CONTRIBUTION OF POPULATION GROWTH TO PER CAPITA INCOME AND SECTORAL OUTPUT GROWTH IN JAPAN, 1880–1970

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I. INTRODUCTION

RAPID population growth in developing countries continues to be generally considered from a Malthusian point of view, i.e., the economic effects of population growth are viewed negatively. The well known basis for this point of view is that diminishing returns result as more labor is added to a fixed amount of land; also that population growth combined with a given amount of food implies less food for each individual. However Simon [21] has challenged this view, predicting that population growth will have a positive effect on per capita income, at least in the long run.[1]

The implication of the Malthusian argument for Japan, given its small land base relative to its population, is clear: population growth can only be expected to have a depressing effect on per capita income. The earlier research of Kelley, Williamson, and Cheetham [9] showed population to have large negative effects,[2] but Minami and Ono [14] concluded that economic development would have been retarded in Japan had population growth been much less.

In fact, Japan has achieved dramatic increases in per capita income and agricultural and nonagricultural output since the Meiji Restoration of 1868. The purpose of this paper is to estimate the direct and indirect contributions of population and labor growth to the growth of per capita income and sectoral output in Japan over the period 1880–1970.

Considering per capita income growth, it is intuitively obvious that, ceteris paribus, the direct contribution of population growth is negative while that of labor growth is positive. Less obvious, however, are the positive indirect con-

1 Simon [21] used a simulation model to predict the effect of population growth on per-worker income. For more developed countries (those with per capita incomes over U.S.$1,000 in 1976) he found that the effect of population growth on per-worker income, although initially negative, would become positive (after 30–80 years). For less developed countries, he found that moderate population growth would contribute more to per-worker income in the long run (after 75–150 years) than either zero population growth or very fast population growth.

2 Although the earlier research of Kelley and Williamson [7] [9] showed the economic effects of population growth to be strongly negative, the results of their later research [8] showed population growth to have more positive effects although they were less optimistic than Simon [21].

tributions which can result from both population and labor growth—"indirect" in the sense of coming by way of the influences of population and labor on the rate of technical change in either sector. The contributions of population and labor growth to per capita income growth in Japan over the period 1880–1960 were estimated tentatively in Yamaguchi [25] [26]. This paper extends these earlier tentative studies through employing a more *consistent model*[3] and an *improved data base*,[4] by estimating the contribution of population and labor growth to agricultural and nonagricultural *output growth* in addition to per capita income growth, and by providing a *sensitivity analysis* and some *policy implications* of the results.

II. OPTIMISTIC AND PESSIMISTIC VIEWS OF POPULATION GROWTH

Population growth can be viewed optimistically or pessimistically depending on whether one sees its effects on the economy as positive or negative. Throughout most of history, the optimistic viewpoint has prevailed. The ancient Greeks and Romans and the more recent Mercantilists considered people to be source of power. However, in the late eighteenth century the Malthusian view gained prominence and population growth came to be viewed negatively. The Malthusian veiw has been supported by much economic research, including Coale and Hoover [3], and Meadows et al. [13].

Wagner [2] tried to evaluate the positive effects of population on per capita income through labor and the negative effects of population through distribution. While Wagner considered only the positive effects of population derived from the supply of labor, Keynes [10] and Hansen [5] attempted more complete evaluations of the positive effects by including consumption and demand factors. Hicks [6], Kuznets [11], and Simon [21] have followed with evaluations of the positive effects of population growth.

It is true that, ceteris paribus, population growth must decrease per capita income. The effect is strengthened by the resulting decrease in the labor participation rate. Also, an increase in the number of children leads to increases in consumption and reduced savings.

However, there is a variety of positive effects which may result from population growth and these should not be overlooked. The most obvious positive effect is labor's contribution to output, this effect being strengthened by children's work and the extension of working hours by parents. A second positive effect derives from scale of economy, division of labor, and increased competition.

[3] The model used in this paper is specified and graphically explained in Yamaguchi and Kennedy [28], the only difference being the model specification here is more refined (P_2 is a numeraire). The model used here is more consistent than in Yamaguchi [25] [26] because it measures production in both sectors by value added (Yamaguchi [25] [26] measured agricultural production by quantity of output and nonagricultural production by value added).

[4] Compared to Yamaguchi [25] [26], improved growth rates for all of the endogenous and exogenous variables (based on the new data of Ohkawa and Shinohara [19]) are used in this study. The $\dot{Y}_1$, $\dot{Y}_2$, $\dot{T}_1$, and $\dot{T}_2$ data in Appendix Table II and all parameter values of Appendix Table III are completely different from those in the earlier works.

Third, the development of infrastructure and education is facilitated through high population density. Simon [21] showed that high population growth had a positive effect on irrigation and agricultural investment in developing countries. Fourth, insofar as necessity is the mother of invention, sometimes population pressure sparks economic progress. Fifth, an increased share of young people may increase the sensitivity for new products, adaptability and enthusiasm for new occupations. Further, young people have more opportunity for a higher level of education and higher mobility of labor. Sixth, population growth facilitates the accumulation of knowledge and the discovery of natural resources. Also the number of geniuses increases in absolute numbers as population grows.

These positive effects of population growth will occur to a greater or lesser extent depending on time and place. Although they are difficult to measure directly, this study attempts to capture at least some of them by measuring the indirect effects of population growth via its influence on the rate of technical change.

III. THE MODEL

Several approaches have been used to study the modern economic growth of Japan since the Meiji Restoration of 1868. Minami and Ono [14] used a classical approach, assuming (like Lewis [12] and Fei and Ranis [4]) an unlimited labor supply. They used Japanese historical data and normal econometric methods to estimate the parameters of their model, and then simulated with it.[5]

A second approach is the neoclassical one used by Kelley and Williamson [7] [8], and Kelley, Williamson, and Cheetham [9]. They assumed that the wage rate equals the marginal product of labor. They lacked adequate time series data for estimating the parameters of their model so obtained parameter values from the best sources of many Japanese researchers' works. They employed historical validation, comparing the simulated results of their model with actual historical data of Japan.

Our model represents a third approach, combining growth accounting with a two-sector (agricultural and nonagricultural) model constructed along neoclassical lines. The model assumes the existence of wage differentials between the two sectors. In this sense it represents a "middle path" in relation to the two approaches described above. The model extends conventional growth accounting to include intersectoral relationships and demand factors (population, per capita income, terms of trade, and imports/exports) more directly. It can incorporate the effects of technical change, population, and labor growth on per capita income, and the flow of physical and human resources between sectors through product and factor markets. The model assumes that technical change is not transferable between sectors. The separate effects of agricultural technical change and nonagricultural technical change can thus be estimated. A distinguishing feature of the model is the independent treatment of population and

[5] Ogawa and Suits [17] also used normal econometric methods to estimate the effects of population on the economic development of Japan.

labor force. This allows their effects on the growth of per capita income and sectoral output to be estimated separately.

Static and dynamic versions of the mathematical model are summarized in Appendix Table I. The dynamic model includes eight exogenous variables: technical change in agriculture (T_1), technical change in nonagriculture (T_2), population (Q), total labor (L), total capital (K), land (B), agricultural demand shifter (a), and the relative wage rate (m_w). The dynamic model also includes eight endogenous variables: agricultural output (Y_1), nonagricultural output (Y_2), agricultural labor (L_1), nonagricultural labor (L_2), agricultural capital (K_1), nonagricultural capital (K_2), relative price (P), and per capita income (E).

Growth rates of the model's endogenous and exogenous variables for the period 1880–1970 are given in Appendix Table II. Real per capita income in Japan grew at an average rate of 3.8 per cent per year. Its decade average fluctuated from a low of 0.5 per cent per year (1920–30) to a high of 10.0 per cent (1960–70). Population grew at an average rate of 1.2 per cent per year. The average rate of total labor growth was only slightly less, 0.9 per cent per year. However, within specific decades, the rates of growth of population and labor varied considerably. The average growth rate of agricultural and nonagricultural output was 1.6 and 5.4 per cent per year, respectively. The rate of agricultural technical change averaged 1.6 per cent per year, while the rate of nonagricultural technical change averaged 2.0 per cent per year. The parameter values used in the model are given in Appendix Table III.

The following two sections of the paper estimate the direct contribution (Section IV) and indirect contribution (Section V) of population cum labor growth to per capita income and sectoral output growth in Japan, 1880–1970. Section VI performs a sensitivity analysis of growth rate multipliers. Section VII summarizes and concludes the paper.

IV. DIRECT CONTRIBUTION OF POPULATION CUM LABOR GROWTH TO THE GROWTH OF PER CAPITA INCOME AND SECTORAL OUTPUT

The model is designed to estimate the *influence* of each exogenous variable on each endogenous variable in a general equilibrium context. We refer to these influences of exogenous variables on endogenous variables as "growth rate multipliers" (or "GRM"). The GRM EQ, for example, equals $\partial\dot{E}/\partial\dot{Q}$ and measures the percentage change in per capita income growth ($\dot{E}$), given a one per cent change in population growth ($\dot{Q}$). The *contribution* of each exogenous variable to each endogenous variable is obtained by multiplying the value of the growth rate multiplier by the historical growth rate of the exogenous variable.

This procedure is used in the following equations to estimate the direct contribution of population cum labor growth (i.e., the sum of population's contribution and labor's contribution) to the growth of per capita income [equation (1)] and sectoral output [equation (2)].

$$CEPop_D = (EQ \times \dot{Q}) + (EL \times \dot{L}) \qquad (1)$$

where $CEPop_D$ is the direct contribution of population cum labor growth to real per capita income growth, EQ (EL) is the influence of population (labor) growth on the growth of per capita income, $\dot{Q}(\dot{L})$ is the growth rate of population (labor).[6]

$$CY_iPop_D = (Y_iQ \times \dot{Q}) + (Y_iL \times \dot{L}) \qquad (2)$$

where CY_iPop_D is the direct contribution of population cum labor growth to output growth in sector i ($i=1$, $2=$agricultural and nonagricultural sector, respectively), Y_iQ (Y_iL) is the influence of population (labor) on output growth in sector i. Where CY_2Pop_D is the direct contribution of population cum labor growth to nonagricultural output growth, $\partial\dot{Y}_2/\partial\dot{Q}$ ($\partial\dot{Y}_2/\partial\dot{L}$) is the influence of population (labor) growth on the growth of nonagricultural output.

