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The recent experience of the Green Revolution has focused attention of economists on the extremely important role of agricultural technical change in economic development. Technical change in this sector is now viewed as an extremely powerful engine of growth and increased allocation of resources to agricultural research at national and international levels highlights this changing emphasis.

At the same time, this emphasis also causes worries about possible adverse employment effects of technical change. Clearly technical change in agriculture generally reduces the amount of capital and labor needed to produce a given level of output. This would even be true if the technical change was slightly labor using. But there is little evidence that this is the case. And given the high labor intensities of the agricultural production in less developed countries, we may expect little growth in labor use from even a bias in technical change. Offsetting increases in labor use, therefore, require either a lowering of agricultural wage rates, which is highly unattractive, increases in rates of growth of agricultural output, or a transfer of labor to nonagricultural activities. Since technical change in agriculture increases per capita income in the economy and tends to reduce agricultural prices, we can expect a positive effect on agricultural and nonagricultural demand to occur as a result of the technical change. But how big these effects will be is largely a matter of guessing. It is also likely that the increased demand alone generated by the technical change will be insufficient to prevent downwards pressure on the real wage rate. If this should be the case, what then are the most attractive policy alternatives to generate demand for the labor released by the agricultural technical change.

In an attempt to answer these questions and to get some feel for the magnitudes of income generating and labor displacement effects we constructed a relatively simple dynamic general equilibrium model with an agricultural and a nonagricultural sector along neoclassical lines. The economy is closed, but it is not too difficult to evaluate how the opening of the economy would affect the conclusions. The model relates technical change in the two sectors -- capital accumulation and labor and population growth -- to per capita income, sectoral outputs, allocation of resources, and terms of trade. Instead of simulating with the model we use it to measure the impact of the exogenous variables on the endogenous ones at different stages of the development of Japan, i.e., we trace structural changes in that economy. In addition, the model allows us to measure the contributions of the exogenous variables to the growth of per capita income during each decade from 1880 to 1960.

The focus of this paper is on technical change in the two sectors.[1/] We take the view that technical change is sector specific, i.e., technical

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1/ Different aspects of this research are discussed in [15] and [16].

advances in agriculture are not transferable to the nonagricultural sector. This strongly differentiates our model from the apparently similar work of Kelley and Williamson [7], [8], who assume factor augmenting production functions in both sectors with identical augmentation parameters for both functions. As the augmentation parameters increase they raise efficiency in both sectors, although by amounts which differ slightly due to differences in production function parameters. Of course, their model was geared to evaluate possible biases in technical change where a factor augmenting framework is clearly appropriate. But the evaluation of the effect of technical change in one sector alone is precluded in their model. It seems to us that assuming nontransferability is a more realistic view of technical change. Clearly, new seed varieties or pesticides do not raise nonagricultural productivity. Similarly, mechanical advances in the nonagricultural sector will pay off for the agricultural sector only if the agricultural machinery industry spends the research and development expenditures necessary to embody the advances in agriculture-specific machinery. Of course, it may be true that some inventions raise productivity in both sectors, but they are probably the exceptions rather than the rule.

We also consider technical change as an investment activity similar to physical capital accumulation. These two investment activities compete for the aggregate saving of the economy (as does investment in human capital, which is not considered in the model). To prevent asymmetric treatment of the investment activities, savings and investment are not treated endogenously in the model. Rather capital accumulation rates and rates of technical change are treated exogenously. This is appropriate because these variables can be viewed as policy targets and because we want to find out what the effect of changes in these rates are on per capita income and other endogenous variables.

The problem of not modeling them endogenously is that there is no way in our model to tell whether the economy allocated its overall investment resources efficiently to physical capital accumulation and to generating technical changes in the two sectors. We find, for example, that a one percent increase in nonagricultural technical change has a higher effect on per capita income growth than a similar increase in the rate of agricultural technical change. And both of these effects are larger than the effect on growth of a one percent increase in the capital accumulation rate. Does this mean that the economy should allocate more resources to nonagricultural technical change. This question cannot be answered without data on how much it costs to achieve a one percent increase in each of these rates of changes. If nonagricultural technical change is more expensive than agricultural technical change, it may still be better to concentrate on the latter. Our model, therefore, can only assess benefits of alternative courses of action. A full cost benefit analysis requires more information on relative costs.

A model similar to ours has been presented in Tolley and Smidt [12] who used it to assess the effect of technical change in agriculture on per capita income growth in the U. S. from 1930 to 1960. Our model departs from theirs in that it introduces population explicitly in the model and treats the labor participation rate as a variable. They also do not consider the role of nonagricultural technical change.

I The Model

The model is discussed in detail elsewhere (Yamaguchi 1973, 1974a). It is basically a two-sector model along neoclassical lines. The economy is closed. The following variables (or their rates of change) are assumed to be given exogenously:

Population
Labor force (or participation rate)
Capital stock
Rate of technical change in agriculture
Rate of technical change in nonagriculture.

The endogenous variables of the system are:

Per capita income
Agricultural output
Nonagricultural output
Sectoral allocation of labor
Sectoral allocation of capital
Terms of trade.

Population and labor force are treated independently to permit separate evaluation of their effects on per capita income. This is a departure from usual growth models, which treat labor as a fixed fraction of the total population. Because population growth thus increases the labor force automatically such a treatment leads to an optimistic evaluation of population effects on per capita income. Only to the extent that diminishing returns to labor exist, will there be a detrimental impact on growth. If, however, an economy is experiencing unemployment problems, an increase in population may be accompanied by a decrease in the labor participation rate and there would be an addition to the ranks of consumers but not to the ranks of labor.[2] The population aspect of the model and empirical results on the population-labor question are dealt with in detail in another paper (Yamaguchi, 1974b).

