explains mainly the different values of growth rates among these two periods. However, this conclusion is only a tentative one. In order to test the validity of this statement, we have to examine further the conditions underlying the production and progress of agricultural income for respective periods.

Table 6 *Productivity in agriculture (Prewar)*

Years	Output per worker	Land per worker	Capital per worker
1921~23	173.4	4.298	353.4
1922~24	169.6	4.299	355.6
1923~25	177.5	4.295	368.8
1924~26	177.5	4.303	396.7
1925~27	180.0	4.306	422.2
1926~28	180.4	4.310	436.8
1927~29	199.3	4.268	420.5
1928~30	195.3	4.226	436.8
1929~31	198.0	4.180	465.6
1930~32	186.9	4.177	482.5

(1) Unit for output and capital is 1 yen of 1928~32 price level, and that for land is 1 tan.
(2) Cultivated land from *Fundamental Statistics of Agriculture*, Kayo ed., capital from Mr. Noda's estimate, and others from Ohkawa and others, *The Growth Rate of Japanese Economy*.

Table 6 shows the per capita values of agricultural output (o), land (a) and capital (k) for the period 1921 through 1932. All these values are expressed in yen of 1928~32 years price level.

Applying the logarithmic trend equations to these time series data, we get the following equations:

(per capita output) $\log o = 2.2636 + 0.00681t$
(per capita land) $\log a = 1.6306 - 0.00146t$
(per capita capital) $\log k = 2.6069 + 0.01521t$

From these equations the annual rates of increase for the respective series of data are estimated as follows: per capita output 1.58%, per capita land minus 0.34%, and per capita capital 3.56%.

Analysing the correlation of these series of data, we get the following production function equation:

$$\log o = 0.3779 \log a + 0.3623 \log k + 0.0013t + 0.4531$$
$$R^2 = 0.6787$$

where t is year, taking 1925~27 as zero. Assuming that t represents the shift variable relating to the production function, we may obtain from this equation the estimation of the rate of technical progress, the result of which is 0.3% per year.

Then comes the analysis of the postwar data. The relevant data are shown in Table 7. The logarithmic linear trend equations for the respective series of data are as follows:

(per capita output) $\log o = 2.8524 + 0.01843t$
(per capita land) $\log a = 1.6963 + 0.00285t$
(per capita capital) $\log k = 3.0155 + 0.01834t$

And the annual rates of increase are respectively as follows: per capita output 4.34%, per capita land 0.66%, and per capita capital 4.31%. It is noteworthy that the rate of increase of per capita capital is almost equal to that of per capita output. Analysing the regression of o upon k, we get the following equation:

Table 7 *Productivity in agriculture (Postwar)*

Fiscal years	Output per worker	Land per worker	Capital per worker
1951	662.4	5.002	951.8
1952	650.3	4.965	969.1
1953	651.6	4.770	957.2
1954	679.9	4.888	985.8
1955	739.5	4.916	1,044.3
1956	794.8	5.081	1,165.3
1957	826.5	5.185	1,212.7

(1) Unit for output and capital is 100 yen of 1951 price level, and that for land 1 tan.
(2) Values of output are those of three years moving averages.
(3) Original data relating to output, capital and cultivated area are taken from estimate of Bureau of Statistics and Research, Ministry of Agriculture and Forestry; and numbers of agr. workers from the third estimate of Bureau of Planning, the said Ministry.

$$\log o = 0.9874 \log k - 0.1251$$
$$r^2 = 0.9689$$

The elasticity coefficient of o upon k is almost equal to unity. This implies that Japanese

Table 8 *Production function of agriculture (1957)*

Area	Output per hour	Capital per hour	Land per hour
Rp, NE	69	145	89
Rh, NE	53	139	75
H, NE	41	114	50
F, NE	38	172	54
U, Kanto	43	113	82
Rp, Kanto	52	117	80
Rh, Kanto	42	119	61
H, Kanto	33	108	53
F, Kanto	41	95	58
U, Kansai	55	163	93
Rp, Kansai	49	142	82
Rh, Kansai	43	132	71
H, Kansai	35	136	72
F, Kansai	44	167	59
U, SW	48	157	104
Rp, SW	41	102	77
Rh, SW	33	93	65
H, SW	32	93	58
F, SW	30	88	55

