Staff Paper Series

STAFF PAPER P74-11 JUNE 1974

POPULATION EFFECTS ON THE ECONOMIC DEVELOPMENT OF JAPAN

by
Mitoshi Yamaguchi

Department of Agricultural and Applied Economics

University of Minnesota
Institute of Agriculture
St. Paul, Minnesota 55101

Staff Paper P74-11 June 1974

POPULATION EFFECTS ON THE ECONOMIC DEVELOPMENT OF JAPAN

Mitoshi Yamaguchi

Staff Papers are published without formal review within the Department of Agricultural and Applied Economics.

Mr. Yamaguchi is currently Assistant Professor in Kobe University, Japan, Economics Department. Research for this paper was supported by the U.S. Agency for International Development through a grant to the University of Minnesota Economic Development Center. The conclusions do not necessarily reflect the position of USAID.

Population Effects on the Economic Development of Japan

Mitoshi Yamaguchi

1. Introduction

For most of human history, the number of annual births and deaths was very similar, causing population to grow at a very slow rate. Since the 18th Century world population has been growing at an increasing rate. In addition, death rates of the less developed nations began to drop in the late 1930's and early 1940's, while birth remained high. As a consequence, the rate of population growth increased rapidly. Few signs of a slow down can be observed in the less developed countries. Indeed the estimated population in 1970 was actually slightly higher than earlier projection had anticipated.

In Japan we can observe three periods with distinct demographic trends since the beginning of the Meiji period, i.e., from 1868 to World War I, the period between the two World Wars, and the Post World War Two period (Table 5). In the first period, both the birth rate and the death rate increased. This is an unusual demographic experience. The reasons for this observed increase may be that: (1) The birth and death rates in the beginning of economic development are likely to be underestimated in official statistics, (Morita (1963)). (2) The Sino-Japanese War and Russo-Japanese War may actually have caused the death rate and birth rate to increase. (3) Abortion and infanticide prevailed illegally in the beginning of the Meiji and the Edo (before 1868) eras, and were outlawed thereafter, which may have caused the increased birth rates. (4) The government encouraged people to have more babies to compensate for the large population decreases which occurred because of wars.

Generally (1) is regarded as the major reason, as Morita (1963) shows, but (2), (3) and (4) may also be part of the explanation.

In the second period, the so-called demographic transition started to occur, i.e., both birth and death rates started to decline.[1/] But this pattern was disturbed during World War II and the immediate postwar period. There was a large increase in birth rate for 1948 and 1949, referred to as "the baby boom." However, the baby boom was of short duration. After 1950 the demographic transition in Japan speeded up and by 1955 the Japanese birth rate and death rate were almost equal to those of advanced countries which had experienced the demographic transition earlier.

The Japanese birth and death rates implied the following population growth rates (See Table 5). From 1880 to 1900 it was 0.9 percent per year while from 1900 to 1960 it fluctuated between 1.1 and 1.5 percent per year. This compares very favorably with the population growth rates experienced by today's less developed countries. Coupled with relatively high rates of technical change this favorable experience led to rapid growth in per capita income.

In this paper we are going to measure how Japanese population growth affected economic development in a general equilibrium context. We distinguish between population growth and labor growth in order to find the effects of population growth and labor participation independently. This leads to richer and somewhat different conclusions than the usual growth theories which assume that the growth rates of population and labor are equal. In such models increase in population can only have a detrimental effect due to diminishing returns to labor. But such diminishing returns set in at very slow rates when elasticities of substitution are large. Models based on a population-growth-equal-labor-growth assumption thus lead to optimistic conclusions of the effect of population growth on per capita income growth. A good example of this approach and optimism is the model of Kelley and Williamson (1973), a model which otherwise has much in common with our approach. However when findings are extrapolated to population growth rates of the order of three percent, the assumption that labor participation rates will be stable is very questionable.

Our model is stated briefly in Section (2). The empirical results based on our model are given in Section (3), and Section (4) summarizes results and presents the conclusions.

2. Model

The model is discussed in detail in Yamaguchi (1973) or Yamaguchi and Binswanger (1974a). It is an agricultural-nonagricultural two sector model and is an extension of the Tolley-Smidt (1964) and Kelley-Williamson (1973) models developed for application to our problem. The model is constructed to permit an evaluation of the effects of technical change, population, and labor growth on per capita income, and the flow of physical and human resources among sectors through product and factor markets for every decade for the period 1880-1965. In contrast to the Kelley and Williamson model (1972), agricultural and nonagricultural technical change are treated independently, and the labor participation rate is not assumed to be fixed.[2/] The period covered extends from 1880 to 1965. Much of the empirical analysis focuses on the change in economic structure over time rather than simulation on a fixed structure.

In our model, the rate of technical change in agriculture, technical change in nonagriculture, population growth, total growth of labor, and the rate of total capital accumulation are regarded as exogenous variables. Given the rates of change of these variables our model determines endogenously the following variables: agricultural and nonagricultural output, real per capita income, the allocation of total labor and total capital among sectors, and the terms of trade (agricultural price/nonagricultural price).

The notations are summarized in Table 1. The other main features of our model are: (1) The demand function for agricultural goods is specified as a per capita demand function multiplied by the total population (Q). The per capita demand function includes a demand shifter (a) which captures autonomous changes in tastes which cannot be explained by population (Q), per capita income (E), and terms of trade (P). (2) The agricultural production function contains land (B), labor (L_1), and capital (K_1) as factors of production. But land is not included in the production function of the nonagricultural sector. (3) Factor market distortions are assumed to exist. In particular, labor only migrates from agriculture to the nonagricultural sector in response to a positive wage differential. (4) The economy is closed.[3/]

The state version of the model is summarized as follows: Subscript 1 refers to agricultural while subscript 2 refers to nonagricultural sector.

Agricultural demand function (1) $Y_1 = f\ (a, Q, P, E)$

$$= a\ Q\ P^{\eta}\ E^{\varepsilon}$$

Agricultural production function (2) $Y_1 = g\ (T_1, L_1, K_1, B)$

$$= T_1\ L_1^{\alpha},\ K_1^{\beta}\ B^{(1-\alpha-\beta)}$$

Nonagricultural production function (3) $Y_2 = h\ (L_2, K_2, T_2)$

$$= T_2\ L_2^{\gamma}\ K_2^{\delta}$$

Adding up constraint (4) $L_1 + L_2 = L = Q - N$

Table 1: SUMMARY OF NOTATIONS

Let i = 1 be the agricultural sector and i = 2 the nonagricultural sector

a	= Demand shifter for agricultural products
B	= Land
E	= Real disposable per capita income
K_i	= Sectoral capital stock
K	= Total private capital stock
L_i	= Sectoral labor force
L	= Total private sector labor
m_r	= Ratio of the return to capital in agricultural sector to the return in nonagricultural sector
m_{Ki}	= Ratio of the return on capital to its marginal revenue product in each sector
m_w	= Ratio of earnings of labor in the agricultural sector to labor earnings in the nonagricultural sector
m_{Li}	= Ratio of earnings of labor to its marginal revenue product in each sector
N	= Population not participating in the labor force
N_r	= Ratio of capital earnings to marginal revenue product in agriculture divided by comparable ratio for nonagricultural sector
N_w	= Ratio of labor earnings to marginal revenue product in agriculture divided by comparable ratio for nonagricultural sector
P_1	= Price of agricultural output
P_2	= Price of nonagricultural output
P	= Ratio of price of agricultural products to price of nonagricultural output
P'	= General price level
Q	= Population
r_i	= Return per unit to capital in each sector
T_i	= Technical change in each sector
w_i	= Sectoral wage rates
Y_1	= Agricultural output
Y_2	= Nonagricultural output
α	= Labor's share in agriculture
β	= Capital's share in agriculture
γ	= Labor's share in nonagriculture
δ	= Capital's share in nonagriculture
λ	= Share of income produced in agriculture
η	= Price elasticity of agricultural goods
ε	= Income elasticity of agricultural goods