2/ For a good example of the resulting optimism see [8].

The rate of technical change is treated separately for the agricultural and nonagricultural sectors because, with the exception of some advances in the basic sciences and increases in general education, technical change is not transferable between sectors. Machinery, soil improvement, and skills of the labor force are sector specific. Furthermore, the institutional environment for research in the two sectors is entirely different. Research in the agricultural sector is carried out primarily in government financed experiment stations and the research results are diffused with the help of government operated extension services. In the nonagricultural sector almost all applied research is carried out privately and is diffused through private channels. Therefore an important question to ask is how much technical change in each sector has contributed to the growth of the economy.

Technical change is also assumed to be neutral in both sectors. An alternative would have been to model with labor-saving or labor-using technical change. This would have made the impact of technical change on labor more dramatic or less dramatic. But little evidence exists to support either the labor-saving or the labor-using hypothesis. Labor-using technical change, furthermore, is unlikely given the high initial labor intensities. The neutrality hypothesis, therefore, seemed adequate as a first approximation.

This paper focuses on measurement and structural change. The parameters of the model are not assumed to be constant and were obtained for each decade. This allows us to trace structural changes in the economy and to measure how the effect of the exogenous variables has changed over time. In a small model like ours it would also be hazardous to assume that the structural parameters of the model remain unchanged over the entire period of 85 years.[3/]

3/ Another reason for nonconstancy of the parameters of the model is the fact that simple functional forms, which are analytically convenient, were chosen. Recognizing that the simple forms may be only approximations to the true, but more complex forms, forces one to admit that the parameters of the simple forms may change over time.

Let i=1 denote the agricultural sector and i=2 the nonagricultural sector. The notations are as follows:

Y_i, L_i, K_i, B = sectoral outputs, labor inputs, capital inputs, and agricultural land

P_i = sectoral output prices

P = P_1/P_2

P' = general price level

w_i, r_i	= sectoral wage and capital rental rates
T_i	= sectoral level of technical efficiency
Q	= population
E	= per capita income
m_w	= agricultural wage rate as a proportion of nonagricultural wage rate
m_r	= agricultural capital rental rate as a proportion of nonagricultural capital rental rate
a	= agricultural demand shifter
η,ε	= agricultural price and income elasticity
α,β	= output elasticity of agricultural labor and capital
γ,δ	= output elasticity of nonagricultural labor and capital
λ	= proportion of income generated in agriculture.

Also, $\dot{X}$ denotes a proportional change of a variable over time. The static version of the model can then be summarized as follows:

(1) $Y_1 = f\ (a, Q, P, E) = aQP^{\eta}\ E^{\varepsilon}$ — Agricultural demand function

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

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

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

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

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

(5) $K_1 + K_2 = K$

(6) $w_1 = P_1 g_{L_1} = \alpha P_1 \ (Y_1/L_1)$

(7) $w_2 = P_2 h_{L_2} = \gamma P_2 (Y_2/L_2)$

(8) $r_1 = P_1 g_{k_1} = \beta P_1 (Y_1/K_1)$ — Proportionality of value of marginal product to factor price

(9) $r_2 = P_2 h_{k_2} = \gamma P_2 (Y_2/K_2)$

(10) $w_1 = m_w w_2$ — Factor mobility condition

(11) $r_1 = m_r r_2$

(12) $P_1 Y_1 + P_2 Y_2 = P'QE$ — Income identity

All functional forms are Cobb-Douglas. The agricultural demand function includes an autonomous demand shifter which picks up changes in tastes and consumption not reflected in the demand elasticities.

A special feature of the model is the introduction of market imperfections in the model in the form of exogenous differentials in factor prices between the sectors. As can be seen from Table 3, the proportion of labor in agriculture (L_1/L) far exceeds the proportion of agriculture in output (λ). This large difference cannot be explained by the factor intensity differences in the two sectors. On the basis of the labor coefficients α and γ of the production functions, agriculture should be less labor intensive than nonagriculture. The high value of L_1/L has to be explained by lower factor rewards in agriculture. This is consistent with the generally observed lower wage rate in agriculture. (Rental rate differences are harder to substantiate empirically.) This feature of the model means that resources are more productive in the nonagricultural sector which strongly affects our conclusions. The imperfections also affect the form of the transformation curve between the two sectors: Johnson [5] 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 the curvature which it has 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 sectoral terms of trade. This is important to the interpretation of the results. Note also that the model is a closed economy model. In an open economy model, the demand side will have to be respecified completely. It is also possible to show what effects such an opening would have on the conclusions of this paper.

The static version can be transformed into the dynamic model of Table 1 by transforming the model into proportional changes. The number of equations is reduced to eight because equations (6) to (11) can be combined into two equations leading to equations (18) and (19) of the matrix equation in Table 1.[4/]

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 details see [14] or [15].

After this transformation the model has the general form

(21) $A_x = b$

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 $(A^{-1})_{2,4}$ element is $\frac{\partial \dot{Y}_2}{\partial \dot{L}}$, which indicated by how much the rate of change of nonagricultural output increases due to an increase in the growth rate of labor.[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.

