INDUSTRIALIZATION AND AGRICULTURAL PRODUCTIVITY: AN INTERNATIONAL COMPARATIVE STUDY*

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This paper is based on the observation that while agricultural productivity in less developed countries whose comparative advantage seems to lie in agriculture is growing slowly relative to agriculture in developed countries. In order to explain this phenomenon, we have established a hypothesis that industrialization promotes agricultural development by improving the conditions of supply of modern inputs to agriculture. This hypothesis is tested on international comparisons and the analysis of Japanese experience.

A RECENT TREND in world agriculture indicates that large differences in productivity between the developed and the less developed countries have been widening even more. With a few exceptions, increase in agricultural production in the less developed countries whose predominance is in agriculture has been small relative to the rate of population growth. In contrast, in the highly industrialized countries agricultural production has been expanding despite the rapid movement of farm labor to industry, resulting in a sharp rise in labor productivity in agriculture together with a sustained growth in land productivity called "Yield Take-Off."[1]

The tendency of such differential growth in agricultural productivity between nations is also manifested in the cross-sectional dimension. On the basis of recent estimates, 39 nations are plotted in Figure 1 for 1957–62 with the horizontal axis representing farm output per male worker and the vertical axis representing farm output per hectare of agricultural land (including permanent pastures and meadows) with output expressed in wheat units. The most dramatic aspect of the figure is that large differences in productivity exist in world agriculture today. Countries with homogeneous man-land ratios tend to locate in the north east; these are countries of higher level of indus-

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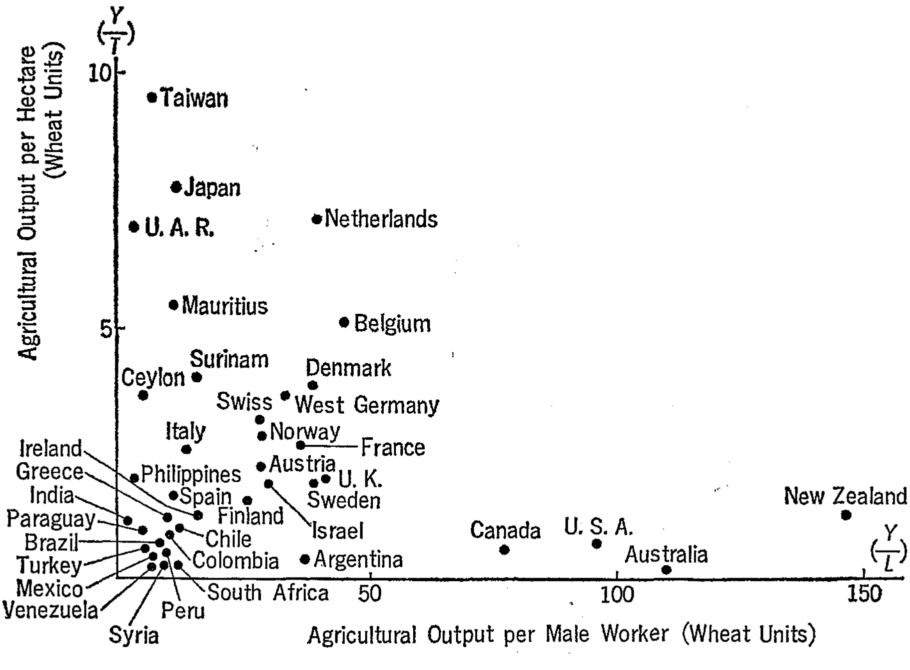
1 Brown, L. R., *Increasing World Food Output,* Foreign Agricultural Economic Report No. 25, U. S. Department of Agriculture, Washington D. C., 1965.

trialization. The countries located close to the efficiency frontier are mostly highly industrialized. Measuring the level of industrialization by the ratio of the number of male workers in non-agricultural occupations (occupations other than agriculture, forestry, hunting and fishing) to the total male labor population, it is 0.82 in New Zealand, 0.87 in Australia, 0.91 in the U. S. A., 0.92 in Belgium, 0.88 in the Netherlands and 0.74 in Japan for the period the comparison in Figure 1 was made. In contrast, this ratio is very low in countries located near the origin: 0.41 in Mexico, 0.31 in Colombia, 0.47 in Syria, 0.39 in Turkey, 0.31 in India and the Philippines.[2] Such observations make us wonder whether industrialization itself may not provide the momentum for growth in agricultural productivity, while a rise in agricultural productivity may also promote industrialization.

Figure 1. International Comparison of Agricultural Productivities 1957–1962 (Data from Appendix A)



Industrialization affects agriculture in many ways. Expansion of industry, requiring more food and materials, shifts the demand for farm products upward, stimulating farmers to increase the use of inputs and to adopt new technology in order to increase output. More crucial are the changes in the supply conditions of inputs to agriculture. A growing non-farm sector absorbs labor from agriculture and, in return, supplies the inputs of non-agricultural origin such as fertilizer, chemicals and machinery. Absorption of farm labor from agriculture by the non-farm sector improves man-land ratio providing

2 See Appendix Table A-3.

impetus for labor-saving innovations in agriculture. Labor-saving innovations would not appear, however, unless such purchased inputs as farm machinery and herbicide are available from the non-farm sector at reasonable prices. In a situation where land rather than labor is the limiting factor, a large increase in agricultural output could be achieved only with a supply of such land-substituting inputs as fertilizer. Improvement in the supply conditions of input from industry to agriculture in the form of lower input prices relative to farm product prices is a major cause for the dynamism of agriculture in developed countries in contrast to the stagnation in less developed countries. It must be noted that not only do the manufacturing industries which produce fertilizer or machinery but the service industries including marketing and transportation (including international trade and transport) play crucial roles in improving the supply conditions for agricultural inputs of industrial origin.[3]

The present study aims to measure this effect of industrialization on agricultural productivity through the improvement of the conditions of input supply. The term *industrialization* as used here does not mean the expansion of the manufacturing industry alone, but it means the progress of inter-industrial division of labor together with the coordinated growth of the manufacturing and service industries.

We will try to approach this problem by analyzing cross-country data recently prepared at the Institute of Developing Economies. First, the influence of industrialization on the output and productivity of agriculture will be evaluated directly by estimating the aggregate agricultural production function with the indicator of industrialization as a shift variable. Second, the causal chain which connects industrialization with agricultural productivity will be traced out in two separate links: (i) industrialization promotes agriculture by improving the supply conditions of farm inputs of non-agricultural origin and (ii) the increased use of such inputs causes significant rise in agricultural productivity. Then, the results of our cross-country analysis will be compared with the agricultural growth experience of Japan since the Meiji Era so as to examine the growth implications of the cross-country study. Agricultural productivity is here defined as farm output per unit of the original factor of production, land or labor.