	(5) $K_1 + K_2 = K$
	(6) $w_1 = P_1 \, m_{L_1} \, g_{L_1}$
Proportionality of value of marginal product to factor price	(7) $w_2 = P_2 \, m_{L_2} \, h_{L_2}$
	(8) $r_1 = P_1 \, m_{K_1} \, g_{K_1}$
	(9) $r_2 = P_2 \, m_{K_2} \, h_{K_2}$
Factor mobility condition	(10) $w_1 = m_w \, w_2$
	(11) $r_1 = m_r \, r_2$
Income identity	(12) $P_1 \, Y_1 + P_2 \, Y_2 = P'QE$

All functional forms are Cobb-Douglas. This implies neutral technical change in each sector. The introduction of market imperfections, however, has important implications: Johnson (1966) showed that, if one combines two Cobb-Douglas production functions into a transformation curve, the result is a transformation curve with very little curvature, unless one chooses output elasticities which differ radically between the sectors. Furthermore, if one adds a market imperfection between the two sectors, the transformation curve can easily lose its curvature and may, indeed, become convex rather than concave to the origin. In the Japanese example considered here the transformation curve is almost a straight line, which implies that changes in consumption patterns have little influence on the terms of trade. This is important to the interpretation of the results.

The static version can be transformed into the dynamic model of Table 2 by transforming the model into proportional changes. The number of equations is reduced to eight because equations (6) to (11) can be combined

Table 2: A matrix exposition of a reduced agriculture-nonagriculture two sector model.

$$
\begin{array}{l}
(13)\\ (14)\\ (15)\\ (16)\\ (17)\\ (18)\\ (19)\\ (20)
\end{array}
\begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & -\eta & -\varepsilon \\
1 & 0 & -\beta & 0 & -\alpha & 0 & 0 & 0 \\
0 & 1 & 0 & -\delta & 0 & -\gamma & 0 & 0 \\
0 & 0 & 0 & 0 & \frac{L_1}{L} & \frac{L_2}{L} & 0 & 0 \\
0 & 0 & \frac{K_1}{K} & \frac{K_2}{K} & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & -1 & -1 & 1 & 0 & 0 \\
0 & 0 & \gamma-\alpha & 0 & \alpha-\gamma & 0 & 1 & 0 \\
\lambda & 1-\lambda & 0 & 0 & 0 & 0 & 0 & -1
\end{pmatrix}
\begin{pmatrix}
\dot{Y}_1 \\ \dot{Y}_2 \\ \dot{K}_1 \\ \dot{K}_2 \\ \dot{L}_1 \\ \dot{L}_2 \\ \dot{P} \\ \dot{E}
\end{pmatrix}
=
\begin{pmatrix}
\dot{a} + \dot{Q} \\
\dot{T}_1 + (1-\alpha-\beta)\dot{B} \\
\dot{T}_2 \\
\dot{L} \\
\dot{K} \\
\dot{N}_w - \dot{N}_r \\
\dot{T}_2 - \dot{T}_1 - (1-\alpha-\beta)\dot{B} + \delta\dot{N}_r + \alpha\dot{N}_w \\
\dot{Q}
\end{pmatrix}
$$

We can also write this matrix as follows: $A \quad x \quad = \quad b$

Where A: 8 x 8
x: 8 x 1
b: 8 x 1

into two equations leading to equations (18) and (19) of the matrix equation in Table 2.[4/]

The model now has the general form

$$(21) \qquad Ax = b$$

where A is a matrix of structural parameters, x is a vector of rates of change of endogenous variables, and b is a vector of rates of change of the exogenous variables (in some cases also weighted by structural parameters).

The inverse of A displays what we call growth-rate multipliers (GRM). As an example, the $(A^{-1})_{8,4}$ element is $\partial\dot{E}/\partial\dot{L}$, which indicates by how much the rate of change of nonagricultural output increases due to an increase in the rate of labor growth.[5/] The behavior of these growth rate multipliers tells us how each exogenous variable influences each endogenous variable in the general equilibrium context. Since the parameters of the A matrix change over time, we can see how these growth rate multipliers have changed over time. Growth rate multipliers were obtained for each five-year interval from 1880 to 1965.

Multiplying the growth rate multipliers of each decade by the corresponding decadal rates of change of the exogenous variables as they occurred in Japan gives us measurements of the contribution of the exogenous variables to the observed rate of changes of the endogenous variables, i.e.,

$$(22) \qquad (\partial\dot{E}/\partial\dot{L})^t \cdot \dot{L}^t = (A^{-1})^t_{8,4} \cdot \dot{L}^t = C_{EL}$$

where C_{EL} is the measured contribution of labor to per capita income growth at time (t).

Simulation or counterfactual analyses are performed by substituting simulated growth rates of the exogenous variable for the actual growth rates in equation (22). The difference between the simulated and the actual contribution to an endogenous variable is then added to the observed change of the endogenous variable to arrive at the path of the endogenous variable under the counterfactual simulation. This constitutes simulation with a changing structure.

3. Empirical Results

In this section, we observe the effects of population and labor growth on the Japanese economy for per capita income, sectoral labor, and capital allocation among the agricultural and the nonagricultural sector, and the terms of trade in each five year period between 1880 and 1965.

The structural parameters used and the observed growth rates of the endogenous and the exogenous tables are given in Tables 3, 4 and 5.

Nonagricultural sector is more labor intensive than the agricultural sector throughout the whole period in Japan ($\gamma > \alpha$). This small labor share in agriculture results from the fact that agricultural sector uses land, capital and labor as inputs but nonagricultural sector uses only capital and labor. The price and income elasticities are almost constant over time as Kaneda showed. The share of income produced in agriculture decreases from 47% in 1880 to 8% in 1965.