5/ For some of the exogenous variables the growth rate multipliers are sums of two elements of A^{-1} since the variable enters on the right hand side of two equations.

Table 1. A matrix exposition of the agriculture-nonagriculature two sector model.

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

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.,

$$(22) \quad \left(\frac{\partial \dot{E}}{\partial \dot{L}_2}\right)^t \cdot \dot{L}_2{}^t = (A^{-1})^t_{8,4} \cdot \dot{L}_2{}^t = ELC$$

where ELC (E for income, L for labor, C for contribution) is the measured contribution of the growth rate of labor to per capita income growth at time t.[6/]

6/ Simulations or counterfactual analyses can be 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. However, no simulation results are reported here.

II. Data and Results

The structural parameters used for the A matrix are tabulated in Table 2.[7/] Note in particular that throughout the period the nonagricultural sector is more labor intensive than the agricultural sector ($\gamma > \alpha$). The price and income elasticities for food demand are the ones reported by Kaneda [6]. He found that they were fairly high and change little over time. Also note agriculture's share of total income is only 47 percent in 1880 and declines steadily to 8 percent in 1965.

7/ For details on sources and transformations see [14].

The rates of change of the exogenous variables are summarized in Table 3. The rates of technical change were measured using equations (14) and (15) of Table 1.[8/] This is the familiar Solow approach.[9/] Note in particular that the average rate of nonagricultural technical change exceeded the agricultural rate of technical change, but the former fluctuated much more than the latter. Population growth rates are low and larger after the turn of the century than before. The labor force grew at about the same average rate as did population, but these rates differed strongly in the short run.

8/ For details of sources and transformations see [14].

9/ We recognize the problems of measurement inherent in that approach. The results of this paper are, of course, conditional on the judgment that despite all the problems of measurement and assumptions, growth accounting within a model can still give us further insight into the growth process.

Table 2. 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) Capital's share in nonagric. output 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 See Appendix

Table 3. 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 $\dot{Q}$
1880	3.73	8.04	2.15	1.46	0.86
1890	2.18	1.00	1.71	0.93	0.95
1900	2.44	-0.80	2.13	0.55	1.16
1910	5.03	3.50	3.56	0.41	1.21
1920	1.41	5.30	2.93	0.83	1.42
1930	3.81	1.55	3.27	0.93	1.13
1940					1.56
1950	4.10	10.30	5.78	2.25	1.17
1960				1.33	1.04
Average for Total Period	3.24	4.12	3.08	1.09	1.17

Source: Col. (1) & (2): Yamaguchi, [14]. Col. (3): <u>LTES</u>, [10], Vol. 3. Col. (4): <u>HSJE</u>, [1]. For computational details see [14].

Table 4 summarizes the rates of change of the endogenous variables. The decline of agriculture's share in income is shown clearly in the absolute decline of the agricultural labor force and the much slower rise of agricultural capital than of nonagricultural capital. Terms of trade turned in favor of agriculture throughout most of the period.

A comparison of the growth rate multipliers of technical change with those of capital and labor is shown in Figure 1. Note, first, that the sum of the two technical change multipliers does not exceed the sum of the capital plus labor multipliers by very much. (Remember that the labor multiplier shows the effect of a rise in labor without a corresponding rise in population, i.e., the effect of a rise in the labor participation rate.) That these sums are of about equal magnitude suggests that technical change is not inherently a more powerful engine of growth than the traditional endowments. Table 5, however, reveals that, overall, technical change has contributed more to the observed growth rates of per capita income than have growth of capital and labor. This is due to the fact that the rates of technical change exceeded the growth rates of capital and labor (see Table 3).

A disturbing conclusion from Figure 1 is the very low multiplier of capital. This is due to the low capital coefficients in the production functions, particularly in agriculture. It is so low because agricultural capital does not include land. But the multiplier remains low even if

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

Decade of	(1) Per capita income	(2) Ag. output Y_1	(3) Nonag. output Y_2	(4) Ag. labor L_1	(5) Nonag. labor L_2	(6) Ag. capital 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, [1] until 1964, JSY [2] after 1964. Col. (2): LTES, [10], 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 [14].

Table 5. The contributions of the exogenous variables to the growth rate of real per capita income (in average rate per year)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Contribution of growth rate of:					
Decade of	Observed Growth Rate	Agr. T.C. T_1	Nonagr. T.C. T_2	Capital K	Labor L	Population Q	L + Q = (6) + (5)
1880	6.25	2.37	7.78	0.39	1.52	-1.38	+0.14
1890	2.53	1.19	0.96	0.30	0.90	-1.43	-0.53
1900	0.13	1.21	-0.70	0.40	0.49	-1.60	-1.11
1910	3.51	2.29	3.02	0.81	0.34	-1.59	-1.25
1920	0.76	0.54	4.64	0.64	0.69	-1.79	-1.10
1930	2.41	1.48	1.45	0.89	0.77	-1.44	-0.67
1950	9.52	1.35	9.30	0.54	2.17	-1.44	+0.73
Average	3.58	1.46	3.78	0.57	0.98	-1.52	-0.54