In this study we will focus our attention on the one-way causal relation, that is, from industrialization to agricultural productivity. But, in reality, there should be operating a reverse force in that increases in agricultural productivity generate agricultural surpluses, a condition for industrialization. Mainly due to the limitation of available data we will only attempt the single-equation least-squares approach. The results should be taken with

3 For example, major innovations that reduced the relative price of fertilizer in the early period of modern agricultural growth in Japan were improvements in transportation of herring meals from northern islands (especially the introduction of steamships) and the import of cheap Manchurian soybean cakes and ammonium sulphate from Europe. See Yūjirō Hayami, "Demand for Fertilizer in the Course of Japanese Agricultural Development," *Journal of Farm Economics*, Vol. 46 (November, 1964), pp. 766–779.

reservation as simultaneity between industrialization and agricultural productivity growth may likely be significant in the case of our problem.

I. CROSS-COUNTRY ANALYSIS

Direct Approach

In order to directly test the hypothesis that industrialization is a significant factor influencing farm output and productivity, we will estimate the following production function from the cross-country data:

(1) $Y=\Phi(T, L; I)$

where Y, T and L respectively denote output, land and labor in agriculture, and I the indicator of industrialization. With the progress of industrialization the supply conditions of inputs from industry to agriculture will improve, resulting in a decline in the input prices relative to product prices. The consequent rise in the inputs of industrial origin, together with new technology embodied in or complementary with such inputs, will contribute to output and productivity of land and labor used in agriculture. Technological progress itself will be promoted with the expansion of the non-farm sector which includes research and development as a part of the service sector. In such ways the progress of industrialization will shift the production function with only land and labor as the factors of production.

Data used for the cross-country regression analysis are presented in Appendix A. Adopted as Y is the composite cross-country series of the gross agricultural output, which is the geometric mean of three cross-country series of aggregate output net of seeds and feed averaging for 1957–62. As labor variable, L, the number of economically active male population in agriculture has been estimated. Agricultural land area including permanent meadows and pastures for the year closest to 1960 is taken from FAO as land variable, L. Estimates of Y, T and L for 39 countries are as plotted in Figure 1.

The indicator of industrialization is based on two sets of data. One is I_p, the percentage of the number of male workers in non-agricultural occupations to the total number of male workers. Another is I_v, the percentage of value-added in non-agricultural sectors to the total GDP. These two measures are the best available indicators of industrialization, reflecting the meaning of industrialization as the progress of inter-sectoral division of labor together with the coordinated growth of the manufacturing and service industries.

The algebraic form of Equation (1) is specified as the unrestricted Cobb-Douglas form for its ease of manipulation and for its good fit to the data. The results of our estimation are summarized in Table 1. They indicate that industrialization as measured is a statistically significant variable. The coefficients of land and labor are significant at 1 percent level and remain stable when I_p or I_v is used as the variable of industrialization and when cross-sections are added or subtracted. Such results seem to support the postulated hypothesis that industrialization works to shift the agricultural production function formed solely by the original factors of production.

Table 1. Estimates of Equation (1) Specified as the Cobb-Douglas Form on 39 Cross-country Data for 1957–62*

Regression Number	Coefficients of the Logarithms of				Constant Term	Coefficient of Determination	Standard Error S. E.
	Land	Labor	Indicator of Industrialization				
	T	L	I_p	I_v		$\bar{R}^2$	
E1	0.269 (0.045)	0.694 (0.064)	1.848 (0.231)		−2.250	0.934	0.1662
E2[a]	0.272 (0.063)	0.614 (0.085)		2.839 (0.632)	−4.110	0.881	0.2224
E3[b]	0.241 (0.064)	0.669 (0.087)		2.920 (0.627)	−4.316	0.894	0.2177

Notes: * Equations linear in the logarithms of the variables are estimated by the method of least squares. Countries included in the sample are those plotted in Figure 1. Data are from Appendix A. The standard errors of respective coefficients are given in parentheses. Variables are: T—agricultural land area in 1000 hectares, L—labor population in agriculture in 1000 male workers, I_p—percentage of the number of male workers in non-agricultural occupations to the total number of male workers, I_v—percentage of value-added in non-agricultural sectors to the total GDP.

a. Based on the data of 39 countries with I_v estimated from I_p for New Zealand, Sweden and Switzerland by the regression equation:

$$\log I_v = 1.178 + 0.402 \log I_p, \ \bar{R} = 0.645$$

b. Based on the data of 36 conutries excluding New Zealand, Sweden and Switzerland from the sample.

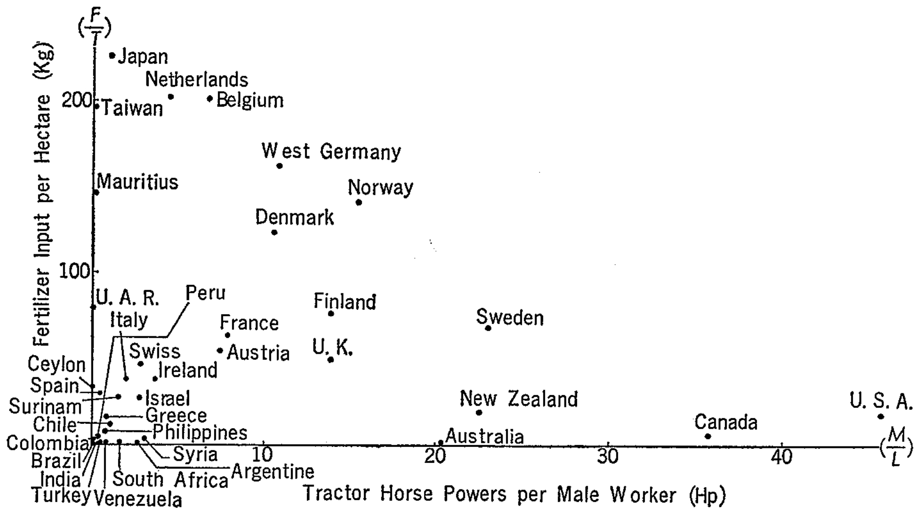
Analysis on Two Separate Links

In this section two major links which connect the influence of industrialization to agricultural productivity will be traced. Those links are : (i) the progress of industrialization brings forth increase in the inputs of industrial origin by improving the conditions of supply of inputs, and (ii) the increase in such inputs raises productivity with respect to the original factors of production, land and labor, in agriculture.