Overall growth rate of nonagricultural output and rate of nonagricultural output and rate of nonagricultural technical change are greater than those of agricultural ones. However, the growth rate of agricultural output and rate of technical change are more stable from decade to decade. Growth rate of nonagricultural labor is positive but that of agricultural labor is negative, especially after World War I. Agricultural labor migrates

Table 3. Parameter values of matrix A

Year	(1) Labor's share in agric. output $\alpha = \frac{w_1L_1}{Y_1}$	(2) Capital's share in agric. output $\beta = \frac{r_1K_1}{Y_1}$	(3) Labor's share in nonagric. output $\gamma = \frac{w_2L_2}{Y_2}$	(4) Capital's share in nonagric. output $\delta = \frac{r_2K_2}{Y_2}$	(5) Price elast. of agric. goods η	(6) Income elast. of agric. goods ϵ	(7) Prop. of labor in agric. $\frac{L_1}{L}$	(8) Prop. of capital in agric. $\frac{K_1}{K}$	(9) Share of income produced by agric. $\lambda = \frac{P_1Y_1}{PQE}$
1880	0.58	0.12	0.70	0.30	-0.60	0.40	0.75	0.63	0.47
1885	0.57	0.12	0.70	0.30	-0.60	0.40	0.68	0.59	0.30
1890	0.54	0.12	0.70	0.30	-0.60	0.40	0.63	0.55	0.32
1895	0.54	0.11	0.70	0.30	-0.60	0.40	0.60	0.50	0.31
1900	0.56	0.10	0.70	0.30	-0.60	0.40	0.57	0.44	0.32
1905	0.55	0.11	0.70	0.30	-0.60	0.40	0.55	0.40	0.34
1910	0.56	0.11	0.70	0.30	-0.60	0.40	0.54	0.35	0.34
1915	0.55	0.12	0.65	0.35	-0.60	0.40	0.53	0.29	0.28
1920	0.55	0.12	0.70	0.30	-0.60	0.45	0.51	0.22	0.26
1925	0.59	0.11	0.70	0.30	-0.60	0.45	0.49	0.19	0.24
1930	0.61	0.12	0.70	0.30	-0.60	0.35	0.47	0.16	0.19
1935	0.55	0.13	0.65	0.35	-0.60	0.35	0.44	0.14	0.21
1940	0.55	0.10	0.65	0.35	-0.60	0.35	0.42	0.11	0.16
1945	0.55	0.10	0.70	0.30	-0.60	0.45	0.44	0.10	0.27
1950	0.55	0.10	0.85	0.15	-0.60	0.45	0.45	0.09	0.22
1955	0.65	0.12	0.85	0.15	-0.60	0.45	0.38	0.09	0.18
1960	0.57	0.13	0.75	0.25	-0.60	0.45	0.30	0.08	0.13
1965	0.60	0.16	0.70	0.30	-0.60	0.45	0.24	0.07	0.08

Sources: Col (1) and Col (2): Recalculated from Yamada and Hayami, 1972. Col (3) and (4): from Sato (1968) for years after 1930; assumed constant before. Col (5) and (6): Kaneda (1968) and Yuize (1964).
Col (7): L_1 from LTES, Vol.9; L from HSJE. Col (8): K_1 from LTES, Vol.9; K from LTES, Vol.3.
Col (9): $\bar{P}_1$, Y_1, from LTES, Vol.9, PQE from HSJE.

where LTES = Estimates of Long Term Economic Statistics of Japanese since 1868.
JSY = Japan Statistical Yearbook.
HSJE = Hundred Year Statistics of the Japanese Economy.

For details of data and transformations, see Yamaguchi, 1973.

Table 4. Average annual growth rates of endogenous variables (in percent per year)

Decade of	(1) Per capita income E	(2) Ag. output Y_1	(3) Nonag. output Y_2	(4) Ag. labor L_1	(5) Nonag. labor L_2	(6) Ag. capitol K_1	(7) Nonag. capitol K_2	(8) Terms of trade P
1880	6.25	3.70 (2.93)1/	13.01	-0.26 (-0.26)1/	5.45	0.13 (0.65)1/	1.50	2.33
1890	2.53	2.46 (1.42)	3.48	-0.06 (-0.05)	2.43	0.46 (1.00)	2.50	0.50
1900	0.13	4.77 (2.42)	1.01	-0.11 (-0.27)	1.42	0.84 (1.72)	2.80	-0.41
1910	3.51	5.21 (2.95)	5.52	-0.10 (-1.22)	0.94	0.50 (0.93)	4.70	0.83
1920	0.76	1.46 (1.50)	7.50	0.00 (0.02)	1.64	0.71 (1.05)	2.80	0.41
1930	2.41	3.76 (1.06)	4.09	-0.29 (-0.29)	1.94	0.35 (0.72)	4.00	3.73
1940		(-0.20)		1.74 (1.74)		(-1.40)		
1950	9.52	4.93 (5.36)	15.48	-1.74 (-1.74)	4.71	(4.56)		
1960		(5.46)		-3.34 (-3.34)	3.14	(6.74)		
Average	3.59	3.76	7.16	-.46	2.71	.50	3.05	1.23

1/ Values in brackets are new values from Yamada and Hayami, 1972.

Source: Col (1): HSJE until 1964, JSY after 1964. Col (2): LTES, Vol. 9. Col (3): HSJE, LTES, Vol. 9. Col (4): LTES, Vol. 9. Col (5): HSJE, LTES, Vol. 9. Col (6): LTES, Vol. 9. Col (7): LTES, Vol. 3 and Vol. 9. Col (8): LTES, Vol. 9 and HSJE. For computational details see Yamaguchi (1973).

Table 5. Average annual growth rates of exogenous variables.

(in percent per year)

Decade of	(1) Agr. T.C. $\dot{T}_1$	(2) Nonagr. T.C. $\dot{T}_2$	(3) Capital $\dot{K}$	(4) Labor $\dot{L}$	(5) Population $\dot{Q}$	(6) Birth rate	(7) Death rate
1880	3.85	8.04	2.15	1.46	0.86	2.43	1.66
1890	2.43	1.00	1.71	0.93	0.95	2.88	2.04
1900	2.69	-0.80	2.13	0.55	1.16	3.21	2.06
1910	5.19	3.50	3.56	0.41	1.21	3.38	2.08
1920	1.38	5.30	2.93	0.83	1.42	3.40	2.41
1930	3.88	1.55	3.27	0.93	1.13	3.29	1.89
1940					1.56	2.88	1.66
1950	5.82	10.30	5.78	2.25	1.17	2.87	1.06
1960				1.33	1.04	1.77	0.75
Average for Total Period	3.61	4.12	3.08	1.09	1.17		

Source: Col (1) & (2): Yamaguchi, 1973. Col (3): LTES, Vol. 3. Col (4) HSJE. Col (5), (6), (7): HSJE. For computational details see Yamaguchi, (1973).

Note: Col (6) & (7) are not the average annual growth rates but the growth rates of the year shown.

to the nonagricultural sector. The growth rate of nonagricultural capital accumulation is much higher than that of agricultural capital accumulation. The terms of trade moved in favor to agriculture except in the decade of 1900.