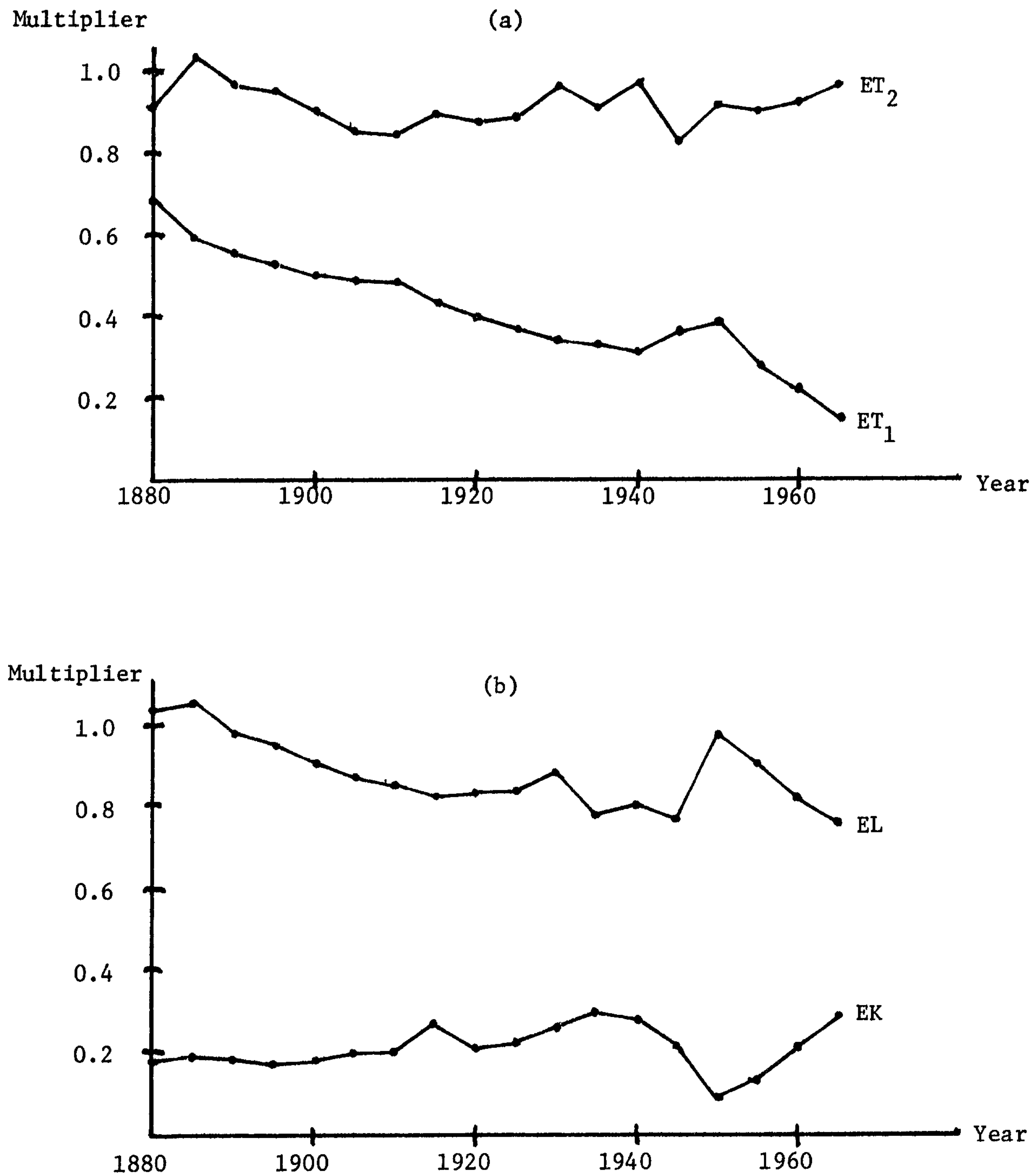

Figure 1. Growth rate multipliers (GRM) with respect to per capita income.

Panel (a) ET_1 = GRM of agricultural technical change on per capita income

ET_2 = GRM of nonagricultural technical change on per capita income

Panel (b) EK = GRM of total capital on per capita income

EL = GRM of total labor on per capita income land is treated as capital, as in [15].[10/]

10/ To some extent this conclusion would be altered if technical change was largely capital embodied. It would then be incorrect to treat capital accumulation and technical change independently. To the extent that capital embodiment is more important in nonagriculture, this would tend to reduce the effectiveness of nonagricultural technical change.

The multiplier of nonagricultural technical change is close to one and fairly constant. The nonagricultural multiplier declines over time as the size of the agricultural sector declines. The agricultural technical change multiplier is always smaller than the nonagricultural one, even at the beginning when both sectors are of about equal size. This reflects the fact that nonagricultural technical change transfers more resources to nonagriculture than agricultural technical change and that resources are more productive in nonagriculture due to the market imperfections.

The same feature also causes the absolute size of the population multiplier to decline over time. An increase in population causes an increase in demand for agricultural goods and a corresponding transfer of resources from the nonagricultural sector to the lower productivity agricultural sector. The smaller the size of the agricultural sector, the larger the negative effect on per capita income of such a transfer. Hence, population growth is more costly the less developed a country.

In Table 5 the multipliers have been multiplied by the actual rates of change of the exogenous variables. The contribution of nonagricultural technical change is the largest, on the average, because both the multiplier and the rate of technical change are largest for this variable. The contribution of agricultural technical change generally exceeds those of labor and capital as well. It is also less variable over time than the one of nonagricultural technical change. The contribution of the labor force growth exceeds that of capital but the difference is smaller than the difference in multipliers. Population growth has, of course, a negative impact on per capita income growth. Indeed, if the contributions of labor growth and population growth are summed, the result is on the average small and negative. Hence, population and labor force growth combined had in Japan a small negative effect on per capita income, a result which agrees with Kelley and Williamson [8]. But this benign assessment of the effect of population growth results only from the fact that the labor force participation rate did not drop. If it had indeed dropped, as it might have in the case of much larger population growth rates, the picture could have been entirely different.

