# An Application of the Harris-Todaro Model to Japan

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By utilizing a reduced form Harris-Todaro model, this paper attempts to clarify the basic mechanism of Japan's long-term migration from rural agricultural to urban industrial sectors. The analysis has been conducted for two subsample periods, namely, pre-war (1885-1935) and post-war (1953-1980). One of the primary findings shows that the historical relationship of Japan's rural-urban migratory streams can be well represented for both subsample periods by the reduced form Harris-Todaro model with unemployment exogenously given. In a later section of the paper, some of the econometric results are compared with those of the U.S. case.

## I. Introduction

As extensively discussed elsewhere (Ogawa and Suits, 1982; Ogawa and Cheong, 1981), Japan's industrialization was facilitated largely through a massive transfer of both labor and capital from agricultural to industrial sectors. This pattern of development continued to exist for more than one century. In a country like Japan with scanty natural resources, an inflow of high-quality human resources from labor-surplus agricultural areas to labor-deficient modern sectors was essential for its economic development. It should be noted, however, that depending upon development stages, modern industries require a varying quantity and quality of human resources from agricultural sectors, thus affecting migratory flows.

By heavily drawing upon a reduced form Harris-Todaro model (Suits, 1983), we will attempt to clarify the basic mechanism of Japan's long-term migration from rural agricultural to urban industrial sectors. In the next section, we will discuss the nature of the model to be used for empirical testing. In Section III, quantitative changes in labor mobility from agricultural to industrial sectors will be described, coupled with productivity changes in both sectors. Section IV discusses empirical results of the application of the Harris-Todaro model to the Japanese long-term data. The ensuing section will deal with a brief comparison between Japan and the United States, and the final section will summarize the present study.

## II. Description of the Model

Although the Harris-Todaro model (Harris and Todaro, 1970) has been widely used to account for migratory streams in developing countries, the model is, by no means, limited to developing economies; it is readily generalizable to analyses of sectoral labor mobility in industrialized countries as well.

In his recent work (1983), Suits adapted the Harris-Todaro model to explain U.S. farm migration over the period 1900-1976. In his adaptation of the model, the unemployment rate is treated as an exogenous variable rather than an endogenous one. For this reason, the Suits version of the model is not the standard Harris-Todaro model, but rather a Harris-Todaro model "that is stood on its head, so to

speak, with the unemployment rate, rather than the nonfarm wage rate taken as given" (Suits, 1983: 7). This adaptation has been done primarily because the main source of changes in U.S. unemployment is not farm migration but an interplay of such factors as fiscal and monetary policies, consumer expectations, and investment opportunities. Hence, the adapted version of the Harris-Todaro model is highly applicable to most of the industrialized societies.

Another feature of Suits' reformulation is that a reduced form is used rather than a system of structural equations. Although the Harris-Todaro model can be well represented by five behavioral equations (Suits, 1983), by focussing analyses upon one of the five dependent variables we can transform the system of equations to a reduced form. The use of a reduced form is certainly advantageous when the availability of data is severely limited, although all the intermediate economic variables are eliminated from analysis.

The dependent variable which Suits selected for his empirical analysis is the fraction of labor force employed in agriculture. Theoretically, the equilibrium allocation of the labor force corresponds to the point f where the value of the marginal product of labor is equated in agricultural and industrial sectors. Note, however, that due to the deficiency of data on marginal productivity, the value of average productivity has been employed as an approximate. Hence, the reduced form equation for empirical testing can be expressed as follows:

$$f = f\ (P_F,\ P_{NF},\ u) \qquad (1)$$

where $f$ = fraction of labor froce engaged in agriculture,
$P_F$ = average output per worker-hour of farm work,
$P_{NF}$ = average output per worker-hour of nonfarm work, and
$u$ = unemployment rate.

## III. Sectoral Growth of the Work Force and Changes in Labor Productivity, 1885-1980

Before proceeding to quantitative analyses, let us examine the long-term trend of (i) output and the work force in agricultural (including forestry) and nonagricultural sectors, and (ii) changes in

average productivity per worker in each sector. Due to the paucity of data, we will consider the following two periods: pre-war (1885-1935) and post-war (1953-1980).