Table 6 shows the effects of population and labor on real per capita income, sectoral outputs, sectoral labor and capital allocation among the sectors and the terms of trade over time. These values come from the growth rate multipliers for each five year period. As we would expect, the rate of technical change in agriculture and nonagriculture affected real per capita income growth positively. Also, population growth has a very large negative effect on real per capita income, while on the other hand, labor affects growth positively. The magnitude of the effect of population growth on real per capita income (i.e., $\partial\dot{E}/\partial\dot{Q}$ in Table 6) decreases over time in Japan. The positive effect of labor growth (i.e., $\partial\dot{E}/\partial\dot{L}$ in Table 6) also decreases slightly over time but its decline is not as large as the one of the population effect. The decline of the size of the negative effect of population on per capita income is an interesting result. It is due to the market imperfections in the model. Considering Table 3 it is apparent that agriculture uses proportionately more resources than would be justified on the basis of its share in income. In particular L_1/L exceeds λ by a large fraction. Given that agriculture is the less labor intensive sector on the basis of the production function parameters, this can only be explained by the labor market imperfection which tend to allocate more labor to agriculture than would obtain in undistorted market equilibrium. Hence resources are less productive in agriculture. Population growth tends to increase agricultural output.

Table 6. The effects of population (Q) and labor (L) on real per capita income (E), sectoral outputs (Y_1 and Y_2), sectoral labor (L_1 and L_2) and capital allocation (K_1 and K_2) among sectors and the terms of trade ($\dot{P}$).

	$\frac{\partial \dot{Y}_1}{\partial \dot{Q}}$	$\frac{\partial \dot{Y}_1}{\partial \dot{L}}$	$\frac{\partial \dot{Y}_2}{\partial \dot{Q}}$	$\frac{\partial \dot{Y}_2}{\partial \dot{L}}$	$\frac{\partial \dot{K}_1}{\partial \dot{Q}}$	$\frac{\partial \dot{K}_1}{\partial \dot{L}}$	$\frac{\partial \dot{K}_2}{\partial \dot{Q}}$	$\frac{\partial \dot{K}_2}{\partial \dot{L}}$	$\frac{\partial \dot{L}_1}{\partial \dot{Q}}$	$\frac{\partial \dot{L}_1}{\partial \dot{L}}$	$\frac{\partial \dot{L}_2}{\partial \dot{Q}}$	$\frac{\partial \dot{L}_2}{\partial \dot{L}}$	$\frac{\partial \dot{P}}{\partial \dot{Q}}$	$\frac{\partial \dot{P}}{\partial \dot{L}}$	$\frac{\partial \dot{E}}{\partial \dot{Q}}$	$\frac{\partial \dot{E}}{\partial \dot{L}}$	$\frac{\partial \dot{E}}{\partial \dot{Q}} + \frac{\partial \dot{E}}{\partial \dot{L}}$
1880	0.38	0.34	-1.44	1.61	0.74	-0.47	-1.27	0.80	0.50	0.68	-1.51	1.96	-0.02	0.11	-1.58	1.01	-0.57
1885	0.36	0.34	-1.03	1.34	0.65	-0.40	-0.93	0.57	0.50	0.69	-1.07	1.66	-0.02	0.12	-1.61	1.04	-0.57
1890	0.40	0.30	-0.96	1.27	0.71	-0.42	-0.87	0.52	0.58	0.65	-0.99	1.59	-0.02	0.14	-1.52	0.96	-0.56
1895	0.42	0.29	-0.88	1.23	0.78	-0.47	-0.78	0.47	0.62	0.63	-0.93	1.56	-0.02	0.15	-1.48	0.94	-0.54
1900	0.45	0.28	-0.81	1.20	0.85	-0.53	-0.67	0.41	0.65	0.60	-0.87	1.53	-0.02	0.13	-1.41	0.90	-0.51
1905	0.48	0.26	-0.77	1.17	0.92	-0.56	-0.61	0.37	0.69	0.58	-0.84	1.51	-0.03	0.15	-1.35	0.86	-0.49
1910	0.50	0.25	-0.73	1.15	0.98	-0.60	-0.53	0.33	0.69	0.57	-0.81	1.50	-0.03	0.14	-1.31	0.84	-0.47
1915	0.49	0.26	-0.63	1.02	1.01	-0.59	-0.41	0.24	0.67	0.61	-0.75	1.44	-0.03	0.10	-1.32	0.81	-0.51
1920	0.45	0.28	-0.53	1.01	0.97	-0.58	-0.27	0.16	0.61	0.64	-0.64	1.38	-0.04	0.15	-1.27	0.82	-0.45
1925	0.46	0.31	-0.47	0.99	0.95	-0.59	-0.22	0.14	0.60	0.63	-0.58	1.36	-0.03	0.11	-1.25	0.83	-0.42
1930	0.56	0.25	-0.50	1.02	1.12	-0.71	-0.21	0.14	0.70	0.55	-0.62	1.40	-0.03	0.09	-1.30	0.87	-0.43
1935	0.58	0.21	-0.47	0.92	1.20	-0.70	-0.20	0.11	0.78	0.54	-0.61	1.36	-0.03	0.10	-1.25	0.77	-0.48
1940	0.58	0.20	-0.44	0.91	1.26	-0.75	-0.16	0.09	0.82	0.51	-0.60	1.36	-0.04	0.13	-1.28	0.80	-0.48
1945	0.50	0.25	-0.43	0.96	1.14	-0.68	-0.13	0.08	0.71	0.58	-0.56	1.33	-0.05	0.16	-1.18	0.76	-0.42
1950	0.50	0.20	-0.51	1.20	1.17	-0.80	-0.12	0.08	0.71	0.52	-0.58	1.40	-0.14	0.40	-1.29	0.98	-0.31
1955	0.50	0.31	-0.33	1.08	0.88	-0.61	-0.09	0.06	0.60	0.58	-0.37	1.26	-0.05	0.19	-1.18	0.94	-0.24
1960	0.50	0.27	-0.24	0.89	0.89	-0.53	-0.08	0.05	0.68	0.59	-0.29	1.17	-0.03	0.16	-1.14	0.81	-0.33
1965	0.51	0.29	-0.16	0.80	0.78	-0.47	-0.06	0.04	0.64	0.61	-0.20	1.12	-0.01	0.08	-1.11	0.76	-0.35

The resource transfer necessitated by this shift in demand is more costly in terms of growth the smaller the nonagricultural sector from which resources are withdrawn.

The last column of Table 6 shows by how much real per capita income growth would decrease if both population and labor growth rates would change by an equiproportional amount, i.e., if after a rise in the population growth rate the labor participation rate stayed constant. Note in particular that the combined negative effect of population growth under this assumption is very small, i.e., a rise of the population-labor growth rate results in a decline in per capita income growth of less than one-half percent. This finding is similar to the finding of Kelley and Williamson (1972) from their slightly different model. But the resulting optimism may be ill founded. Japan has indeed had an almost constant labor participation rate over time. But would that also have been the case if population had grown at 3 percent? A deeper understanding of the relationship between population growth and labor participation is needed before this question can be answered.