The second link will be examined first. We have prepared cross-country data of fertilizer and farm machinery representing the inputs of industrial origin. Fertilizer represents the factors which substitute for land and machinery, the factors which substitute for labor. The former is measured as the sum of N, P_2O_5 and K_2O, and the latter as the horsepower of farm tractors including garden tractors. In Figure 2, data for 38 available countries are plotted with horizontal and vertical axis denoting fertilizer input per hectare of agricultural land and tractor horsepower per male worker respectively. Comparison of Figure 2 with Figure 1 reveals that the efficiency positions of countries in Figure 1 are largely determined by their compositions of input combination in Figure 2.

In order to measure the contributions of fertilizer and machinery to agricultural production and productivity, the following production function

Figure 2. International Comparison of the Inputs of Fertilizer and Machinery Relative to the Endowments of Land and Labor (Data from Appendix A)



will be assumed:

(2) $\quad Y=\Psi(T, L, F, M)$

where F and M are fertilizer and machinery respectively. The results of estimating the Cobb-Douglas specification of Equation (2) are shown in Table 2. There is a clear indication that the inputs of industrial origin as represented by fertilizer and machinery are closely associated with agricultural production and productivity. Land-saving techniques such as the improvement of seeds are highly complementary with fertilizer and most labor-saving techniques are embodied in machinery; the effects of progress in such techniques are reflected in the coefficients of fertilizer and machinery. An interesting finding is that the coefficients of land and fertilizer, a substitute for land, are not significantly different,[4] and by inflating land by fertilizer as in Z2 the fit to the data improves in terms of the adjusted coefficient of determination. Judging from the sums of production coefficients and their standard errors, constant returns to scale seems to be operating at national aggregative level.

Plausibility of the coefficients estimated in Table 2 may be checked with previous estimates of the aggregate production function in various countries. The aggregate production elasticities of U. S. agriculture were estimated by Griliches as 0.1 to 0.2 in the case of land, 0.4 to 0.5 for labor, 0.1 to 0.2 for fertilizer and 0.1 to 0.3 for machinery.[5] It is rather surprising that the

4 F-statistics calculated for testing the null hypothesis that the coefficients of land and labor are equal is as small as 0.25.

5 Zvi Griliches, "Estimates of the Aggregate Agricultural Production Function from Cross-Sectional Data," *Journal of Farm Economics,* Vol. 45 (May, 1963), pp. 419–428, and "Research Expenditures, Education, and the Aggregate Agricultural Production Function," *American Economic Review,* Vol. 54 (December, 1964), pp. 961–974.

Table 2. Estimates of Equation (2) specified as the Cobb-Douglas Form on 38 Cross-Country Data for 1957–62*

Regression Number	Coefficients of the Logarithms of					Constant Term	Coefficient of determinations $\bar{R}^2$	Standard Error S. E.	Sum of Coefficients
	Land T	Labor L	Fertilizer F	Machinery M	$T \times F$				
Z1	0.176 (0.058)	0.425 (0.059)	0.170 (0.057)	0.186 (0.058)		1.277	0.938	0.1565	0.957 (0.042)
Z2		0.426 (0.057)		0.186 (0.057)	0.173 (0.047)	1.279	0.940	0.1542	0.958[a] (0.040)

Notes: * Equations linear in the logarithms of the variables are estimated by the method of least squares. Countries included in the sample are those plotted in Figure 2. Data are from Appendix A. The standard errors of respective coefficients and of the sum of coefficients are given in parentheses. Variables are: T—agricultural land area in 1000 hectares, L—labor population in agriculture in 100 male workers, F—($N+P_2O_5+K_2O$) in commercial fertilizers in 1000 metric tons, M—horsepower of farm tractors in 1000 HP's.

a. Twice of the coefficient of ($T \times F$) is added to the sum of the coefficients of labor and machinery.

Griliches' estimates, despite the completely different nature of the data used, coincide so well with the ones in this study. The production elasticities of Japanese agriculture in value-added terms estimated by Yuize are in the ranges of 0.2 to 0.4 in the case of land and 0.4 to 0.6 in the case of labor.[6] These estimates are consistent with the ones in this study since the ratio of value-added to gross output is a little less than 0.7 in Japanese agriculture around 1960.[7] T. W. Schultz inferred from the influences of the 1918–19 influenza epidemic that the production elasticity of labor in Indian agriculture is 0.4, just consistent with our estimates.[8] Such consistency gives strong support to the results of our estimation in this study.

Now we will return to the first link that industrialization promotes increase in the inputs of industrial origin by improving the conditions of supply. If we assume Equation (2) is linear homogeneous,[9] the following land productivity function can be derived from Equation (2):

6 Yasuhiko Yuize, "*Nōgyō ni okeru kyoshiteki seisankansū no keisoku* (The Aggregate Production Function in Agriculture)," *Nōgyō sōgō kenkyū*, Vol. 18, October 1964, pp. 1–54.

7 Ministry of Agriculture and Forestry, *Nōgyō oyobi nōka no shakai kanjō Shōwa 42 nen* (Social Accounts of Agriculture and Farmhouseholds, 1967), Tokyo, 1968 (mimeo).

8 T. W. Schultz, *Transforming Traditional Agriculture*, New Haven, Yale University Press, 1964, pp. 63–70.

9 The sums of production coefficients are not significantly different from one. We can not conclude from this result that constant return to scale prevails at the farm level, because our data are national aggregates but not measured at per-farm basis. We can infer, however, that constant return is the case at the national aggregate level. This might be one of distinctive characteristics of agricultural production compared to industrial production.

$$(3) \quad \frac{T}{Y} = \psi\left(\frac{L}{T}, \frac{F}{T}, \frac{M}{T}\right).$$

If we assume the profit maximization conditions hold, and in addition, assume that the endowments of land and labor are given and cannot be manipulated by farmers, the following equilibrium equations will be obtained:

$$(4) \quad \frac{P_f}{P_y} = \psi_f\left(\frac{L}{T}, \frac{F}{T}, \frac{M}{T}\right)$$

$$(5) \quad \frac{P_m}{P_y} = \psi_m\left(\frac{L}{T}, \frac{F}{T}, \frac{M}{T}\right)$$

They equate the price of fertilizer relative to the price of farm products (P_f/P_y) to the marginal product of fertilizer (ψ_f) and the machinery's relative price (P_m/P_y) to the marginal product of machinery (ψ_m).