Table 1 shows the pattern of growth of both agricultural and non-agricultural output, and the work force in the two sectors over the period 1885-1980. (All the statistics related to output are expressed in terms of 1975 constant prices.) The growth of nonagricultural output is substantially different from that of the agricultural one; the former is far more rapid than the latter. The total output of the agricultural sector grew in real terms by 1.86 times in the pre-war period and by 4.26 times over the entire sample period. The total production level of the nonagricultural sector expanded 6.22 and 83.12 times, respectively.

The growth pattern of the work force also shows a striking difference between these two sectors. Subsequent to its relatively stable size in the work force in the pre-war period, the agricultural sector underwent a dramatic fall in the number of its workers. In contrast, the size of workers engaged in the nonagricultural sector grew very rapidly throughout the whole period under study. Although in the early part of development, the agricultural sector had a larger work force than the nonagricultural sector, the latter outstripped the former in 1925, after which the difference in the work force between these sectors continuously expanded over time.

Figure 1 presents changes in the three variables contained in Eq. (1). These variables show considerably different trends between pre-war and post-war periods. In pre-war Japan, average productivity per agricultural worker remained at a low level without much increase, and the nonagricultural sector experienced a slightly faster productivity increase. The proportion of agricultural workers in the total work force declined almost continuously from 0.771 in 1885 to 0.451 in 1935.

As opposed to these pre-war trends, every one of these variables changed more conspicuously in post-war Japan. For instance, average productivity per worker for the nonagricultural sector rose from 8.56 million yen in 1953 to 36.51 million yen in 1980. The growth rate of nonagricultural productivity became very high, particularly in the second half of the 1960s. The agricultural worker's average productivity improved at a slow pace in the 1950s. In the 1960s and 1970s,

Table 1. Changes in Output and Work Force in Agricultural and Nonagricultural Sectors, 1885-1980.

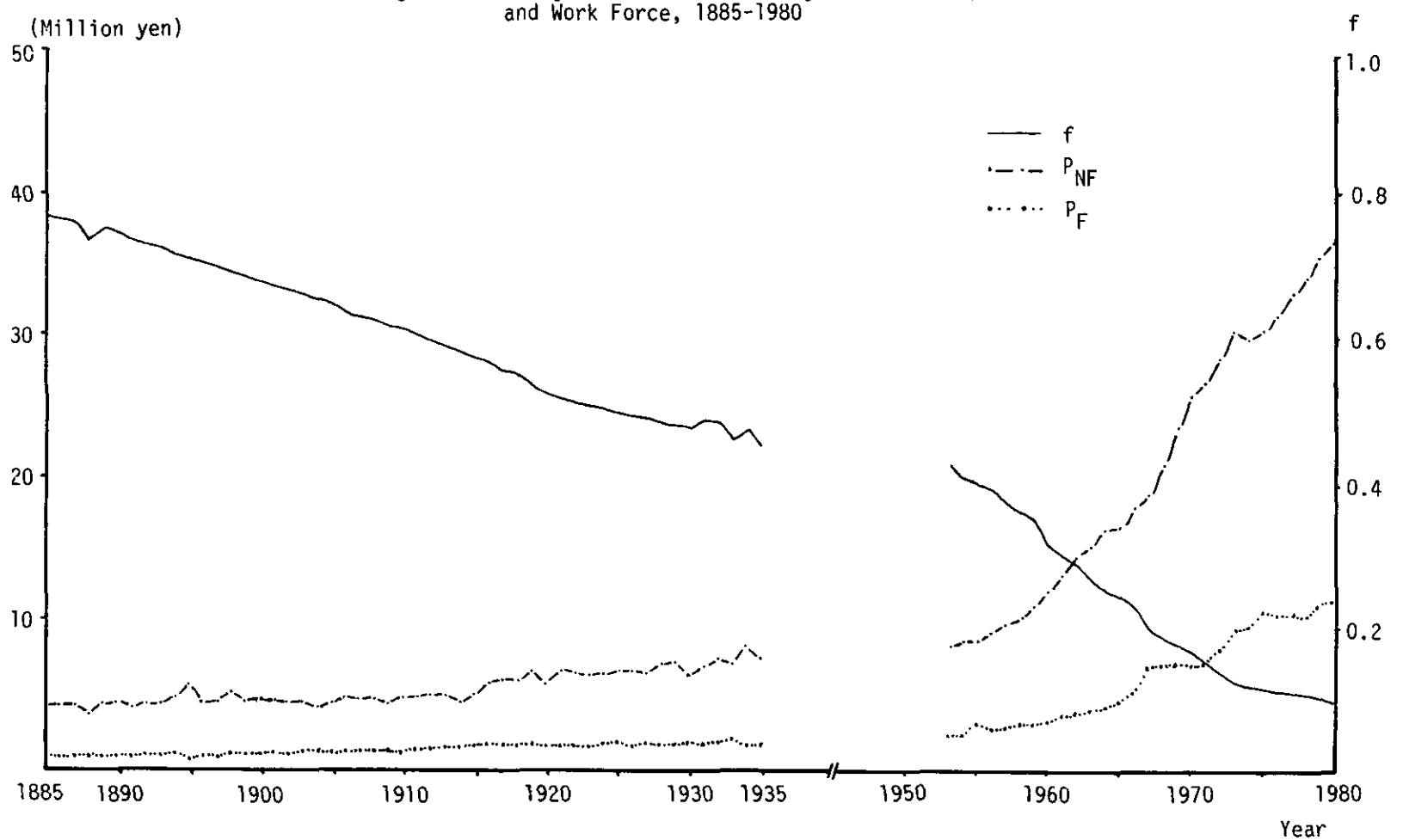
| Year | Total agricultural output* | Total nonagricultural output* | Number of workers in agriculture** | Number of workers in nonagriculture** |
|---|---|---|---|---|
| 1885 | 1.432 | 2.198 | 16.32 | 4.85 |
| 1890 | 1.672 | 2.836 | 16.74 | 5.84 |
| 1895 | 1.127 | 4.093 | 16.91 | 6.86 |
| 1900 | 1.889 | 3.897 | 16.84 | 7.93 |
| 1905 | 1.784 | 4.245 | 16.53 | 9.07 |
| 1910 | 2.082 | 5.100 | 15.97 | 10.20 |
| 1915 | 2.432 | 6.017 | 15.18 | 11.35 |
| 1920 | 2.667 | 7.858 | 14.29 | 12.98 |
| 1925 | 2.678 | 9.796 | 14.21 | 14.23 |
| 1930 | 2.753 | 10.470 | 14.13 | 15.49 |
| 1935 | 2.664 | 13.666 | 14.16 | 17.24 |
| -- | -- | -- | -- | -- |
| 1953 | 4.035 | 19.344 | 16.90 | 22.61 |
| 1955 | 5.348 | 22.674 | 16.45 | 24.77 |
| 1960 | 4.868 | 38.582 | 13.91 | 30.74 |
| 1965 | 5.587 | 68.105 | 11.54 | 37.30 |
| 1970 | 6.168 | 111.680 | 8.42 | 42.68 |
| 1975 | 6.899 | 140.920 | 6.18 | 46.22 |
| 1980 | 6.100 | 182.700 | 5.32 | 50.04 |