Growth rate multipliers showing the separate influences of population and labor growth on the growth of per capita income and sectoral output are given for each five-year period, 1880–1965, in Table I. The influence of population growth (EQ) on per capita income growth is negative. It is most strongly negative in 1905, when a 1 per cent increase in population growth causes a 1.15 per cent decrease in per capita income growth. Labor growth, on the other hand, has a positive influence on per capita income growth, ranging from a low of 0.60 (1945) to a high of 0.83 (1885).

The influence of population growth on agricultural output growth (Y_1Q) is positive, whereas its influence on nonagricultural output growth (Y_2Q) is negative. Labor growth affects both agricultural and nonagricultural output growth positively, the latter being more strongly affected.

Growth rate multipliers embodying the influences of the rate of agricultural and nonagricultural technical change on the growth of per capita income and sectoral output are also shown in Table I. These values will be used later, but it should be noted here that technical change in each sector affects per capita income growth and output positively in every case, except for the effect of nonagricultural technical change on agricultural output growth (Y_1T_2). Growth rate multipliers relevant to agricultural labor (L_1) and nonagricultural labor (L_2) are also given in Table I for later use.

The direct contributions of population and labor growth to per capita income and sectoral output growth are reported for each decade, 1880–1970, in Table II. The historical rates of growth for per capita income ($\dot{E}$), agricultural output ($\dot{Y}_1$) and nonagricultural output ($\dot{Y}_2$) are also shown. The contribution of population growth [column (2)] to per capita income growth is negative in each decade while the contribution of labor growth [column (3)] is positive in each decade. The former outweighs the latter (except in the period 1950–60) yielding a total direct contribution of population cum labor growth, $CEPop_D$ [column (4)], which is negative, averaging -0.65 over the period 1880–1970.[7]

6 The *direct* contributions of population and labor growth to per capita income growth have been previously estimated in Yamaguchi and Binswanger [27] using an earlier data set.

7 This result is consistent with Kelley and Williamson [7] [9]. Note that if the labor participation rate had been less in Japan, as it might have been had population growth been greater, then the average value of $CEPop_D$ would likely be more negative.

TABLE I

GROWTH RATE MULTIPLIERS FOR THE EFFECTS OF POPULATION, LABOR AND AGRICULTURAL AND NONAGRICULTURAL TECHNICAL CHANGE ON REAL PER CAPITA INCOME AND SECTORAL OUTPUT, 1880–1965

Year	Per Capita Income				Agricultural Output				Nonagricultural output				Agricultural Labor				Nonagricultural Labor			
	EQ	EL	ET_1	ET_2	Y_1Q γ'_1	Y_1L β'_1	Y_1T_1 α'_1	Y_1T_2 δ'_1	Y_2Q γ'_2	Y_2L β'_2	Y_2T_1 α'_2	Y_2T_2 δ'_2	L_1Q γ_1	L_1L β_1	L_1T_1 α_1	L_1T_2 δ_1	L_2Q γ_2	L_2L β_2	L_2T_1 α_2	L_2T_2 δ_2
1880	−1.09	0.79	0.50	0.59	0.10	0.49	1.00	−0.10	−0.28	1.08	0.00	1.28	0.12	0.90	0.00	−0.12	−0.30	1.26	0.00	0.30
1885	−1.12	0.83	0.42	0.70	0.08	0.51	0.95	−0.03	−0.23	0.99	0.14	1.09	0.10	0.93	−0.06	−0.04	−0.24	1.16	0.15	0.10
1890	−1.10	0.75	0.43	0.67	0.09	0.48	0.96	−0.05	−0.22	0.93	0.10	1.12	0.12	0.92	−0.05	−0.06	−0.25	1.17	0.11	0.14
1895	−1.10	0.74	0.40	0.70	0.08	0.49	0.94	−0.03	−0.20	0.86	0.13	1.06	0.12	0.93	−0.08	−0.04	−0.22	1.13	0.15	0.07
1900	−1.10	0.71	0.37	0.73	0.08	0.51	0.93	−0.01	−0.18	0.79	0.15	1.03	0.11	0.94	−0.09	−0.02	−0.21	1.12	0.17	0.03
1905	−1.15	0.71	0.36	0.78	0.13	0.48	0.90	−0.03	−0.24	0.79	0.18	1.06	0.17	0.90	−0.13	−0.04	−0.29	1.17	0.22	0.07
1910	−1.14	0.71	0.35	0.79	0.13	0.48	0.89	−0.03	−0.23	0.78	0.18	1.05	0.17	0.90	−0.14	−0.04	−0.28	1.16	0.22	0.06
1915	−1.11	0.64	0.32	0.80	0.14	0.47	0.88	−0.02	−0.19	0.68	0.16	1.03	0.19	0.90	−0.16	−0.03	−0.25	1.14	0.21	0.04
1920	−1.10	0.70	0.30	0.80	0.16	0.46	0.87	−0.03	−0.17	0.77	0.15	1.03	0.21	0.88	−0.18	−0.03	−0.22	1.13	0.19	0.04
1925	−1.09	0.70	0.29	0.79	0.17	0.49	0.86	−0.03	−0.16	0.77	0.13	1.03	0.22	0.87	−0.19	−0.04	−0.20	1.12	0.17	0.03
1930	−1.10	0.70	0.23	0.86	0.17	0.51	0.82	−0.01	−0.14	0.72	0.15	0.99	0.21	0.87	−0.22	0.01	−0.18	1.11	0.20	−0.01
1935	−1.08	0.66	0.23	0.86	0.17	0.46	0.83	−0.01	−0.12	0.69	0.13	1.00	0.22	0.88	−0.23	0.01	−0.17	1.10	0.18	−0.01
1940	−1.07	0.62	0.21	0.87	0.17	0.46	0.82	−0.01	−0.11	0.64	0.11	0.99	0.24	0.87	−0.25	0.01	−0.16	1.09	0.17	−0.01
1945	−1.05	0.60	0.22	0.84	0.11	0.49	0.85	0.05	−0.08	0.62	0.12	0.96	0.15	0.92	−0.22	0.07	−0.12	1.06	0.16	−0.05
1950	−1.08	0.62	0.22	0.86	0.16	0.46	0.83	−0.01	−0.12	0.64	0.12	1.00	0.22	0.88	−0.23	0.01	−0.18	1.10	0.18	−0.01
1955	−1.09	0.79	0.23	0.86	0.28	0.46	0.79	−0.06	−0.16	0.86	0.12	1.04	0.34	0.77	−0.26	−0.08	−0.20	1.13	0.15	0.04
1960	−1.08	0.74	0.16	0.92	0.26	0.42	0.77	−0.03	−0.12	0.77	0.11	1.01	0.36	0.79	−0.31	−0.04	−0.15	1.09	0.13	0.02
1965	−1.06	0.74	0.12	0.94	0.29	0.42	0.73	−0.02	−0.09	0.76	0.08	1.01	0.37	0.78	−0.34	−0.03	−0.11	1.07	0.10	0.01

TABLE II

DIRECT CONTRIBUTION OF POPULATION GROWTH AND LABOR GROWTH TO THE GROWTH OF REAL PER CAPITA INCOME AND SECTORAL OUTPUT, 1880–1970

(% per year)

Decade	(1) $\dot{E}$	(2) $(EQ)\dot{Q}$	(3) $(EL)\dot{L}$	(4) $CEPop_D$ (2)+(3)	(5) $\dot{Y}_1$	(6) $(Y_1Q)\dot{Q}$	(7) $(Y_1L)\dot{L}$	(8) CY_1Pop_D (6)+(7)	(9) $\dot{Y}_2$	(10) $(Y_2Q)\dot{Q}$	(11) $(Y_2L)\dot{L}$	(12) CY_2Pop_D (10)+(11)
1880–90	2.7	−1.01	0.42	−0.59	3.4	0.07	0.26	0.33	3.7	−0.21	0.50	0.29
1890–1900	2.2	−1.10	0.44	−0.66	1.7	0.08	0.29	0.37	3.9	−0.20	0.52	0.32
1900–10	1.3	−1.38	0.28	−1.10	2.2	0.16	0.19	0.35	2.6	−0.29	0.32	0.03
1910–20	2.6	−1.33	0.38	−0.95	3.2	0.17	0.28	0.45	4.0	−0.23	0.41	0.18
1920–30	0.5	−1.74	0.63	−1.11	1.1	0.27	0.44	0.71	2.4	−0.26	0.69	0.43
1930–40	3.9	−1.19	0.99	−0.20	0.4	0.19	0.69	0.88	5.7	−0.13	1.04	0.91
1940–50	—	−1.68	0.12	−1.56	−0.5	0.18	0.10	0.28	—	−0.13	0.12	−0.01
1950–60	7.1	−1.31	1.74	0.43	3.6	0.34	1.01	1.35	9.2	−0.19	1.89	1.70
1960–70	10.0	−1.17	0.96	−0.21	−1.0	0.32	0.55	0.87	11.9	−0.10	0.99	0.89

The total direct contribution of population cum labor growth, CY_1Pop_D [column (8)] to agricultural output growth is positive in each decade, given positive contributions from both population growth [column (6)] and labor growth [column (7)]. With respect to nonagricultural output growth, the total direct contribution of population cum labor growth, CY_2Pop_D [column (12)] is positive in each decade except 1940–50, as the negative contribution of population growth [column (10)] is outweighed by the positive contribution of labor growth [column (11)].