According to our hypothesis, the supply conditions of the inputs of industrial origin improve with the progress of industrialization. This implies that the supply schedule of such inputs shift faster than the demand for farm products, resulting in a decline in input prices relative to output prices. It follows that our hypothesis can be expressed by the following equations:

$$(6) \quad \frac{P_f}{P_y} = \mu(I) \; ; \; \frac{\partial \mu}{\partial I} < 0$$

$$(7) \quad \frac{P_m}{P_y} = \lambda(I) \; ; \; \frac{\partial \lambda}{\partial I} < 0$$

By substituting Equations (6) and (7) to Equations (4) and (5), we have

$$(8) \quad \mu(I) = \psi_f\left(r, \frac{F}{T}, \frac{M}{L} r\right)$$

$$(9) \quad \lambda(I) = \psi_m\left(r, \frac{F}{T}, \frac{M}{L} r\right)$$

where $r = L/T$. Solving the above equations for (F/T) and (M/L), we have

$$(10) \quad \frac{F}{T} = \delta_f\,(I, r)$$

$$(11) \quad \frac{M}{L} = \delta_m\,(I, r).$$

Equations (10) and (11) represent the response of farmers to the improvements in the conditions of the supply of fertilizer and machinery due to progress of industrialization under given factor endowments.

We will approximate Equations (10) and (11) by log-linear forms, to which least squares is applied. The results of estimation are summarized in Table 3. It is clearly shown that the progress of industrialization, measured either as I_p or as I_v, raises the levels of inputs of fertilizer and machinery for the given endowments of land and labor. For the same level of industrialization the combination of the two categories of inputs supplied from the non-farm sector is different due to a difference in man-land ratio: the inputs of land-substituting factors represented by fertilizer increase relative to the inputs of labor-substituting factors represented by machinery as land gets scarce relative to labor, and *vice versa.* Such adjustments of farmers to their original factor endowments are reflected in the positive coefficients of r in the cases of D1 and D2 and in the negative coefficients in the cases of D3 and D4.

Table 3. Estimates of Equations (10) and (11) Specified as the Log-linear Forms on 38 Cross-Country Data for 1957–62

Dependent Variable	Regression Number	Coefficients of the Logarithms of: Indicator of Industrialization I_p	I_v	Man-land Ratio $r=(L/T)$	Constant Term	Coefficient of Determination $\bar{R}^2$	Standard Error S. E.
Fertilizer (F/T)	D1	4.508 (0.603)		1.037 (0.131)	−8.764	0.690	0.4840
	D2		8,109 (1.593)	1.059 (0.168)	−16.050	0.537	0.5914
Machinery (M/L)	D3	4.485 (0.567)		−0.612 (0.124)	−8.513	0.791	0.4556
	D4		8.813 (1.406)	−0.552 (0.149)	−17.196	0.726	0.5219

Note: * Equations linear in the logarithms of the variables are estimated by the method of least squares. Countries included in the sample are those plotted in Figure 2. Data are from Appendix A. The standard errors of respective coefficients are given in parentheses. Variables are: T—agricultural land area in 1000 hectares, L—labor population in agriculture in 1000 male workers, F—commercial fertilizers ($N+P_2O_5+K_2O$) in 1000 metric tons, M—horsepower of farm tractors in 100 HP's, I_p—percentage of the number of male workers in non-agricultural occupations to the total number of male workers, I_v—percentage of value-added in non-agricultural sectors to the total GDP.

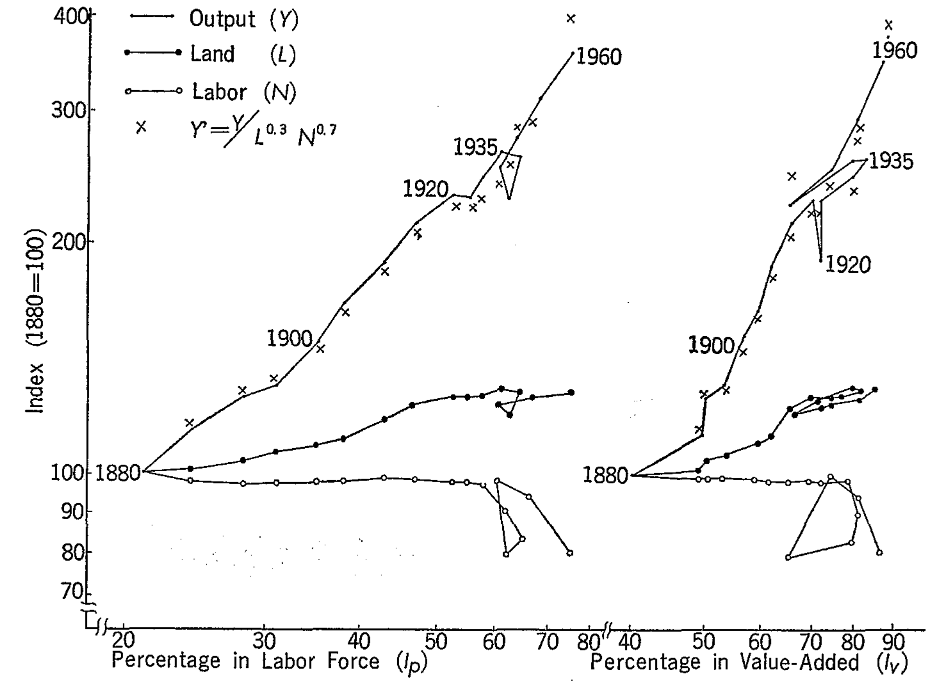
II. JAPAN'S EXPERIENCE IN A CROSS-COUNTRY PERSPECTIVE

Let us now compare the results of the cross-country analysis with the experience of Japanese agricultural development. The time-series data of Japan used for the present analysis are presented in Appendix B.

Figure 3 shows how agricultural production and the endowments of land and labor have changed in the process of industrialization in Japan from 1880 to 1960. During this period agricultural output (Y) increased 2.5 times while land (T) and labor (L) stayed nearly constant. In order to eliminate the influences that changes in land (T) and labor (L) from the movements in agricultural output (Y) may have, we divided Y by the weighted average of T and L to obtain Y'. The weights for T and L, 0.3 and 0.7 respectively, were adopted on the basis of the relative magnitudes of the production elasticities of land and labor estimated from cross-country data in the previous section. As is shown in Figure 3 the relation between Y' and I (I_p or I_v) is almost identical with the relation between Y and I. This indicates that the growth in agricultural output in Japan from 1880 to 1960 can be explained by the rise in I alone.