Source: see footnote 1/

* unit: trillion of 1975 yen

** unit: million persons.

Figure 1. Changes in Sectoral Average Productivity and Work Force, 1885-1980



however, it increased pronouncedly. The value of the average productivity per agricultural worker was only 2.39 million yen in 1953, but it rose to a level of 11.47 million yen in 1980.

The relative distribution of workers became increasingly skewed in favor of the nonagricultural sector, especially over the period 1953-1970. Note that most of this time period corresponds to Japan's post-war miraculous economic recovery and growth, as indicated in Table 1.

In the above, we have reviewed the trend of average output per worker for each sector, and changes in the size of the sectoral work force. In the next section, we will apply these observed data to the Suits version of the Harris-Todaro model with a view to testing the performance of the model.

## IV. Empirical Results

### A. Comparative Static Analysis

Following the same statistical procedure as Suits' recent work on the U.S. case, we will analyze Japan's historical relationship of labor force allocation between agricultural and nonagricultural productivity.[2/]

The behavioral equation to be tested can be expressed as follows:

$$\text{Ln } f_t = a_0 + a_1 \text{ Ln } P_{Ft} + a_2 \text{ Ln } EP_{NFt} + e_t \qquad (2)$$

where $EP_{NFt}$ stands for the expected value of nonagricultural labor productivity when the nonagricultural unemployment is taken into account.