Population growth has a positive effect on real agricultural output growth, i.e., $\partial\dot{Y}_1/\partial\dot{Q} > 0$. The effect increases slightly over time. Conversely, and as expected, population growth has a negative effect on real nonagricultural output, i.e., $\partial\dot{Y}_2/\partial\dot{Q} < 0$. The rising agricultural output draws resources into agriculture, i.e., $\partial\dot{K}_1/\partial\dot{Q} > 0$ and $\partial\dot{L}_1/\partial\dot{Q} > 0$. This goes at the expense of the nonagricultural resource use, i.e., $\partial\dot{K}_2/\partial\dot{Q} < 0$ and $\partial\dot{L}_2/\partial\dot{Q} < 0$ as shown in Table 6. This is due to the demand effect, i.e., population growth decreases real per capita income and the income elasticity of nonagricultural goods is larger than that of agricultural goods. Therefore, agricultural goods which have relatively low income elasticity are demanded relatively more than nonagricultural goods.

We can summarize the implication of population and labor force growth as follows. Population growth increases agricultural output and both of its inputs and tends to decrease nonagricultural output and both of its inputs. Real per capita income decreases because of two population effects. Real per capita income is divided among more consumers and increased food demand necessitates a transfer of resources into the sector with lower labor productivity. The absolute size of the population effect is declining because this latter effect becomes less important the larger the nonagricultural sector.

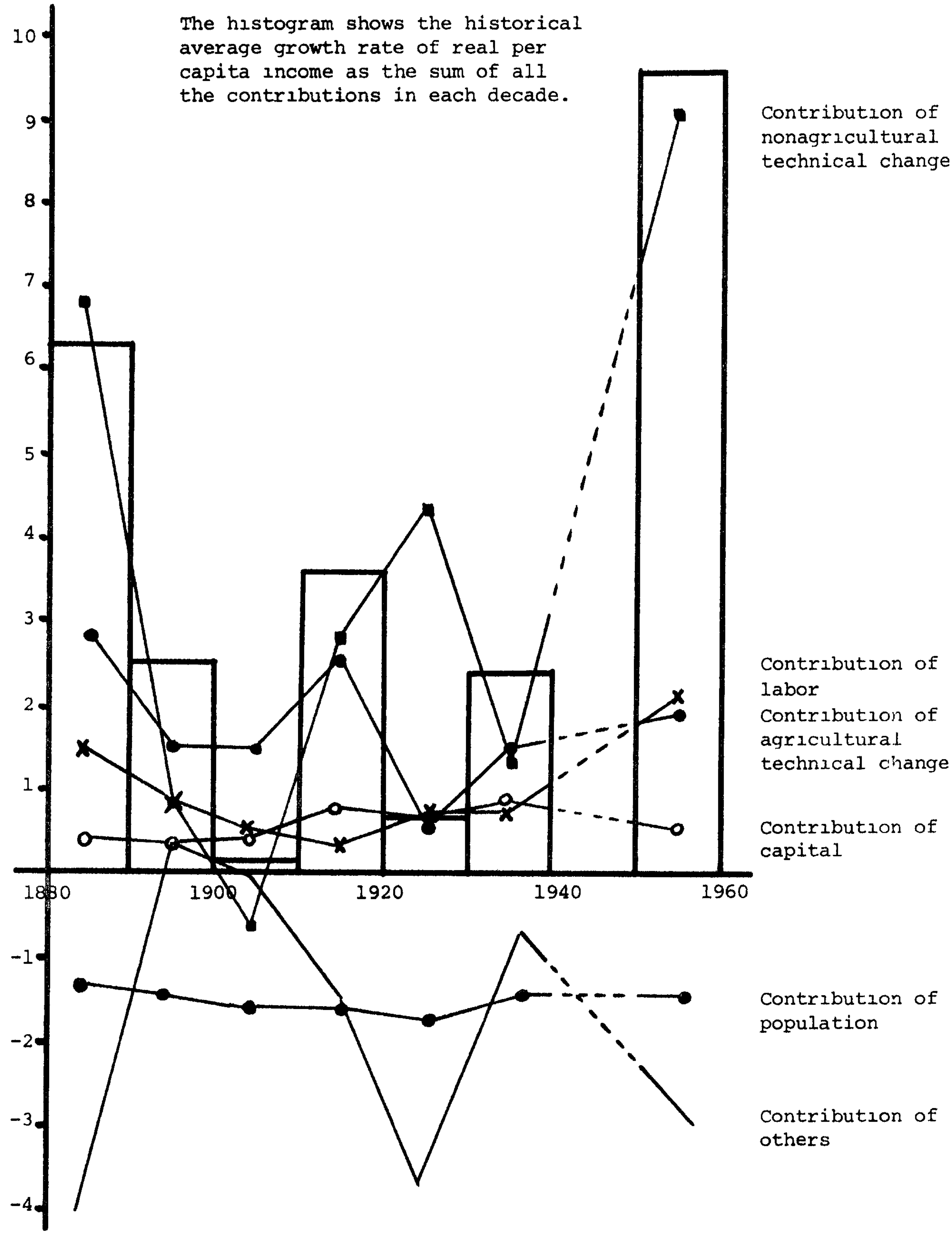
Labor force growth increases agricultural and nonagricultural outputs and labor inputs in both sectors. Agricultural capital decreases at the expense of nonagricultural capital, i.e., capital is withdrawn from the more capital intensive agricultural sector.

Population and labor force growth both tend to increase agricultural output and agricultural labor use, but have opposite effects on all other endogenous variables.[6/]

If a change in the population growth rate always results in an equal change in the labor force growth rate, one can add the population and labor effect to a combined population effect, i.e., if we add both the population and labor growth rate multipliers in each period, we can obtain how the size of these combined effects changed over time. But when one drops the assumption of a constant labor participation rate the sign of the combined effect is undetermined for those variables where the individual effects have opposite signs.

Figure 1 shows the contribution of exogenous variables to real per capita income. The histogram shows the historical average growth rate of real per capita income. As mentioned above, these contributions are found by

Figure 1. The contribution of exogenous variables to real per capita income.