Figure 2 summarizes the effect of the exogenous variables on the terms of trade. The effects of labor, capital, and population are very small as compared with the effects of technical change. This implies that even large changes in output mix have little influence on the terms of trade, i.e., there is very little curvature in the transformation

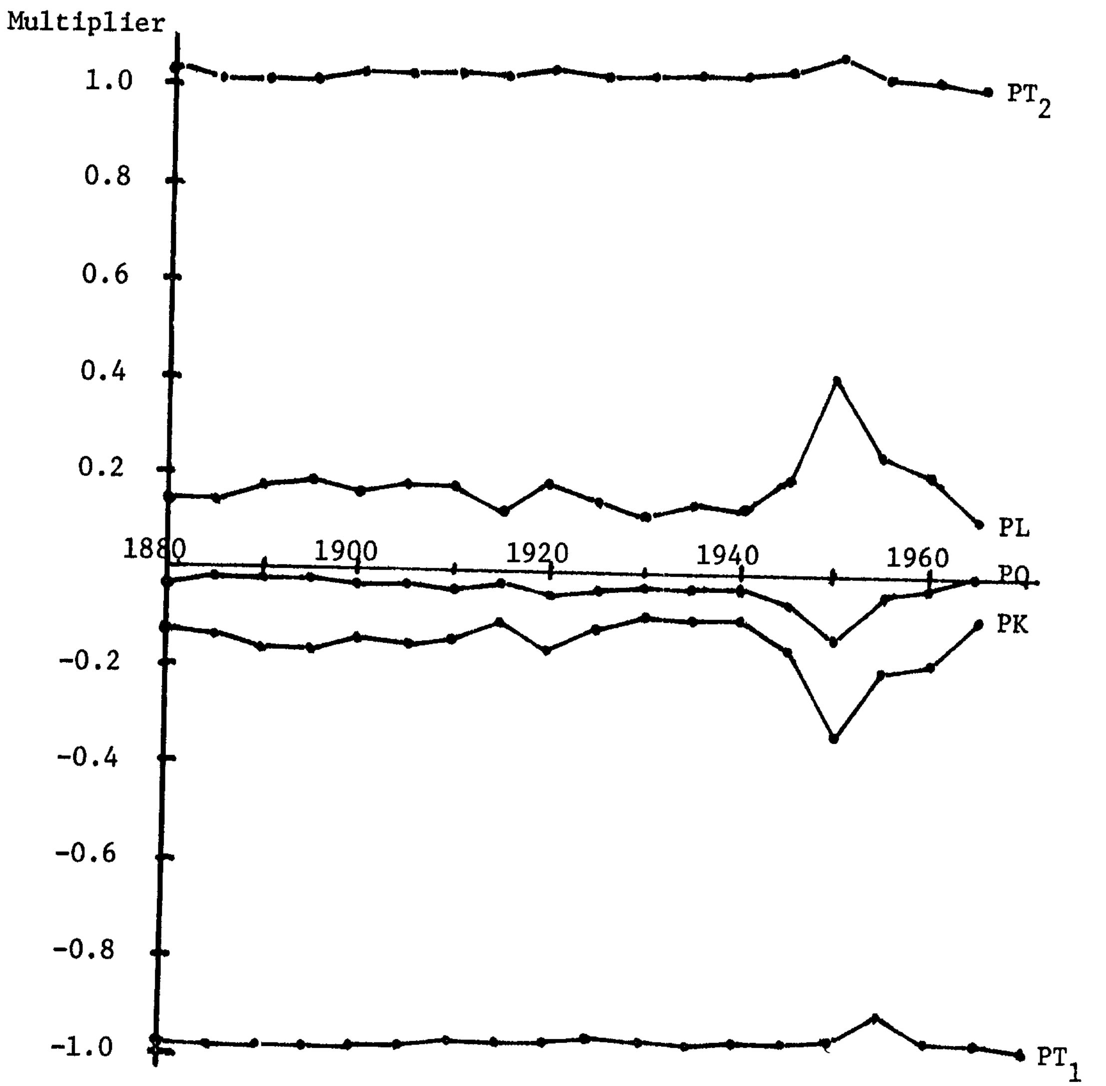

Figure 2. Growth rate multipliers (GRM with respect to the rate of change of relative prices

PT_1 = GRM of agricultural technical change on relative prices
PT_2 = GRM of nonagricultural technical change on relative prices
PK = GRM of total capital on relative prices
PL = GRM of total labor on relative prices
PQ = GRM of population on relative prices

curve. Terms of trade are determined primarily by technical change in the two sectors, while consumption demand determines the output mix.

If this view is correct, cheap food policies aimed at holding labor costs down in the nonagricultural sector can only work if they further agricultural productivity growth. In the long run, sectoral output mix has little to do with food prices, and so does population growth.

Figure 3 summarizes the output allocation effects of technical change. Technical change in each sector increases per capita income and decreases the price of the good which experiences the technical change. Hence, output and consumption of the good increase.

More interesting, however, are the cross effects: agricultural technical change tends to increase nonagricultural output, despite the rise in the relative price of the nonagricultural good. The income effect outweighs the price effect. Conversely, nonagricultural technical change tends to decrease consumption of agricultural commodities. Hence, in the Japanese case, the income elasticity of agricultural goods was not sufficient to outweigh the relative price increase of the agricultural goods due to the nonagricultural technical change. Also, as the size of the agricultural sector declines, the absolute size of the cross effects decreases.