When we have fitted Eq. (2) to the Japanese data, we have divided the sample data into the following two subsample periods: pre-war and post-war. This has been done primarily because the relationship on the transfer of the labor force from agricultural to nonagricultural sectors differs substantially between these two periods, as shown in Figure 1.[3/]

The statistical result for the pre-war period (1885-1935) is:

$$\underset{t}{\text{Ln } f} = \underset{(0.044)}{-1.4062} - \underset{(0.030)}{0.3459}\ \text{Ln } P_{Ft} - \underset{(0.043)}{0.3549}\ \text{Ln } EP_{NFt} \qquad (3)$$

$$D - W = 1.576 \ ; \ R^2 = 0.953$$

Values in the brackets beneath the estimated coefficients represent standard errors. The result totally conforms to a priori expectations; productivity improvements in both agricultural and nonagricultural sectors contribute to a decline in the proportion of the labor force in the agricultural sector. Moreover, the values of both estimated coefficients are very close, which means that the magnitude of the effect of a productivity increase in each sector on labor mobility is approximately the same. This seems to be consistent with our previous observation on the basis of Figure 1 that the productivity growth of each sector was fairly comparable in the pre-war period.

The estimated result for the post-war period (1953-1980) is described as:

$$\underset{t}{\text{Ln } f} = \underset{(0.145)}{-1.4628} - \underset{(0.115)}{0.4257}\ \text{Ln } P_{Ft} - \underset{(0.127)}{0.5578}\ \text{Ln } EP_{NFt} \qquad (4)$$

$$D - W = 0.516 \ ; \ R^2 = 0.990$$

Just as in the case of the pre-war period, this statistical result agrees to theoretical predictions. Nevertheless, as compared with the pre-war case, the values of the estimated coefficients are considerably different in the following two respects. First of all, these coefficients have higher values. This may reflect the fact that as indicated in Figure 1, productivity increases in both sectors were more substantial in the post-war period than in the pre-war period. Secondly, the difference in the values of the two estimated coefficients is large. This may be explained by the fact that the nonagricultural sector underwent a much greater increase in average productivity per worker than the agricultural sector, thus absorbing a massive inflow of workers from agriculture.

B. Dynamic Analysis

Eqs. (3) and (4) have been estimated in the context of the com-

parative statics of sectoral labor allocation. In reality, however, changes in labor productivity in each sector constantly lead to a disequilibrium situation where earnings differ between the two sectors, thus inducing agricultural workers to move to nonagricultural industries. Because the volume of off-farm migration is likely to be proportional to the difference in sectoral earnings, and because earnings are not included in the reduced form, we may capture the migratory flow as a population stock-adjustment process.

Following the theoretical framework which Suits developed in his recent work (1983), we can formulate this dynamic adjustment process as below[4/]:

$$M_t = k\,[b\,F^*_t - (F_{t-1} + I_t)] \tag{5}$$

where $M_t$ = net number of people migrating to (+) or from (-) farms in year t,

$F_{t-1}$ = actual farm population at the end of the previous year,

$I_t$ = natural increase of farm population from births and deaths, and

k, b = parameters to be determined statistically, taking the value range of 0 and 1.

$F^*$ represents equilibrium farm population, which is derived from the following equation:

$$F^* = \hat{f}_t\, LF_t / r_t, \tag{6}$$

where $\hat{f}_t$ is computed from Eq. (2), $LF_t$, the total labor force, and $r_t$, the ratio of farm workers to farm population. It should be further noted, however, that primarily because the sample period under study corresponds to a period of steady and rapid decline in the relative allocation of labor in agriculture, as observed in Figure 1, $\hat{f}_t$ tends to overestimate the equilibrium value. To cope with this problem, the parameter, b, is used as a weight, as shown in Eq. (5).

In estimating Eq. (5), however, we have encountered several data constraints.[5/] Data on $M_t$, $F_{t-1}$, and $I_t$ are available only after 1920, the year of the Japanese first census. To compute the value of $\hat{f}$, therefore, we have re-estimated Eqs. (3) and (4) on the basis of the following two subsample periods: pre-war (1921-1935) and post-war

(1953-1979).

Pre-war period:

$$\underset{}{\text{Ln } f_t} = \underset{(0.172)}{0.0899} - \underset{(0.101)}{0.2157}\ \text{Ln } P_{Ft} - \underset{(0.090)}{0.3409}\ \text{Ln } EP_{NFt} \qquad (7)$$

$$D - W = 1.182 \ ; \ R^2 = 0.680$$

Post-war period:

$$\underset{}{\text{Ln } f_t} = \underset{(0.167)}{0.7856} - \underset{(0.106)}{0.4276}\ \text{Ln } P_{Ft} - \underset{(0.118)}{0.5561}\ \text{Ln } EP_{NFt} \qquad (8)$$

$$D - W = 0.579 \ ; \ R^2 = 0.992$$

Although the signs of the coefficients in Eq. (7) are compatible with theoretical predictions, the estimated result is substantially different from that for Eq. (3). This difference may be partially explained by the following two factors. First of all, the previous subsample period (1885-1935) encompasses a wider array of development stages, but the new subsample period (1921-1935) corresponds solely to the stage of the Rostovian "Drive to Maturity" (Tachi and Okazaki, 1965). Secondly, part of this subsample period was considerably tinged with Japan's upsurge of militarism (Ogawa and Suits, 1982).