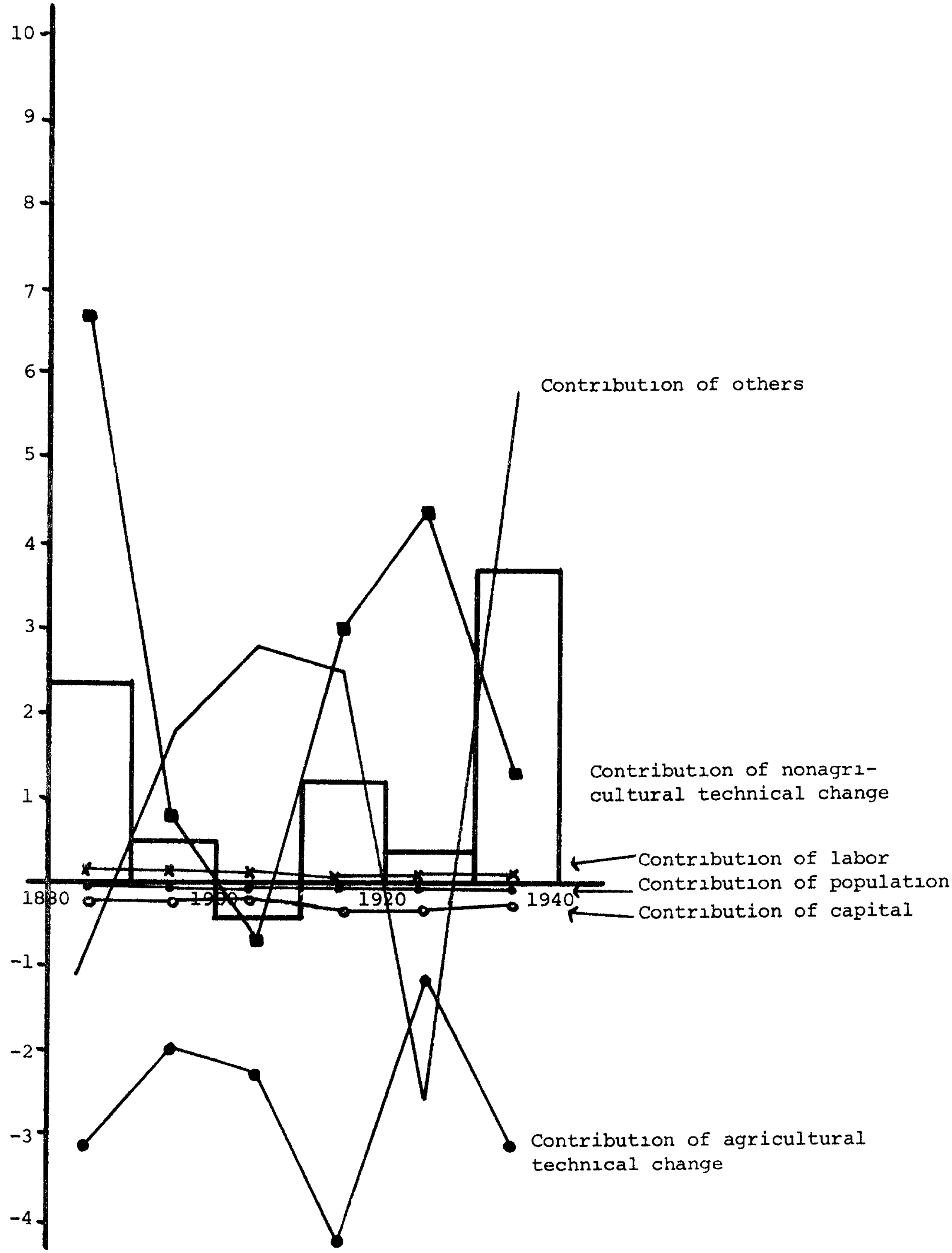


multiplying the growth rate multipliers of each decade by the corresponding decadal rates of change of the exogenous variables as they occurred in Japan. As shown above, the net effect of equiproportional rise in population and labor always have been negative (Table 6). However, as mentioned before, this effect may be positive depending on labor force participation rates. In fact, the decades of the 1880's and 1950's are exceptions and did have positive combined population effects. Similarly, the combined effect of population on agricultural capital in the 1880's was negative instead of positive, as would be expected from the multipliers. In the same way, nonagricultural labor in the 1900's and 1910's and nonagricultural output in the 1900's, 1910's, 1920's and 1930's were also exceptions.

When we observe the effect of population on real per capita income in terms of the growth rate multiplier, we find a larger negative effect at the beginning of economic development that decreased in importance over time (Table 6). However, Figure 1 shows that the negative contribution of population to real per capita income is almost constant.[7/] This means that Japan has been fortunate by having a low population growth in the beginning of economic development when the net negative effect would have been larger. In fact, population growth from 1880 to 1900 was less than 0.9 percent (Table 5).

Another important implication from our model is that the terms of trade is basically determined by technical change in both sectors and others which contain the imperfectness of factor markets. Population and labor have very small effects on the terms of trade while demand determines the output mix (Figure 2). This point is very important because, in the development literature, it is often claimed that an increase in

Figure 2. The contribution of exogenous variables to rate of change of the terms of trade.



population will lead to a strong rise in the terms of trade in favor of agriculture.[8/]

So far we have measured how much population contributed historically to the economic development of Japan during the period 1880-1960. What follows is a simulation with our model to gain some insight into how economic growth in Japan would have differed from the actual economic growth as reflected in per capita income, agricultural and nonagricultural output, and labor and capital allocation among sectors, if Japanese population growth rates had been as high as about 3 percent, the present rate in developing countries. This exercise may shed some light on the population problems developing countries face today.

Table 7 shows the hypothesized population and labor growth rates for the simulation along with the actual ones.[9/] Table 8 is the result of the simulated growth rates of the endogenous variables assuming a 3 percent population growth rate and the actual rate of technical change.

The results are summarized as follows:

(1) Generally speaking, the growth rates of the endogenous variables in the agricultural sector are larger than those in nonagriculture. In fact, the growth rates of capital in the nonagricultural sector become smaller than the actual growth rates. This comes from the fact that agricultural output has to expand faster to accommodate the rising population. It can do so only if it obtains more capital at the expense of the nonagricultural sector. The growth rates of labor in agriculture increase considerably because of an increase in the demand for food and the increase in supply of total labor.

(2) The growth rates of real per capita income become smaller than

Table 7. Assumptions of population and labor growth for simulation.

	Actual average population growth rate (1)	Average population growth rate of simulation (2)	The difference between simulation and actual growth rate (3) = (2) - (1)	Actual average growth rate of labor (4)	Average labor growth rate of similation $(5) = (4)_t + (3)_{t-1}$
	PERCENT				
1880 - 1890	0.86	3	2.14	1.46	1.46
1890 - 1900	0.95	3	2.05	0.93	3.07
1900 - 1910	1.16	3	1.84	0.55	2.60
1910 - 1920	1.21	3	1.79	0.41	2.25
1920 - 1930	1.42	3	1.58	0.83	2.62
1930 - 1940	1.13	3	1.87	0.93	2.51
1940 - 1950	1.56	3	1.44	-	-
1950 - 1960	1.17	3	1.73	2.25	3.69
1960 - 1970	1.04	3	1.96	1.33	3.06

Source: col (1): HSJE

Table 8. Simulated growth rates of endogenous variables assuming a 3% population growth rate and using the actual rate of technical change as average percentages per year in each decade.