V. INDIRECT CONTRIBUTION OF POPULATION CUM LABOR GROWTH TO THE GROWTH OF PER CAPITA INCOME AND SECTORAL OUTPUT

In evaluating the contribution of population growth to economic development, Simon [21] argued that population growth and technical change should not be seen as two independent forces in a race. Rather, technical change should be viewed as a function of population growth.[8] Population growth implies advances in knowledge and technology, economies of scale, and discoveries of resources. As population growth contributes to technical change it will indirectly contribute to per capita income and output growth.

First, with respect to per capita income growth, the indirect contribution of population cum labor growth via agricultural and nonagricultural technical change can be written as in equation (3):

$$CEPop_I = ET_1\frac{\partial \dot{T}_1}{\partial \dot{Q}}\dot{Q} + ET_1\frac{\partial \dot{T}_1}{\partial \dot{L}}\dot{L} + ET_2\frac{\partial \dot{T}_2}{\partial \dot{Q}}\dot{Q} + ET_2\frac{\partial \dot{T}_2}{\partial \dot{L}}\dot{L} \qquad (3)$$

where $CEPop_I$ is the indirect contribution of population cum labor growth to real per capita income growth, ET_1 (ET_2) is the influence of the rate of agricultural (nonagricultural) technical change on per capita income growth, $\partial \dot{T}_1/\partial \dot{Q}$ ($\partial \dot{T}_2/\partial \dot{Q}$) is the influence of population growth on the rate of agricultural (nonagricultural) technical change, and $\partial \dot{T}_1/\partial \dot{L}$ ($\partial \dot{T}_2/\partial \dot{L}$) is the influence of labor growth on the rate of agricultural (nonagricultural) technical change.

The indirect contribution of population cum labor growth to sectoral output growth via agricultural and nonagricultural technical change can be written as in equation (4):

$$CY_iPop_I = Y_iT_1\frac{\partial \dot{T}_1}{\partial \dot{Q}}\dot{Q} + Y_iT_1\frac{\partial \dot{T}_1}{\partial \dot{L}}\dot{L} + Y_iT_2\frac{\partial \dot{T}_2}{\partial \dot{Q}}\dot{Q} + Y_iT_2\frac{\partial \dot{T}_2}{\partial \dot{L}}\dot{L} \qquad (4)$$

where CY_iPop_I is the indirect contribution of population cum labor growth to output growth in sector i, and Y_iT_1 (Y_iT_2) is the influence of the rate of agricultural (nonagricultural) technical change on output growth in sector i.

This section attempts to estimate the indirect contribution of population cum labor growth to the growth of per capita income and sectoral output. Three

[8] Boserup [1] and Clark [2], among others have viewed technical change as a function of population growth.

alternative approaches are used: the Residual and Verdoorn methods as employed by Simon [21], and the "factor augmenting rate" method of ordinary growth theory. Simon explains the Residual and Verdoorn methods as follows:

> The crucial feedback effect of population growth upon the level of productivity is embodied in two alternative ways. The first approach utilizes the notion of the "residual" found in empirical studies of productivity change; the residual is made a function of the labor force, because it seems reasonable to assume that the size of the labor force influences the amount of invention and innovation. The second approach takes advantage of "Verdoorn's Law" which asserts that the change in productivity is a function of total output (and total output obviously is a function of population size). It is reasonable to suppose that output in Verdoorn's Law is an empirical representation for the influence of the size of labor force upon productivity, and hence the two approaches describe the same phenomenon. And in fact they give similar results. [21, p. 10]

The "factor augmenting rate" method of ordinary growth theory is used by Kelley and Williamson [8]. The efficiency of capital ($e^{\lambda_K}K$) and efficiency of labor ($e^{\lambda_L}L$) take into account two sets of factors, the first physical capital and labor (K and L) and the second technical progress variables which augment physical capital and labor (i.e., e^{λ_K} and e^{λ_L}). The direct and indirect contribution of population cum labor growth to per capita income and sectoral output growth are summed to obtain their total contribution.

The first approach used to estimate the indirect contribution of the growth of population cum labor to the growth of per capita income and sectoral output is the Residual method. It assumes, after Simon, that the size of the residual depends on the size of the labor force.[9] In our model, the residual is viewed as variation in the level of technical change. From our model the labor force of each sector can be explained by the model's exogenous variables. Therefore we obtain the following four equations:

$$T_1 = a_1 L_1 , \tag{5}$$

$$L_1 = B_1 T_1^{\alpha_1} L^{\beta_1} Q^{\gamma_1} T_2^{\delta_1} , \tag{6}$$

$$T_2 = a_2 L_2 , \tag{7}$$

$$L_2 = B_2 T_1^{\alpha_2} L^{\beta_2} Q^{\gamma_2} T_2^{\delta_2} , \tag{8}$$

where T_1 (T_2) is agricultural (nonagricultural) technical change, L_1 (L_2) is the agricultural (nonagricultural) labor force, Q is population, L is total labor, and B_1 (B_2) represents the other exogenous variables in the model.[10]

These four equations can be transformed into the following two equations:

$$T_1 = A_1 L^{(\beta_1 + \delta_1 m)/(1-\alpha_1)} Q^{(\gamma_1 + \delta_1 n)/(1-\alpha_1)} , \tag{9}$$

9 In this paper, we equate technical change in each sector to the sector's labor force [equations (5) and (7)]. This is the usual way for the Residual method, although in Yamaguchi [25] technical change in each sector was equated to the square root of the sector's labor force.

10 B_1 and B_2 include total capital, land, agricultural demand shifter, and the relative wage rate.

TABLE III

ELASTICITIES OF THE RATE OF AGRICULTURAL TECHNICAL CHANGE AND NONAGRICULTURAL TECHNICAL CHANGE WITH RESPECT TO THE GROWTH OF POPULATION AND LABOR, 1880–1965

Year	T_1Q	T_1L	T_2Q	T_2L
1880	0.17(0.14)	0.68(0.34)	−0.43(−0.39)	1.80(1.50)
1885	0.10(0.08)	0.82(0.45)	−0.25(−0.24)	1.43(1.16)
1890	0.13(0.10)	0.79(0.41)	−0.27(−0.24)	1.46(1.10)
1895	0.12(0.08)	0.81(0.43)	−0.22(−0.20)	1.35(0.98)
1900	0.10(0.08)	0.84(0.47)	−0.20(−0.17)	1.30(0.89)
1905	0.16(0.12)	0.75(0.41)	−0.27(−0.23)	1.43(0.92)
1910	0.16(0.12)	0.74(0.41)	−0.26(−0.22)	1.41(0.90)
1915	0.17(0.13)	0.74(0.41)	−0.22(−0.17)	1.35(0.77)
1920	0.18(0.15)	0.71(0.38)	−0.19(−0.15)	1.32(0.85)
1925	0.19(0.15)	0.69(0.40)	−0.17(−0.14)	1.28(0.85)
1930	0.17(0.15)	0.72(0.43)	−0.14(−0.12)	1.24(0.78)
1935	0.18(0.15)	0.73(0.39)	−0.14(−0.10)	1.22(0.74)
1940	0.19(0.14)	0.71(0.38)	−0.13(−0.09)	1.20(0.68)
1945	0.13(0.09)	0.69(0.45)	−0.09(−0.07)	1.12(0.65)
1950	0.18(0.14)	0.73(0.39)	−0.15(−0.10)	1.22(0.69)
1955	0.28(0.24)	0.53(0.33)	−0.16(−0.14)	1.26(0.94)
1960	0.28(0.21)	0.57(0.32)	−0.12(−0.10)	1.19(0.81)
1965	0.28(0.23)	0.56(0.32)	−0.08(−0.07)	1.14(0.79)

Notes: 1. $T_iQ=\partial\dot{T}_i/\partial\dot{Q}$, $T_iL=\partial\dot{T}_i/\partial\dot{L}$.
2. Derived by Residual method (no parentheses) and Verdoorn method (in parentheses).

$$T_2=A_2L^mQ^n\,, \tag{10}$$

where

$$m=[\beta_2(1-\alpha_1)+\beta_1\alpha_2]/[(1-\alpha_1)(1-\delta_2)-\alpha_2\delta_1]\,,$$
$$n=[\gamma_2(1-\alpha_1)+\gamma_1\alpha_2]/[(1-\alpha_1)(1-\delta_2)-\alpha_2\delta_1]\,,$$

and where A_i includes the constant plus all other terms, with the exception of technical change in each sector, population and total labor.

The parameter values needed to solve equations (9) and (10) are the growth rate multipliers given for agricultural and nonagricultural labor in Table I. Solving these equations yields elasticity values of agricultural and nonagricultural technical change with respect to population and labor growth. These elasticities are reported for each five-year period, 1880–1965, in Table III. With respect to the rate of agricultural technical change ($\dot{T}_1$), both population growth ($\dot{Q}$) and labor growth ($\dot{L}$) influence it positively. A one per cent increase in $\dot{Q}$ causes $\dot{T}_1$ to increase between 0.10 and 0.28 per cent, while a one per cent increase in $\dot{L}$ causes $\dot{T}_1$ to increase between 0.53 and 0.84 per cent. With respect to the rate of nonagricultural technical change ($\dot{T}_2$), $\dot{Q}$ affects it negatively while $\dot{L}$ affects it positively. A one per cent increase in $\dot{Q}$ causes $\dot{T}_2$ to decrease between 0.08 and 0.43 per cent, while a one per cent increase in $\dot{L}$ causes $\dot{T}_2$ to increase between 1.12 and 1.80 per cent. If both population and labor growth increase by one per cent, the percentage change in the rate of technical change in each sector equals the sum of the two relevant elasticities.