By utilizing Eqs. (7) and (8), we have computed $\hat{f}_t$ for each subsample period, which in turn, has been used to estimate the following statistical relationship:

Pre-war period:

$$M_t = \underset{(0.04)}{0.0599}\ F^*_t - \underset{(0.04)}{0.0699}\ (F_{t-1} + I_t) \qquad (9)$$

$$R^2 = 0.190$$

Post-war period:

$$M_t = \underset{(0.028)}{0.0680}\ F^*_t - \underset{(0.029)}{0.0984}\ (F_{t-1} + I_t) \qquad (10)$$

$$R^2 = 0.336$$

Putting these results in the stock-adjustment form, we have the following expressions:

Pre-war period:

$$M_t = 0.0699\ [0.8562\ F^*_t - (F_{t-1} + I_t)] \tag{11}$$

Post-war period:

$$M_t = 0.0984\ [0.6904\ F^*_t - (F_{t-1} + I_t)] \tag{12}$$

In both subsample periods, all estimated coefficients agree with a priori expectations as to both sign as well as magnitude. As for the pre-war period, as Eq. (11) shows, annual net migration averaged about seven percent of the difference between equilibrium farm population and the number of people who would stay on farms in the absence of migration. Equilibrium farm population, on the average, corresponds to about 86 percent of the value computed from Eq. (6). As regards the post-war period, the former amounts to about ten percent, while the latter, 69 percent. These results seem to indicate that off-farm migration is more active in the post-war period than in the pre-war period.

In addition, the coefficient of determination, $R^2$, is 0.190 for the pre-war period and 0.336 for the post-war period. Although these values are considerably lower than those for Eqs. (7) and (8), they should be regarded fairly high, taking into account that a wide range of factors affect the extent and timing of annual farm migration.

C. Effect of Unemployment

Up to this point, unemployment has been assigned only an indirect role in the analysis. Now, we will reformulate the model in such a way that the role of unemployment can be explicitly analyzed. Suits (1983) has explicitly included unemployment as part of the dynamics of annual farm migration as follows:

$$M_t = k\ [(b_0 + b_1 u_t)\ F^*_t - (F_{t-1} + I_t)] \tag{13}$$

As discussed with respect to Eq. (5), values of $(b_0 + b_1 u_t)$ are ex-

pected to table a value between 0 and 1. Furthermore, because higher unemployment contributes to an increase in the equilibrium fraction of the labor force in agriculture, the value of the coefficient $b_1$ will be positive.

When Eq. (13) is fitted to annual data by the least square method, the result for the pre-war period is:

$$M_t = \underset{(0.037)}{(0.063} \underset{(0.115)}{- 0.1585\ u_t)}\ F^*_t - \underset{(0.036)}{0.0727}\ (F_{t-1} + I_t) \qquad (14)$$

$$R^2 = 0.278$$

The result for the post-war period is:

$$M_t = \underset{(0.033)}{(0.0834} \underset{(0.395)}{- 0.4223\ u_t)}\ F^*_t - \underset{(0.031)}{0.1092}\ (F_{t-1} + I_t) \qquad (15)$$

$$R^2 = 0.359$$

Rewritten in the usual stock-adjustment form, Eqs. (14) and (15) become Eqs. (16) and (17), respectively:

$$M_t = 0.0727\ [(0.867 - 2.181\ u_t)\ F^*_t - (F_{t-1} + I_t)] \qquad (16)$$

$$M_t = 0.1092\ [(0.764 - 3.867\ u_t)\ F^*_t - (F_{t-1} + I_t)] \qquad (17)$$

In either case, the coefficient for $u_t$ does not conform to theoretical expectations in terms of sign and magnitude. More importantly, the estimated coefficients for $u_t$ are not significantly different from 0. One may offer the following two explanations for these results. Firstly, except for only a few years, Japan's unemployment rate has been so low that changes in the unemployment rate hardly affect the flow of population off the farm. (The unemployment rate has been fluctuating between 1.0 and 2.5 percent in post-war Japan.) Secondly, the reliability of the data on unemployment has been rather limited, particularly for the pre-war period.