We estimated the Cobb-Douglas approximation of Equation (1) in the previous section from the time-series data of Japan. The results are J1 and J2 in Table 4. The coefficients of I have positive signs and are significantly different from zero at the one percent level. The coefficients of T and L

Figure 3. Changes in Output, Land and Labor in Agriculture in the Course of Industrialization in Japan, 1880–1960 (Data from Appendix B)



are, however, either non-significant or significant with negative signs. Such coefficients of T and L must be caused by multi-colinearity. The ranges of variations in T and L are so small that we can hardly expect meaningful estimates of the relations between Y and T and between T and L. We ran regressions by dropping T and L out of the equations resulting in J3 and J4. The goodness of fit in J3 and J4 is almost the same as in J1 and J2.

Special attention must be paid to the fact that the estimated coefficients of I are much smaller than those estimated from cross-country data (Table 1). We are not certain whether this indicates (a) the uniqueness of the Japanese experience or (b) difference in the estimates from the cross-section data and the time series data. The relations estimated from the cross-country data are supposedly the ones attained in a long-run equilibrium, while the time-series analysis is subject to adjustment lags. We estimated the distributed lag model of the Koyck-Nerlove type. The results are inferior as shown in J5 and J6, probably due to inappropriate specification of the adjustment lags. Whether or not the difference in the coefficients of I really indicates the uniqueness of the Japanese experience remains to be solved.

How does the experience of Japanese agricultural growth stand in the cross-country dimension? We plotted the time-series path of agricultural productivity in Japan in Figure 4 which is an enlargement of Figure 1. The numbers in the parentheses indicate I_p (left) and I_v (right). The time-series

Table 4. Estimates of Equation (1) Specified as the Cobb-Douglas Form on the Time-Series Data of Japan, Quinquennial Observations, 1880–1960*

		Regression Number					
		J1	J2	J3	J4	J5	J6
Coefficients							
Indicator of Industrialization	I_{pt}	0.7924 (0.2103)		0.9401 (0.0414)		1.3029 (0.4378)	
	I_{vt}		1.0018 (0.2996)		1.6824 (0.0930)		1.0295 (0.2736)
Land	T_t	0.7165 (0.8246)	1.4878 (0.7042)				
Labor	L_t	0.1088 (0.2850)	−0.3802 (0.2509)				
Lagged Output	Y_{t-1}					−0.3425 (0.4336)	0.4238 (0.1446)
Constant Term		0.0060	−1.5414	2.9122	1.4296	3.8279	0.7273
Coefficient of Determination	R^2	0.9746	0.9714	0.9717	0.9562	0.9663	0.9729
	$\bar{R}^2$	0.9687	0.9648	0.9698	0.9533	0.9611	0.9687
Standard Error	S. E.	0.0281	0.0298	0.0276	0.0343	0.0284	0.0254
Durbin-Watson Statistics		0.8024	0.7021	1.0339	1.3292	0.9719	0.6496

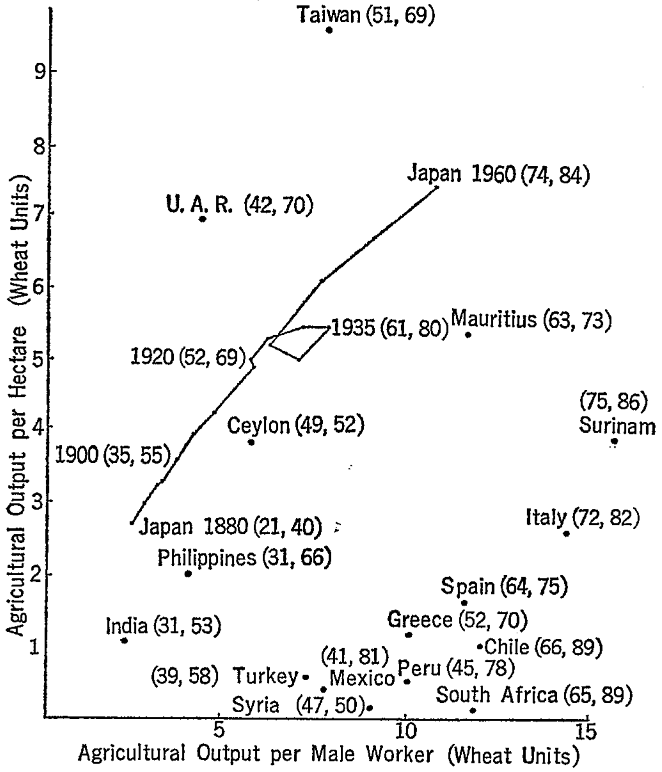
Note: * Equations linear in logarithms of the variables are estimated by the method of least squares. Data are from Appendix B. The standard errors of respective coefficients are given in parentheses.

path of Japan is nearly parallel with the line connecting India, Philippines, Ceylon, and Mauritius. The historical relationship between the level of industrialization and the level of agricultural productivity in Japan as measured in this study is quite similar to the cross-country relationship.

Japan inherited from the Tokugawa Era an unfavorable man-land ratio comparable to the United Arab Republic today. Her initial level of agricultural productivity would have been similar to the present levels of India and the Philippines with more or less similar industrial structures. The possibility for increasing arable land area was limited and the expansion of the non-agricultural sector was not sufficiently rapid to absorb labor so as to cause an absolute decline in the agricultural labor force. The land-labor ratio in Japanese agriculture has, thus, been improved only slightly. Under such circumstances a rise in agricultural productivity was made possible by developing agricultural technology suited to the given land labor endowments. Bio-chemical innovations represented by improvements in seed varieties with increased application of fertilizers were therefore developed in Japan. A prerequisite for the progress in such bio-chemical technology was the development of a fertilizer industry which supplied fertilizers at continuously declining prices relative to product and other factor prices. The declining relative prices of fertilizers as a result of industrialization induced biological innovations in the form of seed improvements and brought about remarkable increases in fertilizer input and in the yield per hectare of arable land.[10]

10 For this discussion, see Yūjirō Hayami, "Innovations in the Fertilizer Industry and Agricultural Development," *Journal of Farm Economics,* Vol. 40 (May, 1967), pp. 403–412.

Figure 4. Historical Growth Path of Japanese Agricultural Productivity Compared with Cross-Country Relationship (Data from Appendix A and B)



Given the fixed land-labor endowments, increases in output and income per capita in agriculture were only made possible through this increase in land productivity.

It can thus be said that the growth in Japanese agriculture was brought about by the changes in factor supply conditions accompanying industrialization and by the adaptation of agriculture to these changes. In turn, industrialization and economic development in Japan would not have been possible without this success in agricultural growth.