The elasticity values of Table III allow us to solve equations (3) and (4) to obtain the Residual method's estimates of the indirect contribution of population cum labor growth to the growth of per capita income ($CEPop_I$), agricultural output (CY_1Pop_I), and nonagricultural output (CY_2Pop_I). These respective estimates are given in columns (5), (10), and (15) of Table IV. $CEPop_I$, for example, equals the sum of $\dot{Q}$'s contribution to $\dot{E}$ via $\dot{T}_1$ [column (1)], $\dot{L}$'s contribution to $\dot{E}$ via $\dot{T}_1$ [column (2)], $\dot{Q}$'s contribution to $\dot{E}$ via $\dot{T}_2$ [column (3)] and $\dot{L}$'s contribution to $\dot{E}$ via $\dot{T}_2$ [column (4)], as in equation (3). $CEPop_I$ is positive in each decade, ranging from a low of 0.15 per cent per year (1940–50) to a high of 2.56 (1950–60). The indirect contribution of population cum labor growth to the growth of agricultural output (CY_1Pop_I) and nonagricultural output (CY_2Pop_I) is also positive in each decade. CY_1Pop_I ranges from 0.32 (1940–50) to 1.06 per cent per year (1930–40) and CY_2Pop_I ranges from 0.12 (1940–50) to 2.86 (1950–60).

The second approach used to estimate the indirect contribution of the growth of population and labor to the growth of per capita income and sectoral output is the Verdoorn method. In each sector, we assume that technical change is a function of the square root of output, which in turn depends on population growth, as in the following four equations:

$$T_1 = a'_1 Y_1^{1/2}, \tag{11}$$

$$Y_1 = B'_1 T_1^{\alpha'_1} L^{\beta'_1} Q^{\gamma'_1} T_2^{\delta'_1}, \tag{12}$$

$$T_2 = a'_2 Y_2^{1/2}, \tag{13}$$

$$Y_2 = B'_2 T_1^{\alpha'_2} L^{\beta'_2} Q^{\gamma'_2} T_2^{\delta'_2}. \tag{14}$$

These four equations can be transformed into the following two equations:

$$T_1 = A'_1 L^{(\beta'_1 + \delta'_1 m')/(2-\alpha'_1)} Q^{(\gamma'_1 + \delta'_1 n')/(2-\alpha'_1)}, \tag{15}$$

$$T_2 = A'_2 L^{m'} Q^{n'}, \tag{16}$$

where

$$m' = (\alpha'_2 \beta'_1 + 2\beta'_2 - \alpha'_1 \beta'_2)/(4 - 2\alpha'_1 - \alpha'_2 \delta'_1 - 2\delta'_2 + \alpha'_1 \delta'_2),$$

$$n' = (\alpha'_2 \gamma'_1 + 2\gamma'_2 - \alpha'_1 \gamma'_2)/(4 - 2\alpha'_1 - \alpha'_2 \beta'_1 - 2\delta'_2 + \alpha'_1 \delta'_2),$$

and where A'_i includes the constant plus all other terms, with the exception of technical change in each sector, population and total labor.

The parameter values needed to solve equations (15) and (16) are the growth rate multipliers given for agricultural and nonagricultural output in Table I. Solving these equations yields elasticity values of agricultural and nonagricultural technical change with respect to population and labor growth. These elasticities are also reported in Table III (in parentheses) for each five-year period, 1880–1965.

As with the Residual method, the rate of agricultural technical change is positively influenced by both population and labor growth, while the rate of

TABLE IV

INDIRECT CONTRIBUTION OF POPULATION AND LABOR GROWTH TO PER CAPITA INCOME AND SECTORAL OUTPUT GROWTH VIA AGRICULTURAL AND NONAGRICULTURAL TECHNICAL CHANGE, 1880–1970

(% per year)

Decade	(1) $(ET_1)(T_1Q)\dot{Q}$	(2) $(ET_1)(T_1L)\dot{L}$	(3) $(ET_2)(T_2Q)\dot{Q}$	(4) $(ET_2)(T_2L)\dot{L}$	(5) $CEPop_I$ (1)+(2)+(3)+(4)
1880–90	0.04(0.03)	0.17(0.09)	−0.16(−0.15)	0.50(0.41)	0.55(0.38)
1890–1900	0.05(0.03)	0.19(0.10)	−0.15(−0.14)	0.57(0.41)	0.66(0.40)
1900–10	0.07(0.05)	0.11(0.06)	−0.25(−0.22)	0.45(0.29)	0.38(0.18)
1910–20	0.07(0.05)	0.14(0.08)	−0.21(−0.16)	0.65(0.37)	0.65(0.34)
1920–30	0.09(0.07)	0.18(0.10)	−0.21(−0.18)	0.91(0.60)	0.97(0.59)
1930–40	0.05(0.03)	0.25(0.13)	−0.13(−0.10)	1.57(0.95)	1.74(1.01)
1940–50	0.05(0.03)	0.03(0.02)	−0.12(−0.09)	0.19(0.11)	0.15(0.07)
1950–60	0.08(0.07)	0.27(0.17)	−0.17(−0.14)	2.38(1.78)	2.56(1.88)
1960–70	0.04(0.03)	0.09(0.05)	−0.08(−0.07)	1.39(0.97)	1.44(0.98)

Decade	(6) $(Y_1T_1)(T_1Q)\dot{Q}$	(7) $(Y_1T_1)(T_1L)\dot{L}$	(8) $(Y_1T_2)(T_2Q)\dot{Q}$	(9) $(Y_1T_2)(T_2L)\dot{L}$	(10) CY_1Pop_I (6)+(7)+(8)+(9)
1880–90	0.09(0.08)	0.39(0.21)	0.01(0.01)	−0.02(−0.02)	0.47(0.28)
1890–1900	0.11(0.08)	0.46(0.24)	0.01(0.01)	−0.02(−0.02)	0.56(0.31)
1900–10	0.17(0.13)	0.27(0.15)	0.01(0.01)	−0.02(−0.01)	0.43(0.28)
1910–20	0.18(0.14)	0.39(0.22)	0.01(0.00)	−0.02(−0.01)	0.56(0.35)
1920–30	0.26(0.21)	0.53(0.31)	0.01(0.01)	−0.03(−0.02)	0.77(0.51)
1930–40	0.16(0.14)	0.91(0.49)	0.00(0.00)	−0.01(−0.01)	1.06(0.62)
1940–50	0.18(0.12)	0.12(0.08)	0.01(0.01)	0.01(−0.01)	0.32(0.20)
1950–60	0.27(0.23)	0.92(0.57)	0.01(0.01)	−0.17(−0.12)	1.03(0.69)
1960–70	0.22(0.18)	0.53(0.30)	0.00(0.00)	−0.03(−0.02)	0.72(0.46)

Decade	(11) $(Y_2T_1)(T_1Q)\dot{Q}$	(12) $(Y_2T_1)(T_1L)\dot{L}$	(13) $(Y_2T_2)(T_2Q)\dot{Q}$	(14) $(Y_2T_2)(T_2L)\dot{L}$	(15) CY_2Pop_I (11)+(12)+(13)+(14)
1880–90	0.01(0.01)	0.06(0.03)	−0.25(−0.24)	0.78(0.63)	0.60(0.43)
1890–1900	0.02(0.01)	0.06(0.03)	−0.23(−0.21)	0.86(0.62)	0.71(0.45)
1900–10	0.03(0.03)	0.05(0.03)	−0.34(−0.29)	0.61(0.39)	0.35(0.16)
1910–20	0.03(0.02)	0.07(0.04)	−0.27(−0.21)	0.83(0.48)	0.66(0.33)
1920–30	0.04(0.03)	0.08(0.05)	−0.28(−0.23)	1.19(0.79)	1.03(0.64)
1930–40	0.03(0.02)	0.14(0.08)	−0.15(−0.11)	1.83(1.11)	1.85(1.10)
1940–50	0.02(0.02)	0.02(0.01)	−0.14(−0.11)	0.22(0.12)	0.12(0.04)
1950–60	0.04(0.03)	0.14(0.09)	−0.10(−0.17)	2.88(2.15)	2.86(2.10)
1960–70	0.02(0.02)	0.06(0.03)	−0.09(−0.08)	1.50(1.04)	1.49(1.01)

Note: Derived by Residual method (no parentheses) and Verdoorn method (in parentheses).

nonagricultural technical change is influenced negatively by population growth but positively by labor growth.

The elasticity values of Table III allow us to solve equations (3) and (4) to obtain the Verdoorn method's estimates of the indirect contribution of population cum labor growth to the growth of per capita income ($CEPop_I$), agricultural output (CY_1Pop_I), and nonagricultural output (CY_2Pop_I). These estimates are given in parentheses in columns (5), (10), and (15) of Table IV respectively. As with the Residual method, the indirect contribution of population cum labor growth to per capita income and sectoral output growth is positive in each decade. $CEPop_I$ ranges from a low of 0.07 per cent per year to a high of 1.88, CY_1Pop_I from 0.20 to 0.69, and CY_2Pop_I from 0.04 to 2.10. In each case the lows are in 1940–50 and the highs in 1950–60.

The final approach used to estimate the indirect contribution of the growth of population and labor to the growth of per capita income and sectoral output is the factor augmenting rate method. We used the following equations to calculate the contribution of capital and labor cum population growth to the rate of agricultural and nonagricultural technical change:

$$\dot{T}_1 = \lambda_K \beta + \lambda_L \alpha \,, \tag{17}$$

$$\dot{T}_2 = \lambda_K \delta + \lambda_L \gamma \,, \tag{18}$$

where $\dot{T}_1$ ($\dot{T}_2$) equals the rate of technical change in the agricultural (nonagricultural) sector, λ_K (λ_L) is capital's (labor cum population's) rate of factor augmentation, β (α) is the factor share of capital (labor cum population) in the agricultural sector, and δ (γ) is the factor share of capital (labor cum population) in the nonagricultural sector.