	Growth rate of real agric. output $\dot{Y}_1$	Growth rate of real nonagric. output $\dot{Y}_2$	Growth rate of agric. capital $\dot{K}_1$	Growth rate of nonagric. capital $\dot{K}_2$	Growth rate of agric. labor $\dot{L}_1$	Growth rate of nonagric. labor $\dot{L}_2$	Rate of change of the terms of trade $\dot{P}$	Growth rate of real per capita income $\dot{E}$
	----------	----------	----------	Percent	----------	----------	----------	----------
1880-1890	5.30	11.83	1.49	-0.58	2.26	4.63	2.44	2.97
	(3.70)	(13.01)	(0.13)	(1.50)	(-0.26)	(5.45)	(2.33)	(6.25)
1890-1900	4.64	4.54	1.41	1.55	3.78	4.34	0.89	1.06
	(2.46)	(3.48)	(0.46)	(2.50)	(-0.06)	(2.43)	(0.50)	(2.53)
1900-1910	6.92	1.68	2.68	1.89	3.49	2.80	-0.12	-1.58
	(4.77)	(1.01)	(1.33)	(2.80)	(-0.11)	(1.42)	(-0.41)	(0.13)
1910-1920	7.26	5.90	2.21	4.00	3.31	1.90	3.00	1.39
	(5.21)	(5.52)	(0.50)	(4.70)	(-0.10)	(0.94)	(0.83)	(3.51)
1920-1930	3.64	8.66	2.04	2.49	3.48	3.45	0.61	-0.77
	(1.46)	(7.50)	(0.71)	(2.80)	(0.00)	(1.64)	(0.41)	(0.76)
1930-1940	6.14	5.01	2.20	3.71	4.14	3.50	3.87	0.65
	(3.76)	(4.09)	(0.35)	(4.00)	(-0.29)	(1.94)	(3.73)	(2.41)
1940-1950								
1950-1960	7.58	18.46			2.27	8.20		9.58
	(4.93)	(15.48)			(-1.74)	(4.71)		(9.52)

The value within each set of parenthesis is the actual Japanese growth rate.

the actual growth rates, except during the 1950's.[10/] However, the absolute value of real per capita income does not decrease except during the 1900's and 1920's. Technical change in agriculture and nonagriculture were still able to offset the rapid rate of population growth. This optimistic result comes, however, from the following two facts. One is that we assumed the actual rates of technical change. In fact, the rates of technical change were very high in Japan. Another is that we assumed a constant rate of labor participation because one can not easily assume a labor participation rate when the growth rate of the population is 3%. However, as we have seen above, the negative effect of population alone on per capita income was very large. Also it is true that the labor participation rate would have decreased considerably if the population growth were actually 3%. Therefore, real per capita income would have decreased much more than this simulation or similar work by Kelley and Williamson indicate.

The kinds of simulations performed here lead to an optimistic view as long as one assumes the labor participation rate as a constant. They also draw attention away from the vigorous employment policies which are needed to prevent labor participation rates from falling when the population rises rapidly.

4. Summary and Conclusions

The main conclusions can briefly be summarized as follows:

(1) We distinguished population growth from labor growth. An increase in population growth alone leads to a very large decrease in per capita income growth. It also leads to large increases in the agricultural output and inputs, and to decreases in the nonagricultural output and inputs. An increase in labor growth alone leads to large increases in real per

capita income, nonagricultural output and inputs, and agricultural output and labor but to decreases in agricultural capital. If one assumes that population and labor always grow equiproportionally the labor and population effect offset each other for most of the variables. In particular the combined effect on per capita income is relatively small. But this smallness hinges on the assumption of constant labor participation rates. As one would expect, population-labor growth pulls resources from the nonagricultural sector into the agricultural sector.

(2) The growth rate multipliers show, among other conclusions, that the negative demand effect of population growth on per capita income always outweighs its positive effect through the resulting increase in labor supply. However, the combined negative effect decreased over time in Japan.

The measured negative contribution of population and labor force growth to real per capita income was almost constant in each decade. This is so because Japan was fortunate to have a low population growth rate in the beginning of economic development when the combined negative effect was large.

(3) Terms of trade are primarily determined by sectoral technical change and not by demand forces, because the transportation curve has very little curvature. But demand forces determined the output mix.

We simulated our model based on assuming a 3 percent population growth rate and the actual rate of technical change. Then resources are pulled into the agricultural sector. Especially, the growth rate of labor in agriculture increases. Labor is substituted for capital to such a large extent that the capital stock grows more slowly, especially in the nonagricultural sector. However, even under these conditions per capita income would have grown in Japan because the rapid rates of technical change would still have outweighed this higher rate of population growth and we assumed the constant labor participation rate. In fact one of the major conclusions of this study is the attention which it draws to the dangers of the innocent assumption of a constant labor participation rate.

(4) Population growth is especially competitive with other development goals in the early stages of development, because it then leads to a transfer of a large proportion of the resources of the nonagricultural sector into the less productive agricultural sector. At later stages of development the economy can afford this transfer more easily.

FOOTNOTES

1/ The high death rates in 1920 were due to a wide-spread influenza epidemic, as well as a series of military conflicts in Asia.

2/ Kelley and Williamson used a factor augmenting framework with equal augmentation parameters in both sectors. This allows them to consider biased technical change but precludes a consideration of the separate influences of technical change in agriculture and technical change in nonagriculture. The separate treatment of labor from population accounts for the fact that in Japan the growth rate of population and the growth rate of labor were very different in the short run, but were almost equal over the long run (see Table 5).

3/ Work is under way to relax this assumption in the future. This requires a complete respecification of the demand side of the model.

4/ The proofs of equations (18) and (19) are complicated due to the labor market imperfections. The derivations of the other equations of the system are straightforward. For the details see Yamaguchi (1974a).

5/ The growth rate multipliers (GRM) are sums of two inverse elements of A for those exogenous variables which appear twice in the vector b, i.e., $\dot{Q}$, $\dot{T}_1$, and $\dot{T}_2$.

6/ In another paper we showed that both agricultural and nonagricultural technical change push the resources out of agricultural sector (See Yamaguchi (1973) or Yamaguchi and Binswanger (1974 a,b)).

We observe here that population growth will pull resources into the agricultural sector. The net population effect also pulls resources from the nonagricultural sector into the agricultural sector.

7/ Two reasons for small growth rates in real per capita income in the 1900's and 1920's are somewhat different. In the 1900's, the Sino -Japanese War in 1894 and the Russo-Japanese War in 1904 had adverse effects on real per capita income. In the 1920's the agricultural depression was very serious. In fact, the rate of agricultural technical change was only 1.38 percent during this decade--the lowest for the periods calculated.

8/ We also measured the contribution of population and labor to the real agricultural and nonagricultural output. Summarizing:

Population made a positive contribution to real agricultural output but a negative one to real nonagricultural output in a fairly stable way over time. Labor also made a fairly positive contribution to real agricultural output. However, the positive contribution of labor to nonagricultural output varied depending on the labor participation rates. (See Yamaguchi 1973).

9/ Before we simulate our model, it is necessary to explain our assumption in more detail. It is based on the following food consumption patterns of one person for every age. (Figure 3).

We cannot incorporate such a pattern correctly. To simplify we assume that the areas A and B are equal. The results are the same as under the assumption that children do not consume until 10 years old and after 10 years they consume adult quantities.