III. CONCLUSION

In this study a hypothesis that the progress of industrialization contributes to the growth in agricultural productivity *via* the supply of the inputs of industrial origin was postulated and tested by cross-country data. First, the hypothesis was tested directly by estimating the aggregate agricultural production function including the indicator of industrialization as a shift variable. Second, the influences of industrialization on agricultural productivity were traced to two major coupling links. One link being the process through which industrialization promotes increases in the inputs of non-agricultural origin by improving the conditions of supply, and the other the process through which the increase in such inputs raises productivities with respect to the original factors of production in agriculture. The estimates were consistent with the postulated hypothesis. The results of our cross-country analysis were then compared with the experience of Japanese agricultural development during 1880–1960.

Although the conclusion rests on slender grounds as both data and estimation techniques are far from satisfactory, the contribution of industrialization to agricultural productivity *via* the presumed route seems to be quite significant. There has been much debate on the inter-sectoral priority of investment for economic development. In order to avoid overemphasis on industrialization, which has led to such difficulties as represented by the setback of Communist China's Great Leap Forward or the recent famine in India, proposals have been made to adopt agriculture-first policies as a development strategy. There is much virtue in such proposals. But, as this study indicates, we must not forget that agriculture cannot develop by itself and that the improvement in the supply conditions of inputs from the non-farm sector with the progress of industrialization is crucial for agricultural growth.

APPENDIX A. CROSS-COUNTRY DATA

Data were taken from Yūjirō Hayami, Kinuyo Inagi, Kenji Koike and Yukihiko Fujita, *Nōgyō seisan kokusai hikaku shiryō* (The Compilation of Data for International Comparison of Agricultural Production), Keizaiseichō chōsabu No. 42–8, Institute of Developing Economies, March 1968, mimeo. All variables are expressed as the aggregates of nations. In principle, flow variables are averaged for 1957–62 and stock variables are measured in 1960.

Agricultural Output (Y): The output variable is the composite cross-country series of gross agricultural output, which is the geometric mean of three cross-country series of gross output net of intermediate goods produced in agriculture. The estimation procedures are: (a) to deduct seeds, feed (including imported feed), eggs for hatching and milk for calf rearing from quantities individual commodities produced (b) to aggregate the quantities of three sets of wheat relative prices derived from farm-gate prices (or the import prices of commodities not produced domestically) of the U. S. A., Japan and India to produce three aggregate output series, and (c) to combine those three series into a single composite series by taking their geometrical means. If we denote quantity produced of the *j*th commodity in the *i*th country by q_{ij}, corresponding quantity to be deducted by d_{ij} and the wheat relative price of the U.S.A., Japan and India by w_{Uj}, w_{Jj} and w_{Ij}, respectively, our composite series of gross output, Y_i's may be expressed as:

$$Y_i = \sqrt[3]{Y_{Ui}\ Y_{Ji}\ Y_{Ii}}$$

where $Y_{Ui} = \sum_j w_{Uj}\ (q_{ij} - d_{ij}),\quad Y_{Ji} = \sum_j w_{Ji}\ (q_{ij} - d_{ij})$

$$Y_{Ii}=\sum_j w_{Ij}\ (q_{ij}-d_{ij}).$$

Data of the quantities produced were taken from FAO's *Production Yearbook* and data for the deduction of seed and feed were from FAO's *Food Balance Sheets.* It is the availability of the latter data which limited the number of countries to 43. Due to lack of data, capital formation and stock changes, especially in the forms of livestock and perennial plants, were not counted in the output. Included in agricultural output are strictly the products of agriculture; the products of fishery and forestry are excluded, though the aggregate output of the primary sector including fishery and forestry was estimated with the price weights of Japan for the deduction of fishery and forestry workers as will be explained later. In principle, quantities produced are measured in farm-gate forms, e.g., sugar cane or cocoon instead of sugar or silk. Major exceptions to this rule are meat products of which the coverage of data is much wider in the form of meat than in the form of livestock.

Farm-gate prices were taken from various sources from the three governments. Import prices to the three countries were obtained from FAO *Trade Yearbook 1965.* Where the imports did not exist at farm-gate forms (e. g., import of cocoon to the U.S.), the import prices in manufactured forms (e. g., silk) were multiplied by the ratios between the prices of the manufactured goods and of their materials in the exporting country (e. g., the price of cocoon relative to the price of silk in Japan).

Prices at farm-gate or at port, thus obtained, are shown in Table A-1 as they are converted to wheat relative prices. The results of applying the aggregation procedures as described above with the weighting systems in table 1 are presented in Table A-2.

Land (T): Land variable is the area of agricultural land including permanent meadows and pastures of the year closest to 1960 in FAO's *Production Yearbook.* The proportion of arable land to total agricultural land area can be considered a variable which farmers could manipulate by changing the method of farming and the intensity of cultivation. We preferred to use as land variable the unweighted sum of arable land and pasture land areas partly to avoid arbitrariness and partly because we wish to make comparisons of the equilibrium reached when the adjustments in land utilization resulting from changes in the demand for agricultural land are completed.

Labor (L): Labor variable is the number of economically active males in agriculture, which was estimated from ILO's economically active population in agricultural occupation (agriculture, forestry, hunting and fishing)—ILO, *Yearbook of Labor Statistics 1964.* Only males are counted in order to preserve international comparability of data. Deduction of forestry and fishery workers (excepting hunters) from the ILO's labor population in agricultural occupations was made by multiplying the population by the ratio of gross output in agriculture to the gross output of agriculture, forestry and fishing combined, both aggregated with Japan's wheat relative prices. That is, the economically active male population in agriculture in Country i, L_i, can be

Table A-1. Weights for Aggregation: Wheat Relative Prices per Metric Ton, 1957–62*