Note that these equations assume identical factor augmenting rates (λ_K, λ_L) in both sectors. This implies either that technical change can be transferred between sectors or that the rates happen to coincide. In either case, this precluded varying rates of technical change between the two sectors, unlike with our own model where technical change is assumed to be sector specific.

The contribution of the growth of labor cum population ($\dot{L}$) to the rate of agricultural technical change ($\dot{T}_1$) equals the elasticity of $\dot{T}_1$ with respect to $\dot{L}$ ($\partial\dot{T}_1/\partial\dot{L}$) multiplied by $\dot{L}$. In equation (17), labor cum population's contribution to the rate of agricultural technical change is represented by $\lambda_L\alpha$. Similarly, the contribution of $\dot{L}$ to the rate of nonagricultural technical change ($\dot{T}_2$) equals the elasticity of $\dot{T}_2$ with respect to $\dot{L}$ ($\partial\dot{T}_2/\partial\dot{L}$) multiplied by $\dot{L}$. This is represented in equation (18) by $\lambda_L\gamma$. Thus, the factor augmenting rate method allows us to rewrite equations (3) and (4) as equations (19) and (20) respectively.

$$CEPop_I = (ET_1 \times \lambda_L \alpha) + (ET_2 \times \lambda_L \gamma) \,, \tag{19}$$

$$CY_iPop_I = (Y_iT_1 \times \lambda_1 \alpha) + (Y_iT_2 \times \lambda_L \gamma) \,. \tag{20}$$

Using equations (17) and (18), given values for T_1 and T_2 (from Appendix Table II) and values of factor shares (from Appendix Table III),[11] we can solve

[11] For each decade, the factor share of the median year is used. In the nonagricultural sector, the factor shares (γ and δ) are simply the values shown in Appendix Table III.

for λ_L. Rather than determine values of λ_L for each decade, an average value over the period 1880–1970 is used. This is because λ_L is most appropriately viewed as a long term efficiency measure, in that increased efficiency of machinery and labor must usually be preceded by a lengthy period of research, education, or training. The calculation of λ_L depends on the values of $\dot{T}_1$ and $\dot{T}_2$ [equations (17) and (18)]. But the values of $\dot{T}_1$ and $\dot{T}_2$ (particularly $\dot{T}_2$) fluctuate fairly widely in the short run—more than λ_L can be reasonably expected to fluctuate. Hence, an average value is calculated for λ_L and equals 1.2.[12]

Having calculated λ_L, we now solve equations (19) and (20) to determine the indirect contribution of population cum labor growth on the growth of per capita income and sectoral output. This is done for each decade,[13] 1880–1970, and the results are reported in Table V.

As with the Residual and Verdoorn methods, the indirect contribution of population cum labor growth to the growth of per capita income ($CEPop_I$), agricultural output (CY_1Pop_I), and nonagricultural output (CY_2Pop_I) is positive in each decade. $CEPop_I$ ranges from a low of 0.89 per cent per year (1960–1970) to a high of 1.00 (1900–10), CY_1Pop_I from 0.71 (1960–70) to 0.93 (1880–90), and CY_2Pop_I from 0.90 (1945–50) and (1960–70) to 1.04 (1900–10).[14]

Table VI sums the direct and indirect contributions of population cum labor growth to the growth of per capita income and sectoral output to obtain their total contribution. This is done for each of the three methods used to estimate the indirect contribution. With respect to per capita income growth, in the early decades studied, 1880–1930, the negative direct contribution ($CEPop_D$) tends to dominate the positive indirect contribution ($CEPop_I$) under the Residual and Verdoorn methods, yielding a total contribution ($CEPop_T$) which tends to be negative. Under the factor augmenting rate method, $CEPop_T$ during this period

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In the agricultural sector, it is necessary to account for the fact that land is included in the production function. The factor share of land is apportioned to labor and capital according to the proportion of labor and capital's individual factor shares to the sum of their factor shares. This portion of land's share is added to the values of α and β shown in Appendix Table III. For example, the factor share for labor used in 1880–1890 is 0.83. This equals 0.57 (1885's value in Appendix Table III) plus 0.26 which is labor's proportion (0.57/0.69) of land's factor share (0.31).

12 This value of λ_L ($=1.2$) comes from substituting average values into equations (17) and (18) and solving them: $1.6=\lambda_K(0.16)+\lambda_L(0.84)$ and $2.0=\lambda_K(0.32)+\lambda_L(0.68)$.

13 Average values are used for λ_L ($=1.2$) and the factor shares (α, γ), while values for each decade are used for the growth rate multipliers (ET_1 and ET_2). GRM values used for each decade are the median years (from Table I). The values of factor shares for each decade are also median years (from Appendix Table III). Also, population cum labor may have an effect on the value of λ_K through new housing investment and equipment investment. However, it would be difficult to capture this effect in our model and would go beyond the scope of our study. Therefore we follow the same approach as in ordinary growth theory: Kelley and Williamson [7] [8], Minami and Ono [14], and Ogawa and Suits [17].

14 The indirect contribution of population cum labor growth to per capita income and sectoral output growth will of course vary with varying economic and social conditions. In Japan, this indirect contribution would likely have been less were it not for the education, motivation, and adaptive capabilities of its population.

TABLE V

INDIRECT CONTRIBUTION OF POPULATION CUM LABOR GROWTH TO PER CAPITA INCOME AND SECTORAL OUTPUT GROWTH VIA AGRICULTURAL AND NONAGRICULTURAL TECHNICAL CHANGE, 1880–1970 (FACTOR AUGMENTING RATE METHOD)

(% per year)

Decade	(1) $(ET_1)\lambda_L\alpha$	(2) $(ET_2)\lambda_L\gamma$	(3) $CEPop_I$ (1)+(2)	(4) $(Y_1T_1)\lambda_L\alpha$	(5) $(Y_1T_2)\lambda_L\gamma$	(6) CY_1Pop_I (4)+(5)	(7) $(Y_2T_1)\lambda_L\alpha$	(8) $(Y_2T_2)\lambda_L\gamma$	(9) CY_2Pop_I (7)+(8)
1880–90	0.42	0.57	0.99	0.95	−0.02	0.93	0.14	0.89	1.03
1890–1900	0.40	0.57	0.97	0.94	−0.02	0.92	0.13	0.86	0.99
1900–10	0.36	0.64	1.00	0.90	−0.02	0.88	0.18	0.86	1.04
1910–20	0.32	0.65	0.97	0.88	−0.02	0.86	0.16	0.84	1.00
1920–30	0.29	0.64	0.93	0.86	−0.02	0.84	0.13	0.84	0.97
1930–40	0.23	0.70	0.93	0.83	−0.01	0.82	0.13	0.82	0.95
1940–50	0.22	0.89	0.91	0.85	−0.04	0.81	0.12	0.78	0.90
1950–60	0.23	0.70	0.93	0.79	−0.05	0.74	0.12	0.85	0.97
1960–70	0.12	0.77	0.89	0.73	−0.02	0.71	0.08	0.82	0.90

TABLE VI

TOTAL CONTRIBUTION OF POPULATION CUM LABOR GROWTH TO PER CAPITA INCOME AND SECTORAL OUTPUT GROWTH, 1880–1970

(% per year)

Decade	Direct Contribution to Per Capita Income Growth ($CEPop_D$)	Indirect Contribution to Per Capita Income Growth ($CEPop_I$)			Total Contribution to Per Capita Income Growth ($CEPop_T$)		
		Residual Method	Verdoorn Method	Factor Aug-menting Rate Method	Residual Method	Verdoorn Method	Factor Aug-menting Rate Method
	(1)	(2)	(3)	(4)	(5) (1)+(2)	(6) (1)+(3)	(7) (1)+(4)
1880–90	−0.59	0.55	0.38	0.99	−0.04	−0.21	0.40
1890–1900	−0.66	0.66	0.40	0.97	0.00	−0.26	0.31
1900–10	−1.10	0.38	0.18	1.00	−0.72	−0.92	−0.10
1910–20	−0.95	0.65	0.34	0.97	−0.30	−0.61	0.02
1920–30	−1.11	0.97	0.59	0.93	−0.14	−0.52	−0.18
1930–40	−0.20	1.74	1.01	0.93	1.54	0.81	0.73
1940–50	−1.56	0.15	0.07	0.91	−1.41	−1.49	−0.65
1950–60	0.43	2.56	1.88	0.93	2.99	2.31	1.36
1960–70	−0.21	1.44	0.98	0.89	1.23	0.77	0.68
Average	−0.65	1.01	0.65	0.95	0.35	0.01	0.29

Decade	Direct Contribution to Agric. Output Growth (CY_1Pop_D)	Indirect Contribution to Agric. Output Growth (CY_1Pop_I)			Total Contribution to Agric. Output Growth (CY_1Pop_T)		
		Residual Method	Verdoorn Method	Factor Aug-menting Rate Method	Residual Method	Verdoorn Method	Factor Aug-menting Rate Method
	(8)	(9)	(10)	(11)	(12) (8)+(9)	(13) (8)+(10)	(14) (8)+(11)
1880–90	0.33	0.47	0.28	0.93	0.80	0.61	1.26
1890–1900	0.37	0.56	0.31	0.92	0.93	0.68	1.29
1900–10	0.35	0.43	0.28	0.88	0.78	0.63	1.23
1910–20	0.45	0.56	0.35	0.86	1.01	0.80	1.31
1920–30	0.71	0.77	0.51	0.84	1.48	1.22	1.55
1930–40	0.88	1.06	0.62	0.82	1.94	1.50	1.70
1940–50	0.28	0.32	0.20	0.81	0.60	0.48	1.09
1950–60	1.35	1.03	0.69	0.74	2.38	2.04	2.09
1960–70	0.87	0.72	0.46	0.71	1.59	1.33	1.58
Average	0.62	0.66	0.41	0.83	1.28	1.03	1.46

is positive in three decades (1880–90, 1890–1900, and 1910–20) and negative in two (1900–10 and 1920–30). However, in the later decades studied, 1930–70, $CEPop_T$ is positive under each of the three methods in each decade, with the exception of the period of World War II (1940–50), when it is strongly negative. Over the entire period, 1880–1970, the average of $CEPop_T$ is positive under the Residual method (0.35), the factor augmenting rate method (0.29) and the