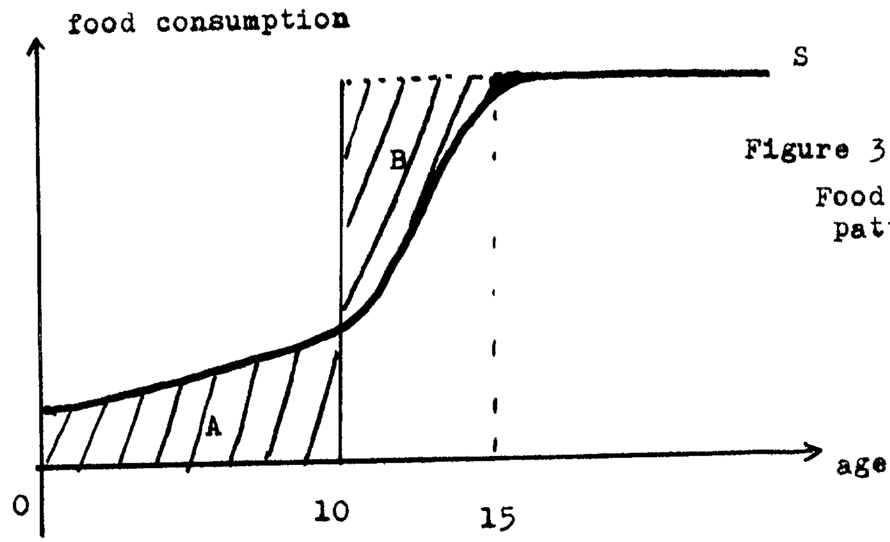


Figure 3

Food consumption pattern for each age

Column(2) and column (5) (Table 7) contain the hypothesized average population and labor growth rates. Column (5) is obtained by adding (4) plus (3) of the previous decade. For example, the average labor growth rate of 3.07 percent in the 1890's was obtained by summing 2.14 in column (3) and 0.93 in column (4). Columns (2) and (5) indicate that the simulated population and labor growth rates are different. We also assume that the labor participation rate would have followed the historic path, even if the population growth rate had been 3 percent. It is quite likely that this would not have been true with a 3 percent population growth rate. Therefore, our simulation gives the most optimistic picture.

10/ But this results from the fact that the average labor growth rate of the simulation, 3.06 percent in the 1950's, is larger than the average simulation population growth rate of 3.0 percent as shown in Table 7.

References

Bank of Japan, Hundred-year Statistics of the Japanese Economy, Statistics Department, July 1966.

Bureau of Statistics, Japan Statistical Yearbook, Office of the Prime Minister, Various issues.

Dovring, F., "The Share of Agriculture in a Growing Population," Monthly Bulletin of Agricultural Economics and Statistics (FAO) 8 (August-September 1959): 1-11.

Easterlin, R. A., "Does Human Fertility Adjust to the Environment?" American Economic Review 61 (May 1971): 399-407.

Hayami, Y. and V. W. Ruttan, Agricultural Development—An International Perspective (Baltimore: Johns Hopkins Press, 1971).

Houthakker, H. S., "An International Comparison of Household Expenditure Patterns, Commemorating the Centenary of Engel's Law," Econometrica 25,No. 4 (October 1957): 532-551.

Johnson, Harry G., "Factor Market Distortions and the Shape of the Transformation Curve," Econometrica 34, No. 3 (July 1966): 686-698.

Jorgenson, D. W., "The Development of a Dual Economy," Economic Journal 71 (June 1961): 309-334.

________________, "The Role of Agriculture in Economic Development: Classical versus Neoclassical Models of Growth," in Subsistence Agriculture and Economic Development, ed. C. R. Wharton, Jr. (Chicago: Aldine Publishing Co., 1969), pp. 320-348.

Jureen, L., "Long-Term Trends in Food Consumption: A Multi-Country Study," Econometrica 24 (January 1956): 1-21.

Kaneda, H., "Long-Term Changes in Food Consumption Patterns in Japan, 1878-1964," Food Research Institute Studies 8, No. 1 (1968): 3-32.

Kelley, A. C. and J. G. Williamson, Simple Parables of Japanese Economic Progress: Report on Early Findings, Economic History Discussion Paper Series No. EH 72-7 (Madison: University of Wisconsin, April 1972).

________________________________, "Modeling Economic Development and General Equilibrium Histories," American Economic Review, 63, No. 2 (May 1973): 450-458.

Morita, Y., "Estimated Birth and Death rates in the Early Meiji Period of Japan," Population Study, Vol. 17, No. 1 (July 1963): 33-56.

Nakayama, S., "Shokuryo Shohi Suijun no Choki-Henka ni Tsuite" (Long-Term Trend of Food Consumption in Japan, 1878-1955), Nogyo Sogo Kenkyu (October 1958): 13-38.

Noda, T., "Nosan-Butsu Juyo no Choki-Henka to Shotokudanryokusei" (Long-Term Changes in Demand for Agricultural Products and Income Elasticities) in Nippon no Keizai to Nogyo (The Japanese Economy and Agriculture), eds. S. Tobata and K. Ohkawa (Tokyo, Iwanami-Syoten, 1963).

________, "Juyo to Boeki no Choki-Henka" (Long-Term Changes in Demand and International Trade) in Nihon Nogyo no Seicho Bunseki (Growth Analysis of Japanese Agriculture), ed. K. Ohkawa (Tokyo, Iwanami-Syoten, 1963).

Phillips, L., H. L. Votey, Jr., and D. E. Maxwell, "A Synthesis of the Economic and Demographic Models of Fertility: An Econometric Test," Review of Economics and Statistics 51 (August 1969): 298-308.

Ruttan, V. W., "Two Sector Models and Development Policy," in Subsistence Agriculture and Economic Development, ed. C. R. Wharton, Jr. (Chicago: Aldine Publishing Co., 1969).

Solow, R. M., "Technical Change and the Aggregate Production Function," Review of Economics and Statistics 39, No. 3 (August 1957): 312-320.

Tolley, G. S., and S. Smidt, "Agriculture and the Secular Position of the U.S. Economy," Econometrica 32 (October 1964): 554-575.

U.S. Bureau of the Census, Historical Statistics of the United States, Colonial Times to 1957 (Washington: U.S. Government Printing Office, 1960).

Weintraub, R., "The Birth Rate and Economic Development, An Empirical Study," Econometrica 30 (October 1962): 812-817.

Yamaguchi, M., Keizai-seicho to syotoku-junkan (Economic Growth and Income Distribution with Special Reference to Agriculture) (M.S. dissertation, Kyoto University, 1969).

____________, Technical Change and Population Growth in the Economic Development of Japan (Ph.D. dissertation, University of Minnesota, 1973).

____________, and Hans P. Binswanger, "Some Structural Changes in the United States and Japanese Economies," Staff Paper, University of Minnesota, 1974 a.

____________, "The Role of Sectoral Technical Change in Development: Japan 1880-1965," Staff Paper, University of Minnesota, 1974 b.

Yamada, S., and Y. Hayami, "Growth Rates of Japanese Agriculture, 1880-1965," paper presented to Conference on Agricultural Growth in

Japan, Korea, Taiwan and the Philippines, September 1972, Honolulu.

Yuize, Y., "Syokuryo no Juyo Doko," (Demand Trend for Food) in Nihon Nogyo Dokuhon (Reading of Japanese Agriculture), ed. K. Baba (Tokyo, Toyo-Keizai-Shimposha, 1964).