Commodities j	U. S. A. W_U	Japan W_J	India W_I
Wheat	1.00	1.00	1.00
Rice (rough)	1.58	1.61	0.94
Rye	0.58	0.77	0.69
Barley	0.61	1.00	0.69
Oats	0.63	0.70	0.69
Maize	0.63	0.72	0.78
Millet	0.68	0.74	0.87
Sorghum	0.55	0.81	0.81
Buck Wheat	0.74	1.24	0.84
Mixed grain	0.61	0.74	0.69
Potatoes	0.57	0.27	0.58
Sweet Potatoes	0.81	0.22	0.58
Cassava	0.16	0.11	0.58
Pulses (all)	2.12	1.94	0.84
Nuts (unshelled)	13.14	2.31	5.24
Vegetables	0.83	0.42	1.31
Citrus fruits	0.98	1.15	1.40
Dates	2.05	0.55	3.33
Banana	0.65	1.52	0.63
Other fresh fruits	1.27	0.94	1.79
Fruits (unspecified)	1.13	1.05	1.79
Cotton seed	0.75	0.83	0.78
Copra	0.84	0.48	3.10
Groundnuts	3.39	2.55	1.21
Linseed	1.30	0.66	1.50
Sesame seed	4.56	3.98	2.07
Soybeans	1.16	1.50	1.22
Olive	1.66	1.30	1.13
Palm kernels	1.13	0.76	3.10
Rape seed	0.87	1.45	1.91
Sunflower seed	2.50	1.17	1.11
Sugar cane	0.12	0.18	0.10
Sugar beets	0.19	0.15	0.15
Cocoa	8.27	6.30	6.16
Coffee	10.84	7.82	8.21
Tea	15.70	3.44	8.88
Abaca	5.77	3.88	4.12
Cotton	10.30	6.06	2.17
Flax	5.50	3.37	6.27
Hemp	6.94	6.29	1.70
Henequen	2.54	2.30	2.41
Jute	3.11	2.30	1.93
Sisal	2.54	2.30	2.41
Cocoon	17.32	12.86	18.88
Wool (greasy basis)	14.44	13.52	14.58
Tobacco	19.47	8.56	4.63
Rubber	9.33	6.74	7.14
Beef & veal	12.36	9.99	5.00
Pork	9.51	7.36	5.00
Mutton & lambs	12.58	5.03	5.00
Poultry	6.47	5.15	2.98
Milk	1.36	0.76	1.21
Egg	7.35	5.12	5.24
Timber	—	0.15[a]	—
Fish	—	1.44	—
Whale	—	31.96[b]	—

Notes: * Farm-gate values of 1 metric ton of wheat in native currencies were: 6.76 Dollars in the U.S.A.; 36072 Yen in Japan; 46.4 Rupees in India.

a. per cubic meter of round wood. b. per whale.

Table A-2. Gross Agricultural Output net of Seed and Feed, 1957–62 Averages of 43 Countries

(Unit: 1000 W. U.'s)

Countries	U. S. A. Weights	Japan Weights		India Weights	Composite Y
		Agriculture	(Agr., Forest. & Fish.)		
i	Y_U	Y_J	$(\tilde{Y}_J)$	Y_I	$=\sqrt[3]{Y_U\ Y_J\ Y_I}$
Argentina	64,260	50,262	(52,196)	43,637	52,041
Australia	49,800	38,451	(40,801)	38,841	42,054
Austria	10,733	7,527	(9,254)	8,654	8,875
Belgium (& Luxemburg)	11,835	8,018	(8,458)	8,710	9,384
Brazil	99,715	83,345	(100,213)	71,527	84,082
Canada	43,762	33,357	(48,555)	33,515	36,574
Ceylon	9,927	4,046	(4,171)	6,438	6,371
Chile	7,023	5,174	(6,580)	5,709	5,920
Taiwan	10,137	8,520	(9,062)	7,017	8,463
Colombia	20,422	16,386	(19,602)	14,030	16,745
Denmark	15,083	10,939	(12,016)	10,051	11,836
Finland	5,392	3,598	(10,459)	4,272	4,360
France	104,415	72,618	(79,751)	91,352	88,479
West Germany	62,191	44,012	(48,831)	48,142	50,887
Greece	13,138	8,767	(9,382)	11,076	10,845
India	238,072	196,219	(200,054)	162,552	196,553
Ireland	7,406	5,297	(5,394)	5,075	5,840
Israel	2,633	2,024	(2,048)	2,440	2,352
Italy	63,781	41,173	(44,353)	60,717	54,225
Japan	60,770	47,646	(66,704)	49,828	52,436
Libya	562	318	(475)	518	452
Mauritius	635	836	(848)	539	659
Mexico	52,820	42,169	(43,138)	33,268	42,003
Holland	20,951	12,854	(13,484)	16,600	16,474
New Zealand	20,724	13,149	(13,968)	14,702	15,882
Norway	3,804	2,399	(6,241)	2,931	2,991
Pakistan	56,509	40,303	(51,403)	40,471	48,311
Paraguay	1,276	1,100	(1,374)	1,237	1,202
Peru	8,634	6,824	(12,271)	6,921	7,416
Philippines	19,228	14,449	(16,014)	15,116	16,134
Portugal	10,422	7,600	(9,159)	9,336	9,043
South Africa	19,218	15,294	(16,631)	15,414	16,547
Spain	43,644	27,624	(30,881)	37,357	35,579
Surinam	226	180	(232)	145	181
Sweden	9,971	7,061	(13,866)	7,738	8,167
Switzerland	8,257	5,375	(5,925)	7,068	6,795
Syria	5,087	3,906	(3,911)	4,050	4,317
Turkey	36,506	24,905	(26,247)	33,718	31,297
United Arab Rep.	20,983	16,141	(16,486)	16,819	17,859
U. K.	49,787	32,440	(34,458)	35,425	38,533
U. S. A.	409,445	302,491	(351,704)	280,439	326,274
Venezuela	6,420	5,730	(6,558)	4,864	5,635
Yugoslavia	22,439	16,620	(19,131)	17,526	18,697