TABLE VI (Continued)

Decade	Direct Contribution to Nonagric. Output Growth (CY_2Pop_D)	Indirect Contribution to Nonagric. Output Growth ($CY_2\ Pop_I$)			Total Contribution to Nonagric. Output Growth (CY_2Pop_T)		
		Residual Method	Verdoorn Method	Factor Augmenting Rate Method	Residual Method	Verdoorn Method	Factor Augmenting Rate Method
	(15)	(16)	(17)	(18)	(19) (15)+(16)	(20) (15)+(17)	(21) (15)+(18)
1880–90	0.29	0.60	0.43	1.03	0.89	0.72	1.32
1890–1900	0.32	0.71	0.45	0.99	1.03	0.77	1.31
1900–10	0.03	0.35	0.16	1.04	0.38	0.19	1.07
1910–20	0.18	0.66	0.33	1.00	0.84	0.51	1.18
1920–30	0.43	1.03	0.64	0.97	1.46	1.07	1.40
1930–40	0.91	1.85	1.10	0.95	2.76	2.01	1.86
1940–50	−0.01	0.12	0.04	0.90	0.11	0.03	0.89
1950–60	1.70	2.86	2.10	0.97	4.56	3.80	2.67
1960–70	0.89	1.49	1.01	0.90	2.38	1.90	1.79
Average	0.53	1.07	0.70	0.97	1.60	1.22	1.50

Verdoorn method (0.01).[15] If the decade of World War II were excluded from the average, then the average of $CEPop_T$ would be more positive under the Verdoorn method (0.17).

The total contribution of population cum labor growth to both agricultural output growth (CY_1Pop_T) and nonagricultural output growth (CY_2Pop_T) is positive in each decade, the contribution to the latter being the largest.[16] Under the Residual, Verdoorn, and factor augmenting rate methods, CY_1Pop_T averages 1.28, 1.03, and 1.46 per cent per year, while CY_2Pop_T averages 1.60, 1.22, and 1.50, respectively.

VI. SENSITIVITY ANALYSIS OF GROWTH RATE MULTIPLIERS AND SOME POLICY IMPLICATIONS

This section examines sensitivity results to show how the influence of population

15 Differences in the total contribution of population cum labor growth to the growth of per capita income between this paper and Yamaguchi [25] stem partly from the differences in the values of parameters ε (income elasticity of agricultural goods) and k_1 (proportion of capital in agriculture). The larger value for ε and smaller value for k_1 used in the present paper tend to increase the total influence of population cum labor on per capita income, as shown in Section VI.

16 Although the direct contribution of population cum labor growth tended to be less for nonagricultural than for agricultural output growth [given that population (Q) affected the former negatively but the latter positively], the indirect contribution, tended to be larger. The larger indirect contribution to output growth in the nonagricultural sector arose because Y_2T_2 exceeded Y_1T_1 and the cross effects of technical change in one sector on output growth in the other were asymmetric (i.e., Y_1T_2 was negative while Y_2T_1 was positive). These asymmetric cross effects resulted from the push and pull of agricultural resources on the nonagricultural sector caused by sectoral technical change. For an ex-

cum labor on economic development (as measured by GRM values) is affected by the parameter values. The theoretical value of each GRM can be calculated from the A^{-1} matrix as follows:

$$ET_1=[(\eta+1-\lambda)(\gamma l_1+\delta k_1)-\eta\lambda]/|A|, \quad (21)$$

$$ET_2=[(\eta+1-\lambda)(\alpha l_2+\beta k_2)+\eta(\lambda-1)]/|A|, \quad (22)$$

$$EQ=[(\delta-\beta)(1-\lambda+\eta)k_2+(\gamma-\alpha)(1-\lambda+\eta)l_2+\lambda-1]/|A|, \quad (23)$$

$$EL=[(\beta\gamma-\alpha\delta)(1+\eta-\lambda)k_2+\{\alpha+\eta(\alpha-\gamma)\}(1-\lambda)]/|A|, \quad (24)$$

$$Y_1T_1=[\{\varepsilon(1-\lambda)+\eta\}(\gamma l_1+\delta k_1)-\eta]/|A|, \quad (25)$$

$$Y_1T_2=[\{\varepsilon(1-\lambda)+\eta\}(\alpha l_2+\beta k_2)]/|A|, \quad (26)$$

$$Y_1Q=[(1-\varepsilon)(\alpha l_2+\beta k_2)]/|A|, \quad (27)$$

$$Y_1L=[\{\varepsilon\beta\gamma(1-\lambda)+\eta(\beta\gamma-\alpha\delta)+\alpha\varepsilon(1-\lambda)(\gamma-1)\}k_2 + \alpha\varepsilon(1-\lambda)]/|A|, \quad (28)$$

$$L_1T_1=[(\varepsilon\lambda-\eta-1)l_2]/|A|, \quad (29)$$

$$L_1T_2=[\eta+\varepsilon(1-\lambda)]l_2/|A|, \quad (30)$$

$$L_1Q=(1-\varepsilon)l_2/|A|, \quad (31)$$

$$L_1L=[\{\delta\varepsilon(\lambda-1)+\eta(\beta-\delta)+\beta(1-\lambda\varepsilon)\}k_2+\varepsilon(1-\lambda)]/|A|, \quad (32)$$

$$L_2T_1=(1-\varepsilon\lambda+\eta)l_1/|A|, \quad (33)$$

$$L_2T_2=[\varepsilon(\lambda-1)-\eta]l_1/|A|, \quad (34)$$

$$L_2Q=(\varepsilon-1)l_1/|A|, \quad (35)$$

$$L_2L=[\{\delta\varepsilon(\lambda-1)+\eta(\beta-\delta)+\beta(1-\varepsilon\lambda)\}k_2+\delta\varepsilon(1-\lambda) + \eta(\alpha-\gamma)]/|A|, \quad (36)$$

where

$$|A|=(\alpha+\beta)(1+\eta-\lambda\varepsilon)-\eta+[-\alpha-\eta(\alpha-\gamma)+\varepsilon\{\gamma+(\alpha-\gamma)\lambda\}]l_1 + [-\beta-\eta(\beta-\delta)+\varepsilon\{\delta+(\beta-\delta)\lambda\}]k_1 .$$

These equations allow us to determine how the direct and indirect influence of population cum labor on economic development is affected by changes in the parameter values. From these theoretical values of GRM, we can see that the negative *direct* effect of population cum labor on per capita income ($EQ+EL$) becomes more negative as λ, l_1, k_1 and δ increase and less negative as ε, $|\eta|$, α, β, and γ increase. The direct effect of population cum labor on agricultural output (Y_1Q+Y_1L) would increase as α, β, γ, and δ increase and would decrease as ε, $|\eta|$, λ, l_1, and k_1 increase. The direct effect of population cum labor on nonagricultural output (Y_2Q+Y_2L) would increase as ε, $|\eta|$, λ, α, γ, β, and δ increase and would decrease as l_1 and k_1 increase. Taking ε's effect on $EQ+EL$ as an example, we can show that ε is not included in the numerator of either EQ or EL, only in the denominator $|A|$. Thus, we can determine ε's effect on $EQ+EL$ by determining its effect on $|A|$. Differentiating $|A|$ with respect to ε

planation of these push and pull effects, see Yamaguchi and Binswanger [27], and Yamaguchi and Kennedy [28].

gives a positive result, judging from the ranges of the parameter values in Appendix Table III, as in equation (37):

$$\frac{\partial|A|}{\partial\varepsilon}=(\alpha+\beta)(-\lambda)+[\gamma+(\alpha-\gamma)\lambda]l_1+[\delta+(\beta-\delta)\lambda]k_1>0\,. \qquad (37)$$

Increases in $|A|$ imply a value for $EQ+EL$ which is less negative. Thus, as ε increases, $EQ+EL$ becomes less negative. Similarly, we can show the effect of ε on (Y_1Q+Y_1L) and on (Y_2Q+Y_2L) as well as the effects of the other parameters.

Table VII reports the results of sensitivity runs for the year 1880 involving a single parameter, in turn, set equal to zero. The 1880 base values of the parameters are also shown. First the direct influences of population cum labor on per capita income $(EQ+EL)$, agricultural output (Y_1Q+Y_1L), and nonagricultural output (Y_2Q+Y_2L) are shown. For example, if α (labor's share in agricultural output) were reduced to zero (from 0.58) holding all other parameters at their base values, the value of $(EQ+EL)$ would change from -0.30 to -0.59.

The indirect influence of population cum labor on per capita income $(EPop_I)$ and sectoral output (Y_iPop_I) can be written as in equations (38) and (39):

$$EPop_I=ET_1(T_1Q+T_1L)+ET_2(T_2Q+T_2L)\,, \qquad (38)$$

$$Y_iPop_I=Y_iT_1(T_1Q+T_1L)+Y_iT_2(T_2Q+T_2L)\,. \qquad (39)$$

The theoretical values of ET_1, ET_2, Y_iT_1, and Y_iT_2 can be obtained from the theoretical values of GRM. T_iQ and T_iL can be calculated from equations (9), (10), (15), and (16) as follows: $T_1Q=(\gamma_1+\delta_1 n)/(1-\alpha_1)$, $T_1L=(\beta_1+\delta_1 m)/(1-\alpha_1)$, $T_2Q=n$, and $T_2L=m$ where m and n are defined as on p. 246 (Residual method), and $T_1Q=(\gamma'_1+\delta'_1 n')/(2-\alpha'_1)$, $T_1L=(\beta'_1+\delta'_1 m')/(2-\alpha'_1)$, $T_2Q=n'$, and $T_2L=m'$ where m' and n' are defined as on p. 247 (Verdoorn method). Also α_i, β_i, γ_i, and δ_i, etc. are defined (as GRMs) as follows: $\alpha_i=L_iT_1$, $\beta_i=L_iL$, $\gamma_i=L_iQ$, and $\delta_i=L_iT_2$; $\alpha'_i=Y_iT_1$, $\beta'_i=Y_iL$, $\gamma'_i=Y_iQ$ and $\delta'_i=Y_iT_2$.