(1) Unit: 1 yen per labor hour.
(2) Denotions are as follows: NE north east district, SW south west district, Rp agricultural village in the plains, Rh agr. village in the hillside, H village in the mountains, and F fishing village.
(3) Source: *Farm Household Economy Survey for 1957.*

agriculture has recently carried out the technical progress of neutral type. In order to estimate the rate of technical progress we have tried to apply the same type of production function equation to these postwar data, but failed to arrive at the satisfactory result. Where each series of data show clearly time trends, the multi-collinearity prevents us to obtain the statistically significant estimation through the correlation analysis of time series data. We have to apply another type of procedure.

Table 8 shows the cross section data relating to the per labor hour values of agricultural income, land and capital for the fiscal year of 1957. Applying the production function equation, we get the following result:

$$\log y_a = 0.5416 \log a + 0.3750 \log k - 0.0105$$

$$(0.1411) \qquad (0.1411)$$

$$R^2 = 0.6997$$

Where the figures put in parenthesis show the standard errors of each parameters. It is clear that the values of each parameters are statistically significant in 2% error level.

In case there are no technical progress, this equation should be equally applicable to the data of other years. However, if any systematic bias appear in the errors of such application, it indicates that production functions shift through these years. In such case we may be able to estimate from systematic tendency in errors the behavior of shift in technological levels.

Table 9 *Technical progress in agriculture*

Fiscal years	Agricultural income per hour		
	estimated ($\hat{y}_a$)	observed (y_a)	$d=y_a/\hat{y}_a$
1951	47.43 (yen)	45.78 (yen)	96.52 (%)
1952	43.44	42.72	89.34
1953	46.39	38.33	82.62
1954	48.71	42.76	87.78
1955	49.53	52.33	105.65
1956	51.41	50.75	98.71
1957	52.78	52.78	100.00
1958	53.40	54.51	102.07

Unit: yen in the price level of 1957.

Applying this production function equation to the relevant data of years 1951 through 1953, we get the estimated values of per labor hour income $\hat{y}_a$ for each years, and then divide the observed values of y_a by these estimated values of $\hat{y}_a$, the results of which are denoted as d. (see: Table 9) These values of d indicate the shift in technological levels that may occur between 1957 and other years. If we could make clear the upward tendency in these values of d 1951 through 1958, we could estimate the rate of technical progress.

The logarithmic linear trend equation, as applied to these values of d, is estimated as follows:

$$\log d = 1.9800 + 0.00617t$$

From this equation the rate of technical progress is estimated 1.53%. Where the procedures of estimation are not the same, we must be careful over the comparison of results. However, the difference in the estimated value of the rate of technical progress is so wide that we may be entitled to state that the technical progress is more rapid in postwar period than in prewar period.

Thus conditions are somewhat improved, but the rate of capital formation still remains much lower in agricultural sector than that in national economy as a whole. We must try to find out some causes, specific to agricultural sector, which hold the rate of capital formation in check. As the first step of our approach we will estimate the rate of profit and then compare this to the rate of interest prevailing in agricultural sector.

The above mentioned equation of production function of 1957 may again be used in estimating the rate of profit of agriculture. If the marginal productivity principle is valid, we may compute the share of profit from the parameter attached to capital input. The amount of agricultural profit (P_a) is estimated 37.50% of agricultural income (Y_a). That is: $\bar{P}_a=0.3750\bar{Y}_a$. We assume this relation is normal one during the period, fiscal year 1951 through 1958. For this period the average value of agricultural capital was 1,681.8 billion yen in 1952's price level and that of agricultural income 795.1 billion yen in the same units. Therefore, the average capital coefficient ($\bar{K}_a/\bar{Y}_a$) is estimated 2.12. Dividing the both sides of the said equation of agricultural profit by the value of $\bar{K}_a$, we get the estimation of the rate of agricultural profit (ρ_a). The result is: $\rho_a=17.68\%$.

For the same period the medium value of loan rates of agricultural cooperatives is estimated 11% per year. The loan rates of public financial institutions are generally a little lower than this rate. They ranges mostly from 5% through 9%. Thus, the estimated rate of profit seems reasonably higher than the rates of interest prevailing in agricultural sector. If this inference is valid, agricultural investment seems profitable. But we must be careful in forming our conclusion over such matter.