Table A-3. Basic Data for Cross-Country Analysis

Countries	Agricultural Land Area (1,000 ha.)	Number of Male Workers in Agricultural Occupations	Conversion Factor for Labor Force	Fertilizer: $N+P_2O_5+K_2O$ (1,000 m. ton)	Machinery Tractor Horsepower (1,000 HP)	Indicator of Industrialization (%)	
	T	$\tilde{L}$	$A=Y_j/\tilde{Y}_j$	F	M	I_p	I_v
Argentina	137,829	1,345	1.0	14.4	3,485	77.1	84.2
Australia	468,135	420	1.1	605.3	7,782	86.7	86.9
Austria	4,050	362	1.2	220.5	2,247	82.0	87.9
Belgium (& Luxemburg)	1,857	226	1.1	376.9	1,405	91.6	92.6
Brazil	126,728	10,523	1.2	191.0	1,972	34.2	72.7
Canada	62,848	704	1.5	323.6	16,800	85.1	93.1
Ceylon	1,723	1,147	1.0	57.0	13	49.4	52.3
Chile	5,968	639	1.3	77.1	473	65.6	88.5
Taiwan	880	1,187	1.1	172.6	37	50.8	69.1
Colombia	19,653	1,930	1.2	38.2	349	36.8	65.1
Denmark	3,127	332	1.1	386.3	3,227	77.1	85.5
Finland	2,849	466	2.9	216.1	2,288	62.2	80.2
France	34,539	2,634	1.1	2,183.4	18,996	79.9	90.5
West Germany	14,254	1,625	1.1	2,307.2	16,173	90.4	93.9
Greece	8,911	1,178	1.1	144.4	818	51.8	70.1
India	176,036	88,570	1.0	340.4	686	31.4	52.6
Ireland	4,560	348	1.0	173.7	1,243	57.7	74.5
Israel	1,210	78	1.0	32.4	214	85.9	88.3
Italy	20,930	4,150	1.1	815.6	7,536	72.4	81.7
Japan	7,020	6,863	1.4	1,576.9	5,234	74.4	84.0
Libya	11,280	—	1.5	3.4	71	—	—
Mauritius	123	57	1.0	18.0	9	62.7	72.5
Mexico	102,909	5,480	1.0	188.2	1,229	41.1	80.6
Holland	2,317	406	1.0	467.2	1,857	87.5	89.8
New Zealand	13,341	119	1.1	263.2	2,452	82.3	—
Norway	1,033	261	2.6	144.8	1,568	75.9	89.0
Pakistan	—	19,425	1.0	47.5	117	26.6	47.5
Paraguay	1,222	291	1.3	—	17	38.7	63.4
Peru	13,956	1,340	1.8	56.1	204	45.2	78.1
Philippines	7,954	4,397	1.1	65.9	128	30.8	66.4
Portugal	n. a	1,341	1.2	122.6	309	52.4	74.0
South Africa	101,171	1,539	1.1	213.3	2,250	65.0	89.1
Spain	21,826	3,368	1.1	659.4	1,273	63.6	74.5
Surinam	46	15	1.3	0.5	17	74.9	86.4
Sweden	4,282	408	2.0	285.7	4,682	82.1	—
Switzerland	2,161	257	1.1	99.2	652	85.3	—
Syria	12,566	478	1.0	8.9	1,423	46.8	64.9
Turkey	54,018	4,706	1.1	45.0	1,375	38.9	58.1
United Arab Rep.	2,569	4,133	1.0	204.0	220	42.2	69.6
U. K.	19,894	1,025	1.1	983.8	12,989	93.5	95.9
U. S. A.	439,941	4,069	1.2	7,225.2	155,540	91.4	96.0
Venezuela	19,178	745	1.1	12.8	320	62.0	92.6
Yugoslavia	14,923	—	1.2	252.5	1,134	—	72.1

estimated from that in agricultural occupations $\tilde{L}_i$, as $L_i = \tilde{L}_i \frac{Y_{Ji}}{\tilde{Y}_{Ji}}$ (see Y_{Ji} and $\tilde{Y}_{Ji}$ in Table A-2). This method is based on the assumption that labor productivity between these agricultural occupations is equal.

Fertilizer (F): Fertilizer is measured as the sum of the physical weights of N, P_2O_5 and K_2O contained in fertilizers consumed. Data were taken from FAO, *Fertilizers-Annual Review.*

Tractor Horsepower (M): Data for tractor horsepower in 1960 were obtained for OECD countries from OECD, *Evolution de la motorization de l'agriculture et de la consommation et des prix des carburant dans les pays membres,* June 1963, mimeo. For countries outside of OECD, tractor horsepower was estimated from the number of farm tractors by assuming that the average H.P.'s of tractors and garden tractors is 30 and 5 respectively. The data for the number of tractors were taken from FAO, *Production Yearbook.*

Indicators of Industrialization (I): The percentages of the number of male workers in non-agricultural occupation to the total number of male workers (I_p) were calculated from ILO, *Yearbook of Labor Statistics.* The percentages of value-added in non-agricultural sector to the total GDP (I_v) for the averages of 1957–62 were calculated from UN, *Yearbook of National Accounts Statistics.*

APPENDIX B. TIME-SERIES DATA OF JAPAN

In principle, flow variables are in five-year averages centering years shown, and stock variables are measured in years as shown in Table B-1. Unless otherwise noted, data were taken from Kazushi Ohkawa et. al., ed., *Long Term Economic Statistics of Japan since 1868,* Vol. 9, Tokyo, 1966 (henceforth abbreviated as *LTES*).

Agricultural Output (Y): Data for agricultural output net of intermediate goods produced in agriculture comparable to cross-country data were estimated by multiplying the 1957–62 average output in wheat units (Table A-2) by the index of gross output net of agricultural intermediate goods. This index was calculated by multiplying the index of gross agricultural production (Series 10, Table 33, pp. 222–223, *LTES*) by one minus the ratio of the 1934–36 constant price aggregate of agricultural intermediate goods (Series 6–7, Table 16, pp. 186–187, *LTES*) to the 1934–36 constant price aggregate of gross agricultural production (Series 14, Table 4, pp. 152–153).

Land (T): Data for agricultural land area including permanent pasture were estimated by multiplying arable land area (Series 14, Table 32, pp. 216–217, *LTES*) by 1.16 which is the ratio of agricultural land area to arable land area in 1960 Census of Agriculture.

Labor (L): Number of gainfully occupied male workers (Series 1, Table 33, pp. 218–219, *LTES*).

Indicators of Industrialization (I): The percentages of the number of male workers in non-agricultural occupations to the total number of workers (I_p) are: (a) percentages calculated from the population Census data for Census

Table B-1. Basic Data for Japan's Time-Series Analysis

Time	Agricultural Output (1,000 wheat units) Y_t	Land (1,000 ha.) T	Labor (1,000 workers) L	Indicator of Industrialization (%) I_p	I_v
1880	14,892	5,507	7,842	21	40
1885	16,884	5,584	7,766	24	49
1890	18,720	5,708	7,677	28	50
1895	19,454	5,839	7,651	31	53
1900	22,233	6,031	7,680	35	55
1905	24,540	6,147	7,617	38	58
1910	28,001	6,471	7,606	43	60
1915	31,881	6,701	7,585	47	65
1920	34,503	6,957	7,593	52	69
1925	34,398	6,860	7,586	55	71
1930	37,125	6,914	7,579	57	78
1935	39,170	7,080	6,972	61	80
1940	39,222	7,100	6,365	64	79
1945	33,664	6,660	6,130	62	65
1950	37,701	6,795	7,720	60	74
1955	44,256	6,938	7,350	66	79
1960	53,327	7,043	6,230	74	85

years, (b) linear interpolations for inter-census, (c) the percentage in 1920 (the first census year) multiplied by the ratios of the number of gainful workers in agriculture to the total number of gainful workers in Kazushi Ohkawa *et. al*, *The Growth Rate of Japanese Economy*, Tokyo, 1957. The percentages of value-added in non-agriculture were calculated from Yūjirō Hayami and Saburō Yamada, "Agricultural Productivity at the Beginning of Industrialization," in *Paper Presented at Agriculture and Economic Development : A Symposium of Japan's Experience*, Tokyo, 1967.