As shown above, the indirect effects of population cum labor depend on T_iQ and T_iL, which include a number of parameters which are also GRM. However, sensitivity results of Q and L's influence on sectoral technical change $(T_1Q,\ T_1L,\ T_2Q,\ T_2L)$, and the indirect influence of population cum labor on per capita income $(EPop_I)$, agricultural output (Y_1Pop_I), and nonagricultural output (Y_2Pop_I) are also reported in Table VII for both Residual method (no parentheses) and the Verdoorn method (in parentheses). For example, lowering α to zero while holding other parameters constant causes $EPop_I$ to increase from 1.23 to 1.28 under the Residual method and to decrease from 0.90 to 0.68 under the Verdoorn method.

Therefore, we can summarize the effects of nine parameters on the indirect effects of population cum labor as follows: For the Residual method, the indirect effect of population cum labor on per capita income $(EPop_I)$ would increase when all parameters except α and β increase. The indirect effect of population cum labor on agricultural output (Y_1Pop_I) would increase when l_1

TABLE VII

SENSITIVITY ANALYSIS OF THE DIRECT AND INDIRECT EFFECTS OF POPULATION CUM LABOR ON PER CAPITA INCOME AND SECTORAL OUTPUT, 1880

(% per year)

	Base[a]	$\alpha=0$	$\beta=0$	$\gamma=0$	$\delta=0$	$\eta=0$	$\varepsilon=0$	$l_1=0$	$k_1=0$	$\lambda=0$
$EQ+EL$	−0.30	−0.59	−0.31	−0.62	−0.29	−0.39	−0.48	−0.27	−0.30	−0.27
Y_1Q+Y_1L	0.60	0.01	0.59	0.31	0.51	0.69	0.79	0.62	0.60	0.62
Y_2Q+Y_2L	0.79	0.79	0.79	−0.02	0.63	0.53	0.25	0.84	0.80	0.73
T_1Q	0.17[b]	0.17	0.17	0.13	0.16	0.07	−20.03	0.34	0.16	0.05
	(0.14)[c]	(0.04)	(0.10)	(0.08)	(0.13)	(0.06)	(−26.41)	(0.23)	(0.16)	(0.04)
T_1L	0.68	0.68	0.68	0.70	0.65	0.93	35.77	0.37	0.69	0.93
	(0.34)	(−0.07)	(0.41)	(0.22)	(0.30)	(0.57)	(39.45)	(0.20)	(0.31)	(0.55)
T_2Q	−0.43	−0.43	−0.43	−0.32	−0.42	−0.16	49.03	0.00	−0.42	−0.13
	(−0.39)	(−0.39)	(−0.39)	(−0.02)	(−0.33)	(−0.16)	(74.24)	(−0.02)	(−0.33)	(−0.13)
T_2L	1.80	1.80	1.80	0.19	1.49	1.17	−84.12	1.00	0.18	1.17
	(1.50)	(1.50)	(1.50)	(0.00)	(1.17)	(0.86)	(−108.40)	(0.88)	(1.39)	(0.92)
$EPop_I$	1.23	1.28	1.25	0.35	1.03	1.11	−20.38	0.76	1.19	1.19
	(0.90)	(0.68)	(0.93)	(0.14)	(0.70)	(0.72)	(−21.68)	(0.56)	(0.84)	(0.86)
Y_1Pop_I	0.71	0.81	0.75	0.84	0.72	0.88	27.56	0.49	0.69	0.93
	(0.37)	(−0.06)	(0.43)	(0.31)	(0.35)	(0.57)	(25.30)	(0.24)	(0.34)	(0.57)
Y_2Pop_I	1.76	1.76	1.76	−0.14	1.33	1.33	−68.31	1.02	1.69	1.19
	(1.43)	(1.43)	(1.43)	(−0.02)	(1.05)	(0.86)	(−68.65)	(0.88)	(1.33)	(0.86)

[a] The base values of the parameters for 1880 (from Appendix Table III) are:

- α (labor's share in agricultural output) =0.58
- β (capital's share in agricultural output) =0.12
- γ (labor's share in nonagricultural output) =0.84
- δ (capital's share in nonagricultural output) =0.16
- η (relative price elasticity of agricultural goods) = −0.60
- ε (income elasticity of agricultural goods) =0.80
- l_1 (proportion of labor in agriculture) =0.71
- k_1 (proportion of capital in agriculture) =0.43
- λ (share of income produced by agriculture) =0.50

[b] Residual method.

[c] Verdoorn method in parentheses.

and k_1 increase and would decrease when α, β, γ, δ, $|\eta|$, ε, and λ increase. The indirect effect of population cum labor on nonagricultural output (Y_2Pop_I) would increase when γ, δ, $|\eta|$, ε, l_1, k_1, and λ increase. α and β have no effect on Y_2.

For the Verdoorn method, the indirect effect of population cum labor on per capita income ($EPop_I$) would increase when all parameters except β increase. The indirect effect of population cum labor on agricultural output (Y_1Pop_I) would increase when α, γ, δ, l_1, and k_1 increase and would decrease when β, $|\eta|$, λ and ε increase. The indirect effect of population cum labor on nonagricultural output (Y_2Pop_I) would increase when γ, δ, $|\eta|$, ε, l_1, k_1, and λ increase, and would not be affected by α and β.

We can summarize the sensitivity results of Table VII for the case of population cum labor's influence on per capita income as follows. Both the direct and indirect influence would decrease when ε, $|\eta|$, α, and γ decrease (with the exception of the indirect influence of α under the Residual method). The direct influence would increase and the indirect influence would decrease when l_1, k_1, λ, and δ decrease. The direct influence would decrease and the indirect influence would increase when β decreases.

A number of implications can be derived from the sensitivity results reported above, including the following:

(1) The total influence (i.e., direct plus indirect) of population cum labor on per capita income will be larger the higher the agricultural income elasticity (ε) and price elasticity ($|\eta|$).

(2) In most cases, the total influence of population cum labor on per capita income will be larger the higher labor's share in both agriculture (α) and nonagriculture (γ).

(3) As l_1, k_1, and λ increase, the direct influence of population cum labor on per capita income becomes more negative while the indriect influence becomes more positive. This implies that in the early stages of economic development (when l_1, k_1, and λ are relatively large) the total influence of population can be expected to be negative in economies lacking the capacity (e.g., educational opportunities) for their population to increase the rate of technical change and thereby capture the positive indirect influence of population growth.

As well as considering how parameter values affect the influence of population cum labor on economic development, we need to consider how they affect the influence of technical change on development. For example, as ε increases, the influence of technical change in both sectors on per capita income (ET_1, ET_2) decreases.[17] Also, ET_1 decreases and ET_2 increases with increases in $|\eta|$ and α and decreases in γ.

Although increases in agricultural income and price elasticities increase the influence of population cum labor on per capita income, it is important to note

[17] Increases in ε must increase the elasticities T_1Q, T_1L, T_2Q and/or T_2L enough to offset the decreases in ET_1 *and* ET_2 [in equation (38)]. Otherwise, increasing ε would not cause the indirect influence of population cum labor on per capita income ($EPop_I$) to become more positive.

that they reduce the influence of technical change on per capita income. This implies that in economies where the rates of technical change in both sectors exceed population growth, policies which reduce agricultural elasticities (perhaps by providing a demonstration effect for nonagricultural goods) may be recommended. But in economies with low rates of technical change, policies which reduce agricultural elasticities are to be avoided. This further implies that in the early stages of economic development, when the direct influence of population cum labor is highly negative and the rates of technical change tend to be low, policies which increase agricultural income and price elasticities should be seriously considered.

VII. SUMMARY AND CONCLUSION

Throughout history the prevailing view of the economic effects of population growth has wavered from optimism to pessimism. Examples of the former include the ancient Greek and Roman views in which people were considered the source of power. The mercantilists and Adam Smith are also considered optimistic populationists. However, conventional wisdom today follows Malthus in viewing the economic effects of population growth negatively. But Simon has challenged the Malthusian view, predicting that population growth has a positive effect on per capita income, at least in the long run.

This paper measured the total contribution (including both positive and negative effects) of population cum labor growth on per capita income and sectoral output growth in Japan over the period 1880–1970. It used a two-sector growth accounting model. The model treated population and labor growth as separate variables so their contributions to per capita income and sectoral output growth could be estimated separately.

The first step was to estimate the direct contribution of population cum labor growth to per capita income and sectoral output growth. The next step was to estimate the indirect contribution, via population and labor's influence on technical change in each sector. Three alternative methods were employed: the Residual method, the Verdoorn method, and the factor augmenting rate method. Each of the methods yielded consistent results.

The next step was to obtain the total contribution of population cum labor growth to per capita income and sectoral output growth by combining their direct and indirect contributions. With respect to per capita income growth, the total contribution of population cum labor growth tended to be negative in the decades 1880–1930 and positive in the decades 1930–70, with the exception of 1940–50. However, over the period 1880–1970 population cum labor growth on average tended to make a positive contribution to per capita income growth under the Residual method (0.35 per cent per year), the factor augmenting rate method (0.29 per cent per year), and the Verdoorn method (0.01 per cent per year). Population cum labor growth contributed positively to sectoral output growth. The average contribution to agricultural output growth ranged from 1.03 (Verdoorn) to 1.46 per cent per year (factor augmenting rate), while the average contribution to nonagricultural output growth ranged from 1.22 (Verdoorn) to 1.60 per cent per year (Residual).