In estimating the rate of profit we have assumed the validity of the marginal productivity principle. This assumption have to be re-examined. This principle presupposes that farmers have the prefect freedom in rationally allocating the amount of input of labor and other resources. However, in fact, farmers cannot freely allocate the labor input. Almost 95% of the labor input comes from family labor. The size of family labor is predetermined. Even if farmers leave some of their family labor unemployed, they must provide them the means of livelihood. Whether rational or not, they have to somehow utilize their family labor. And the result is too much input of labor into their farming. The 'over-employment' of labor is a familiar feature of Japanese agriculture. Under such malallocation of resources the validity of the marginal productivity principle becomes quite doubtful.

According to our equation of production function, the share of labor is estimated theoretically 0.0834 of agricultural income. In 1957 the agricultural income per labor hour was only 52.78 yen in the average. If the share of labor is 0.0834 of this income, the remuneration of labor becomes incredibly small amount of 4.40 yen per hour. In the same year the average wage rate was estimated 103.1 yen per hour among industrial workers. This is 1.953 times of the average agricultural income. Even if the whole of agricultural income is distributed as the remuneration of labor, that rate of earning is only 51.2% of the average wage rate of industrial workers.

In order to enhance the agricultural income as high as the industrial wage rate, we must remove the 'over-employed' surplus labor from the agricultural sector. How many are such surplus labor? We will try to estimate.

If the total input of land and capital remains constant, their input per labor hour may be raised x times as high, when the total input of labor is decreased to $1/x$ times of the present numbers. Let us assume that the agricultural income per hour (y_a) becomes equal to the average wage rate of industrial workers (w), when the per hour input of land and labor is raised x times as high. Thus, we get the following equation:

$$\log w = 0.5416 \log (x \cdot a) + 0.3750 \log (x \cdot k_a) - 0.0105$$

This equation can be rewritten as:

$$\log x = \frac{1}{0.9166}[\log w - \log y_a]$$

From this equation the value of x is estimated 2.0735, and hence that of $(1/x)$ is 0.4822. This implies the optimal size of employment is 0.4822 of the present size. In 1957 the total number of agricultural employment are 15.36 million. Out of this 15.36 million, 7.95 million are 'over-employed' surplus labor, which hold agricultural investment in check.

So far as more than half of the total employment can be regarded as surplus, the estimated rate of profit cannot have incentive power for farmers. However high the rate of profit be estimated, that rate cannot be the criterion of investment in agricultural sector.

IV *Demand for food and agricultural income*

The demand behavior for food is one of the strategic factors explaining the comparatively lower rate of growth in agricultural income. The income elasticity coefficient of food demand being less than unity, the growth rate of agricultural income is held in check and suppressed to the value lower than that of national income. This relationship has long been known as Engel's law. In this section we will try to apply this law to the behavior of Japanese agricultural income and explain the demand side factors underlying the inequality in growth rates. However, in applying this law, we have to take into our considerations the various factors, which, though often being omitted from the simplified formulation of this law, play important role in connecting the aggregate household expenditures for food and the formation of agricultural income.

The aggregate household expenditures for food determine not directly, but indirectly through the processing and marketing mechanism, the formation of agricultural income. Considerable parts of these expenditures leak out and only less than half of them are shared by farmers. The magnitude of the farmer's share is, of cause, determined through the working of this mechanism. Some of the outstanding factors relating to its working are as follows.

(1) The food stuffs consumed by household are not entirely of domestic agricultural products. Some of them come from imported food products, and others from domestic, but not agricultural, products, such as forestry and fishery products. (2) The food expenditures of household are not paid directly to farmers, but indirectly through the hands of processers and dealers. Some of them are spent for processing and marketing services. (3) The gross returns of farmers are not same as their net income. Out of their gross returns they must pay their farming expenses. All these factors make some of the total expenditure leak out and suppress the relative share of farmers.