Table 6 shows the resource allocation effects of sectoral technical change. As above, technical change in nonagriculture pulls resources into that sector, despite the reduction in factor requirements to produce

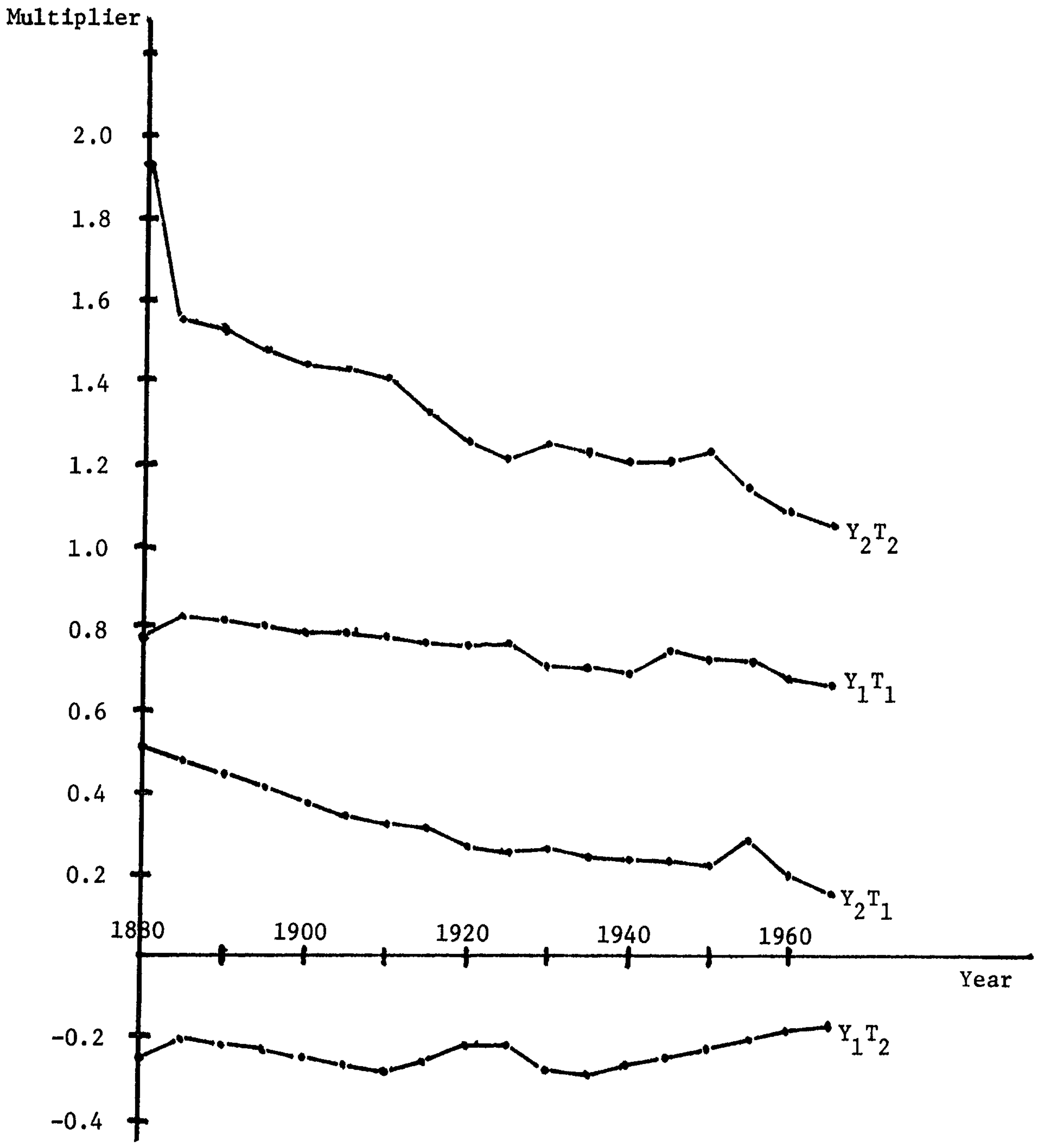

Figure 3. Growth rate multipliers (GRM) of sectoral technical changes on sectoral outputs

Y_1T_1 = GRM of agricultural technical change on agricultural output

Y_2T_2 = GRM of nonagricultural technical change on nonagricultural output

Y_1T_2 = GRM of nonagricultural technical change on agricultural output

Y_2T_1 = GRM of agricultural technical change on nonagricultural output

Table 6. Growth rate multipliers (GRM) of sectoral technical change on allocation of capital and labor among sectors[1] (average percent per year)