These results are of course dependent on our model and the particular data set used. Therefore, the results of a sensitivity analysis were reported to show how growth rate multiplier values are affected by changes in the parameters. Each of the three methods used to estimate the indirect contribution of population cum labor growth to per capita income and sectoral output growth was necessarily arbitrary and involved certain assumptions. However, the fact that each of three very different methods yielded consistent results provides fairly substantive evidence that population cum labor growth made a positive contribution to per capita income and sectoral output growth in Japan over the period 1880–1970. Finally, some policy implications suggested by the results were noted.

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APPENDIX TABLE I

STATIC AND DYNAMIC VERSIONS OF THE MATHEMATICAL MODEL

A. Static Model

(1) $Y_1 = aQP^{\eta}E^{\varepsilon}$	(5) $K_1 + K_2 = K$	(9) $r_2 = \delta(Y_2/K_2)$
(2) $Y_1 = T_1L_1^{\alpha}K_1^{\beta}B^{(1-\alpha-\beta)}$	(6) $w_1 = \alpha P(Y_1/L_1)$	(10) $w_1 = m_w w_2$
(3) $Y_2 = T_2L_2^{\gamma}K_2^{\delta}$	(7) $w_2 = \gamma(Y_2/L_2)$	(11) $r_1 = r_2$
(4) $L_1 + L_2 = L$	(8) $r_1 = \beta P(Y_1/K_1)$	(12) $PY_1 + Y_2 = QE$

B. Dynamic Model

$$\begin{matrix}(13)\\(14)\\(15)\\(16)\\(17)\\(18)\\(19)\\(20)\end{matrix}\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & -\eta & -\varepsilon \\ 1 & 0 & -\beta & 0 & -\alpha & 0 & 0 & 0 \\ 0 & 1 & 0 & -\delta & 0 & -\gamma & 0 & 0 \\ 0 & 0 & 0 & 0 & l_1 & l_2 & 0 & 0 \\ 0 & 0 & \kappa_1 & \kappa_2 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & -1 & 1 & 0 & 0 \\ 0 & 0 & \beta-\delta & 0 & \alpha-\gamma & 0 & 1 & 0 \\ \lambda & 1-\lambda & 0 & 0 & 0 & 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} \dot{Y}_1 \\ \dot{Y}_2 \\ \dot{K}_1 \\ \dot{K}_2 \\ \dot{L}_1 \\ \dot{L}_2 \\ \dot{P} \\ \dot{E} \end{bmatrix} = \begin{bmatrix} \dot{a}+\dot{Q} \\ \dot{T}_1+(1-\alpha-\beta)\dot{B} \\ \dot{T}_2 \\ \dot{L} \\ \dot{K} \\ \dot{m}_w \\ \dot{T}_2-\dot{T}_1-(1-\alpha-\beta)\dot{B}+\gamma\dot{m}_w \\ \dot{Q} \end{bmatrix}$$

Equation (1):	Agricultural demand function
Equation (2):	Agricultural production function
Equation (3):	Nonagricultural production function
Equation (4) (5):	Adding up constraint
Equation (6) (7) (8) (9):	Value of marginal product equals factor price
Equation (10) (11):	Factor mobility condition
Equation (12):	Income identity

$i=1, 2$=agricultural and nonagricultural sector, respectively
w_i, r_i=sectoral wage and capital rental rates
η, ε=agricultural price and income elasticity
α, β=output elasticity of agricultural labour and capital
γ, δ=output elasticity of nonagricultural labour and capital
λ=proportion of income generated in agriculture

APPENDIX TABLE II

AVERAGE ANNUAL GROWTH RATES OF ENDOGENOUS AND EXOGENOUS VARIABLES

(%)

	1880–1890	1890–1900	1900–1910	1910–1920	1920–1930	1930–1940	1940–1950	1950–1960	1960–1970	Average
Endogenous variables										
$\dot{Y}_1$	3.4	1.7	2.2	3.2	1.1	0.4	−0.5	3.6	−1.0	1.6
$\dot{Y}_2$	3.7	3.9	2.6	4.0	2.4	5.7	—	9.2	11.9	5.4
$\dot{K}_1$	0.7	1.0	1.7	0.9	1.0	0.7	−1.4	4.6	8.9	2.0
$\dot{K}_2$	3.3	3.5	4.5	6.7	4.8	4.7	—	6.3	11.5	5.7
$\dot{L}_1$	0.0	0.1	0.0	−1.2	0.0	−0.3	1.7	−1.7	−3.6	−0.6
$\dot{L}_2$	1.7	1.4	1.3	3.2	1.7	2.8	−1.0	4.7	2.9	2.1
$\dot{P}$	6.3	−1.9	−0.8	0.7	−3.3	7.2	—	−1.5	2.1	0.4
$\dot{E}$	2.7	2.2	1.3	2.6	0.5	3.9	—	7.1	10.0	3.8
Exogenous variables										
$\dot{K}$	2.3	2.6	3.6	5.3	4.2	4.2	—	6.1	11.3	5.0
$\dot{L}$	0.5	0.6	0.4	0.6	0.9	1.5	0.2	2.2	1.3	0.9
$\dot{Q}$	0.9	1.0	1.2	1.2	1.6	1.1	1.6	1.2	1.1	1.2
$\dot{B}$	0.4	0.6	0.7	0.7	−0.1	0.3	−0.4	0.4	−0.5	0.2
$\dot{T}_1$	3.2	1.3	1.8	3.5	1.0	0.4	−1.2	4.1	0.1	1.6
$\dot{T}_2$	1.7	2.0	0.2	−0.7	−0.3	2.2	—	4.1	6.5	2.0
$\dot{a}$	3.2	−2.5	−0.4	0.5	−2.6	1.0	—	−1.7	−3.6	−0.8

Sources: For $\dot{Y}_1$, $\dot{K}_1$, $\dot{K}_2$, $\dot{L}_1$, $\dot{L}_2$, $\dot{K}$, $\dot{L}$, and $\dot{Q}$, from Ohkawa and Shinohara [19]; for $\dot{Y}_2$, from Ohkawa et al. [20, Vol. 1], Ohkawa and Shinohara [19], and $\dot{Y}_1$; for $\dot{P}$ and $\dot{E}$, from Ohkawa et al. [20, Vol. 1] and Ohkawa and Shinohara [19]; for $\dot{B}$, from Ohkawa et al. [20, Vol. 9]; $\dot{T}_1=\dot{Y}_1-\alpha\dot{L}_1-\beta\dot{K}_1-(1-\alpha-\beta)\dot{B}$; $\dot{T}_2=\dot{Y}_2-\gamma\dot{L}_2-\delta\dot{K}_2$; and $\dot{a}=\dot{Y}_1-\dot{Q}-\eta\dot{P}-\varepsilon E$.

APPENDIX TABLE III

PARAMETER VALUES USED IN THE MODEL

Year	(1) Labor's Share in Agric. Output $\alpha=\frac{w_1L_1}{P_1Y_1}$	(2) Capital's Share in Agric. Output $\beta=\frac{r_1K_1}{P_1Y_1}$	(3) Labor's Share in Nonagric. Output $\gamma=\frac{w_2L_2}{P_2Y_2}$	(4) Capital's Share in Nonagric. Output $\delta=\frac{r_2K_2}{P_2Y_2}$	(5) Price Elast. of Agric. Goods η	(6) Income Elast. of Agric. Goods ε	(7) Prop. of Labor in Agric. $l_1=\frac{L_1}{L}$	(8) Prop. of Capital in Agric. $\kappa_1=\frac{K_1}{K}$	(9) Share of Income Produced by Agric. $\lambda=\frac{P_1Y_1}{P'QE}$
1880	0.58	0.12	0.84	0.16	−0.60	0.80	0.71	0.43	0.50
1885	0.57	0.12	0.84	0.16	−0.60	0.80	0.70	0.42	0.35
1890	0.54	0.12	0.78	0.22	−0.60	0.80	0.68	0.39	0.39
1895	0.54	0.11	0.74	0.26	−0.60	0.80	0.66	0.37	0.33
1900	0.56	0.10	0.69	0.31	−0.60	0.80	0.65	0.33	0.29
1905	0.55	0.11	0.65	0.35	−0.60	0.71	0.63	0.31	0.25
1910	0.56	0.11	0.65	0.35	−0.60	0.71	0.62	0.27	0.24
1915	0.55	0.12	0.58	0.42	−0.60	0.71	0.57	0.23	0.22
1920	0.55	0.12	0.67	0.33	−0.60	0.71	0.51	0.18	0.22
1925	0.59	0.11	0.67	0.33	−0.60	0.71	0.48	0.15	0.22
1930	0.61	0.12	0.64	0.36	−0.60	0.71	0.47	0.13	0.13
1935	0.55	0.13	0.62	0.38	−0.60	0.71	0.44	0.11	0.14
1940	0.55	0.10	0.58	0.42	−0.60	0.71	0.40	0.09	0.13
1945	0.55	0.10	0.58	0.42	−0.60	0.80	0.44	0.10	0.14
1950	0.55	0.10	0.58	0.42	−0.60	0.71	0.44	0.09	0.14
1955	0.65	0.12	0.75	0.25	−0.60	0.61	0.37	0.09	0.16
1960	0.57	0.13	0.70	0.30	−0.60	0.61	0.30	0.08	0.09
1965	0.60	0.16	0.71	0.29	−0.60	0.61	0.23	0.07	0.06

Sources: Columns (1) and (2), from the data of Yamada and Hayami [23]; Columns (3) and (4), from Minami and Ono [15] [16]; Volumn (5), from Yamaguchi [26]; Column (6), from Ohkawa [18]; Columns (7), (8), and (9), from Ohkawa and Shinohara [19].