These statistical results suggest that the presence of unemployment exerted no influence upon migratory streams and that the Japanese people moved from farm to city chiefly due to the difference between expected high urban earnings and low rural earnings.

## V. Comparison with the U.S. Case

Let us now compare the results discussed above with those which Suits obtained from the U.S. data over the period 1900-1976. Although there are some difficulties in the comparability of data between these two studies, the following few observations are in order.

One of them is related to the result on the proportion of the labor force on farms. In both U.S. and Japanese cases, the results are completely consistent with theoretical predictions. However, the magnitude of the coefficients differ between these two countries; the U.S. case shows higher values than the Japanese case. Moreover, in the U.S. case the coefficient of $P_{Ft}$ is larger than that of $EP_{NFt}$, but the Japanese case shows the opposite. These results may support the hypothesis that urban industrial 'pull' factors constituted a dominant force in shifting the population off farms in Japan, while rural agricultural 'push' factors played a predominant role in inducing farm migration in the United States.

Secondly, as compared with the Japanese case, annual net form migration in the United States shows a higher percentage of the difference between equilibrium farm population and the number of people who would reside on farms in the absence of migration. This may suggest that the relative volume of the annual net farm migration was greater in the United States than in Japan. It should be stressed, however, that the relative difference between these two countries became pronouncedly smaller in the post-war period.

A third observation is concerned with the effect of unemployment on off-farm migration. Although changes in the unemployment rate adversely affected migratory flows in the United States to a significant degree, they played a negligible role in determining the volume of net farm migration in Japan.

## VI. Conclusion

The present analysis has shown that the historical relationship of Japan's migratory streams from rural agricultural to urban industrial sectors can be well represented by a reduced form Harris-Todaro model with unemployment exogenously given. Unlike the case of the United States, however, the equilibrium ratio of agricultural to the

total labor force is not affected by changes in unemployment, but is solely dependent upon the productivity of labor in both agricultural and nonagricultural sectors. Furthermore, as distinct from the U.S., nonagricultural productivity improvements contributed to changing the equilibrium allocation of the labor force considerably more than agricultural productivity increases.

## VII. Acknowledgements

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## Notes

1/ As regards the pre-war period, the data on the number of workers in each sector have been derived from the estimates prepared by K. Ohkawa (Department of Statistics of the Bank of Japan, 1966) and those on total output, from Estimates of Long-term Economic Statistics in Japan Since 1968 (Ohkawa et al, 1974). As for the post-war period, the labor-related data have been collected from a series of the Annual Report on the Labour Force Survey (Statistics Bureau of the Prime Minister's Office, various years), while the production-oriented data, from published national income statistics (Economic Planning Agency, various years).

2/ It should be noted, however, that although Suits examined the allocation of labor between farm and nonfarm, due to data constraints we will employ agricultural and nonagricultural classifications as an approximation. The agricultural sector includes forestry as well.

3/ We have applied the F-test to the entire data set (79 observations) so as to statistically examine whether or not these two time periods (51 and 28 observations, respectively) can be combined together for analyses. The computed F-ratio was 27.21, thus rejecting the case.

4/ Although Suits has allowed for the effect of military conscription on net farm migration, due to the lack of appropriate data we have excluded the variable from analysis.

5/ The data on $M_t$, $F_{t-1}$, and $I_t$ have been collected from Ryoshin Minami, "Noka Jinko Ido no Suikei to Bunseki (Estimates and Analyses on the Migration of the Farm Population)," Hitotsubashi Ronso, Vol. 52, No. 5, (1967), and Department of Statistics of the Bank of Japan, Hundred-year Statistics of the Japanese Economy, (1966). Additional data have been also gathered from various Japanese censuses. It should be noted that we have used both fertility and mortality rates for rural areas as proxies for the vital rates of the farm population. Furthermore, in the post-war case, due to the lack of appropriate data, we have employed both fertility and mortality rates for the whole country as an approximation of vital rates for the farm population. Toward the end of the 1950s, rural-urban fertility and mortality differentials had narrowed to a considerable extent. For this reason, the above-mentioned statistical assumption seems to do no major harm to our analyses.

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