Five Year Span Beginning	(1) K_1T_1	(2) K_1T_2	(3) L_1T_1	(4) L_1T_2	(5) K_2T_1	(6) K_2T_2	(7) L_2T_1	(8) L_2T_2
1880	-.26	-.48	-.18	-.33	.45	.82	.54	.98
1885	-.30	-.35	-.24	-.27	.44	.50	.50	.57
1890	-.32	-.34	-.27	-.32	.40	.48	.45	.55
1895	-.36	-.42	-.29	-.34	.36	.42	.43	.50
1900	-.34	-.47	-.30	-.36	.31	.37	.40	.48
1905	-.41	-.52	-.30	-.39	.27	.34	.37	.47
1910	-.43	-.55	-.31	-.39	.23	.30	.36	.46
1915	-.49	-.53	-.32	-.35	.20	.22	.36	.39
1920	-.51	-.48	-.32	-.30	.14	.13	.33	.31
1925	-.51	-.45	-.32	-.28	.12	.11	.31	.27
1930	-.58	-.55	-.36	-.35	.11	.10	.32	.31
1935	-.61	-.60	-.39	-.39	.10	.10	.31	.31
1940	-.67	-.59	-.44	-.39	.08	.07	.32	.28
1945	-.58	-.57	-.36	-.35	.06	.06	.28	.28
1950	-.64	-.53	-.39	-.32	.06	.05	.32	.26
1955	-.52	-.38	-.35	-.26	.05	.04	.22	.16
1960	-.56	-.34	-.43	-.26	.05	.03	.18	.11
1965	-.52	-.27	-.42	-.22	.04	.02	.13	.07

[1] K_1T_1, K_1T_2: GRM of agricultural and nonagricultural technical change on agricultural capital.

L_1T_1, L_1T_2: GRM of agricultural and nonagricultural technical change on agricultural labor.

K_2T_1, K_2T_2: GRM of agricultural and nonagricultural technical change on nonagricultural capital.

L_2T_1, L_2T_2: GRM of agricultural and nonagricultural technical change on nonagricultural labor.

one unit of output. On the other hand, technical change in agriculture pushes resources out of that sector, which is an important observation for countries experiencing employment problems.

III. Summary and Implications

The main conclusions can briefly be summarized as follows:

1) Technical change in Japan has contributed more to growth than the traditional factors, not because it is a more powerful engine of growth but because the rates of technical change exceeded the rates of accumulation of the traditional factors.

2) Nonagricultural technical change has contributed more to per capita income growth than agricultural technical change, primarily because the agricultural technical change multiplier has been smaller than the nonagricultural one except for the period 1880 to 1885 and because it has been steadily declining through time as the importance of that sector declined in the economy.

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

4) Technical change in agriculture tends to push resources out of agriculture while nonagricultural technical change tends to draw resources into nonagriculture. This asymmetrical effect of technical change is due to the low price and income elasticities for agricultural commodities in a closed economy.

5) Population growth has a more detrimental effect on per capita income the smaller the nonagricultural sector out of which resources must be drawn for an increased food production.

Given these conclusions, one can ask whether Japan could have increased its growth rate if it had chosen another allocation of investment resources among physical capital and technical change in the two sectors. As mentioned in the introduction, this question cannot be answered without cost data for the efficiency gains. Simulations altering these rates of technical change or capital growth cannot answer the question either, because we do not know at what cost the simulated rates could have been achieved. One point, however, deserves notice: The multiplier of nonagricultural technical change always exceeded the one of agricultural technical change, which in turn was larger than the multiplier of physical capital. Nonagriculture also experienced a higher average rate of technical change than agriculture, and both rates of technical change exceeded the rate of capital accumulation. (Note that the rates of change are independent of the multipliers.) Japan experienced the highest rate of change in the variable with the highest multiplier. This is at least consistent with the hypothesis that Japan did succeed in allocating investment resources in a growth maximizing way.

Japan also had a favorable population growth experience. At the early stages of development, when population growth was most detrimental, it had a smaller growth rate of population than at later stages. And, of course, the population growth rates were small throughout the period compared with growth rates in today's less developed countries. It was so small that it did not affect the labor participation rate in a negative way.

Many of today's less developed countries have agricultural sectors as large or larger than Japan in the 1880's. In addition, they have larger population growth rates than Japan had at that time, which makes employment problems more difficult. What are the implications for these countries?

Needless to say, high population growth rates are competitive with almost any development goals. But population policy is not an area where the advice of agricultural economists is particularly valuable or where we have much to contribute. We have more to say with respect to agricultural technical change. Clearly the countries need rapid technical change based agricultural growth and there is hope that this can be achieved. Furthermore, it should be achieved without depressing agricultural wage rates and aggravating unemployment problems. Our research points out that this is difficult since technical change pushes labor out of the agricultural sector. (This transfer of resources out of agriculture is not undesirable per se, because it transfers resources to a more productive sector.)

Recognizing this problem implies that we cannot afford to neglect the nonagricultural sector. Unless this sector experiences growth and technical change labor has nowhere to go and will only depress wage rates. What emerges is a difficult balancing act between the sectors which is the more difficult the higher the population growth rates and the earlier the development stage.

There are two ways in which this balancing act can be made somewhat easier and which are not reflected in the model. The first is labor-using technical change. Apart from the unlikely occurrence of strong labor-using biases on the grounds that the sectors are already highly labor intensive, this approach has the disadvantage of pressing on the wage rate. On the other hand, labor-saving technical change is made more likely, especially for mechanical and engineering technology largely developed in the developed countries. That even neutral technical change tends to displace labor gives added urgency to try to avoid labor-saving biases and to push for the development of modern mechanical and engineering technology specific to labor intensive environments.

The second possibility neglected in the model is the expansion of export markets. Such markets can contribute much to solve the balancing problem. They would change the agricultural demand elasticities to much higher values. Technical change in agriculture reduces agricultural prices and makes the output more competitive internationally. The agricultural demand so generated would use more of the resources released through the technical change. Exports, therefore, deserve more emphasis at the policy making level.