However, if the relative share of farmers is constant through time, we need not bother about the leakage of food expenditures in analysing the comparative growth rate of agricultural income. Suppose that the agricultural income (Y_a) is w per cent of the total food expenditure (F) and this percentage does not change, the growth rate of Y_a is equal to that of F. But whether this percentage is constant or not is the matter we must make clear through quantitative analysis of the relevant data. And if this share is not constant, it becomes important for us to examine carefully the behaviors of factors determining this share. Recently in Japan the pattern of consumption, as well as the type of farming, have undergone structural changes. So-called westernization of food consumption pattern tends to enhance the cost of processing. And the mechanization of agricultural production lowers the rate of net income. Both bring about the declining share of farmers. In formulating our working hypothesis, we must pay due considerations to such structural changes.

Our formulas are as follows. First, the total food expenditure (F) is related to national income (Y) through the formula (4.1)

$$\log F = a \log Y + h_1 \qquad (4.1)$$

where a is the income elasticity coefficient of food demand. Probably a is less than unity. Second, the agricultural output (O) is related to the total food expenditure (F) through the formula (4.2)

$$\log O = b \log F + h_2 \qquad (4.2)$$

If b is less than unity, it may suggest that the dependence on imported food and/or the cost of processing and marketing become more important. Third, the agricultural income (Y_a) is related to the agricultural output (O) through the formula (4.3)

$$\log Y_a = c \log O + h_3 \qquad (4.3)$$

The less than unity value of c implies the declining rate of income of agriculture.

Combining these formulas, we get the following formula (4.4), which relates the behavior of agricultural income to that of national income.

$$\log Y_a = abc \log Y + H_1 \qquad (4.4)$$

Of course, we may get the formula directly relating these two variables, Y_a and Y, that is:

$$\log Y_a = \lambda \log Y + H_2 \qquad (4.5)$$

This is no other than the formula of inequality in growth rates. If the value of λ is almost

Table 10 *Expenditures for food and agricultural income*

Fiscal years	National income	Expenditure for food	Agricul. output	Agricul. income
1951	4,525.2	1,806.9	1,020	750.3
1952	4,965.7	2,017.8	1,016	718.0
1953	5,244.3	2,192.5	1,033	703.2
1954	5,401.3	2,196.4	1,090	734.3
1955	6,016.1	2,342.8	1,175	781.6
1956	6,541.0	2,474.0	1,248	830.9
1957	7,007.3	2,532.9	1,263	831.4
1958	7,421.0	2,667.6	1,315	874.3
1959	8,576.1	2,761.4	1,362	907.3

(1) Unit: 1 billion yen of 1951 price level.
(2) Source: data prepared for Agricultural Outlook Service by Bureau of Statistics and Research, Ministry of Agriculture and Forestry.

equal to that of *abc*, we may interprete the value of λ in terms of these three parameters a, b and c; and explain the inequality in growth rates through the demand behavior for food and related propagation mechanism.

The data relevant to these formulas are shown in Table 10. These data cover the fiscal years 1951 through 1959. The average values are as follows: national income 6,188.6 billion yen, food expenditure 2,332.4 billion yen, agricultural output 1,169.1 billion yen and agricultural income 792.3 billion yen. The average propensity for food expenditure is 37.68% and agriculture's share of national income is 12.31%. The latter is about one third of the former.

Analysing these data, we get the following statistical equations:

$$\log F=0.6375 \log Y+0.9526 \qquad (4.1.1)$$
$$r^2=0.9434$$
$$\log O=0.7906 \log F+0.4056 \qquad (4.2.1)$$
$$r^2=0.8857$$
$$\log Y_a=0.7589 \log O+0.5710 \qquad (4.3.1)$$
$$r^2=0.9310$$

Combining these equations, (4.1.1) through (4.3.1), we get the equation explaining the relationship between agricultural income and national income.

$$\log Y_a=0.3852 \log Y+1.4503 \qquad (4.4.1)$$

Analysing directly the same relationship, we also get the following equation:

$$\log Y_a=0.4007 \log Y+1.3814 \qquad (4.5.1)$$
$$r^2=0.8723$$

Comparing these two equations, the elasticity coefficient of equation (4.5.1) is slightly higher than that of equation (4.4.1), but the error is not so large.

From these results of estimation, we get the following informations. (1) If the farmers' share of nation's food expenditure remains constant through these years, the growth rate of agricultural income may be 0.63 of that of national income. But (2) because of the declining tendency in that share, this rate is suppressed to the low value of 0.40. Such are the behaviors of the demand side factors which explain the comparatively lower growth rate of agricultural income.