This research brings us back to earlier concerns of the development literature with the transfer of resources from agriculture to the non-agricultural sector, as in the work of Lewis [9] and Fei and Ranis [4]. There is a bonus to be gained from expanding the nonagricultural sector.

But it is not in the form of a laborer without opportunity cost in agriculture who almost miraculously brings with him his own wage rate and food as he enters the nonagricultural sector. Such free surpluses do not exist here. Instead, growth due to technical change in either sector or to capital accumulation increases primarily nonagricultural demand. This permits the nonagricultural wage rate to rise sufficiently above the minimum differential to draw additional labor out of agriculture (and capital as well). The probably higher maintenance cost of a person in nonagriculture is reflected in the differential needed to induce them to migrate and stay in the nonagricultural sector. The economy pays for that in equilibrium by that wage differential, hence the benefit from transfer is not free. Also the dynamics are different. The system does not move primarily through capital accumulation in nonagriculture alone, but through technical change in both sectors and through capital accumulation in both sectors. Artificially forced transfer leads to no bonuses. The framework is closer to Colin Clark's [3] framework which recognizes two sources of benefit: (a) growth of output per worker in both sectors, and (b) transfer of labor to higher productivity sectors. Development policy in the 1950's chose to emphasize the transfer of labor rather than growth of output per worker in both sectors, which was probably not intended initially in that kind of framework.

APPENDIX: DATA

Explanations for the Individual Columns in Table 2

(1) Labor's share in agriculture

Labor's share in agriculture was recalculated from the data in the appendix of Yamada and Hayami (1972) to fit the factor definitions used here.

(2) Capital's share in agriculture

Capital's share in agriculture was obtained by subtracting labor's share in agriculture from 1.00.

(3) and (4) Labor and capital's share in nonagriculture

The nonagricultural factor share was developed by Sato (1968). The share after 1930 is calculated by taking the five-year's average centering the years shown on page 279 of Sato. Unfortunately, no data could be obtained before 1930. Therefore, we assumed that labor's share in nonagriculture was 70% and capital's share was 30%.

(5) and (6) Price and income elasticities of agricultural goods

Kaneda (1968) recalculated the earlier work of Nakayama (1958) and Noda (1963). He found that income elasticities estimated by Nakayama should be 0.32 and Noda 0.50 instead of approximately 0.80 from 1878-1922. We adopted 0.40 as the income elasticities of this period.

Kaneda obtained income elasticities of 0.494 for March 1921, 0.386 for 1926/27, 0.347 for 1931/32, and 0.329 for 1935/36. Income elasticities of 0.45 for the 1920's and 0.35 for the period 1930-1945 were, therefore, used.

With respect to the income elasticities of the post-World War II years, Kaneda obtained 0.481 for 1953, 0.456 for 1957, and 0.472 for 1961 for urban workers' households and around 0.530 for farm households. Independently, Yuize (1964) obtained the value of 0.455 for the period 1956-1962. Therefore, the income elasticity of the postwar years was set at 0.45. Kaneda obtained -0.762 as the price elasticities for the postwar years for urban workers' households and -0.172 for farm households. Yuize obtained price elasticities of -0.696. The price elasticity was set at -0.60 for the postwar years.

With respect to pre-World War II, published sources are not available. However, the Japanese income elasticities were almost constant over the whole period. Therefore, price elasticities were also held constant at -0.60 for the pre-World War II period.

(7) and (9) Proportion of total labor and share of income produced in agriculture

The total of agricultural labor is obtained from column (3) of Table 33, p. 218, in LTES, Vol. 9. Total labor data comes from HSJE, p. 56. From these two data series the proportion of total labor in agriculture can be obtained. First, we can obtain the total national income from HSJE. We also obtain the value of agricultural output from LTES. Therefore, we can obtain the share of income from them.

(8) Proportion of total capital in agriculture

Since in these international comparisons only two inputs (capital (K) and labor (L)) in our agricultural production function were assumed, it is necessary to include the land value in the agricultural capital.

Therefore, the arable land (column (14) of Table 32, p. 216, LTES, Vol. 9) was multiplied by 0.0269 million yen (the price of land (100 cho) in 1935) and added the value to net agricultural capital (column (12) of Table 3, p. 154, LTES, Vol. 3 or column (8) of Table 29, p. 212, LTES, Vol. 9) and net total capital (the second column from the last of Table 1, p. 149, LTES, Vol. 3). Thus, the data of agricultural and total capital including the value of agricultural land were obtained.

The proportion of total capital in agriculture can be obtained from these two series until 1940.

Total capital data after 1940 can only be obtained from Reference Table 3 in LTES, Vol. 3. However, this is the value in 1960 prices. Therefore, it is necessary to recalculate into the values of 1934-1936 prices. In addition, total capital is measured in gross terms instead of net terms, as used so far. However, the growth rates of gross and net capital stock do not differ very much.

Thus, the total gross capital in 1939 in Reference Table 3 in LTES, Vol. 3 is compared with that of 1950, obtaining a value 1.2 times larger in 1950 than 1939; likewise, 2.0 times greater in 1960 than 1939. Hence, the value of net total capital (the second column from the last of Table 1, p. 149, LTES, Vol. 3) in 1950 and 1960 were multiplied by 1.2 and 2.0 to get the value of net total capital in 1950 and 1960, respectively.

As for agricultural capital and land value, the data after 1940 are available. Therefore, the proportion of total capital in agriculture K_1/K can be measured.

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