# THE ROLE OF FUTURE ORIENTED TECHNOLOGY IN JAPAN'S ECONOMIC DEVELOPMENT†

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One of the puzzles about the Japanese economy is the finding that although Japan has been a labor abundant country until the 1960s (Minami, 1973) technological change has taken the shape of labor saving improvements both in the prewar and postwar periods (Watanabe, 1965; Beckmann and Sato, 1969). The present paper puts forward a hypothesis which can explain this phenomenon and moreover show how this seemingly inefficient choice of technology served as a driving force in Japan's economic growth. The gist of the argument is that by introducing capital-intensive technologies Japan actually acted according to the principle of dynamic comparative advantage. It has long been realised that static comparative advantage, based on existing factor endowments cannot serve as a good criterion for resource allocation within an optimal development plan (Chenery, 1961). One major element which should be included in investment decisions is the future change in the quality and quantity of the factors of production; we believe that by utilising capital intensive technologies Japan actually followed this path. First we present a formal model to introduce the concept of future oriented technology, then show how the Japanese experience is seen in the light of the model.

## I *The Model*

### *Choice of technology for one sector*

We start by looking at one sector of the economy. In a dynamic context, the optimal technology to be chosen for this sector will depend not only on factor endowment available to the sector, but on the following considerations as well:

1. the stream of conventional resources[1] available to the sector throughout the planning period;
2. the stream of research resources available for improving technology;
3. the potential for improvement inherent in the alternative technologies.

We assume that the sector has a choice between two neoclassical technologies, $\alpha$ and $\beta$, which are mutually exclusive.[2] Production is subject to constant returns to scale with

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[1] We distinguish between conventional resources—capital and labor—whose purpose is to produce goods, and research resources whose purpose is to improve technology.

[2] For example, suppose that $\alpha$ is the indigenous technology and $\beta$ is one available from abroad. The question is whether to adopt the foreign technology.

respect to capital and labor under both technologies. The differences between the two technologies are stated in assumptions *A1* and *A2*.

*A1 Technology $\beta$ is relatively capital intensive.*[3]

*A2 Technology $\beta$ has an inherently greater potential for improvement than does technology $\alpha$.*

To explain *A2* in more detail: We assume that $\lambda_{it}$, the level of technology $i$ at time $t(0 \leq t \leq T)$, depends on the accumulated allocations of research resources between 0 and $t$, $Q_{it}$,[4] in accordance with the following expression:[5]

$$(1) \quad \lambda_{it} = \lambda_{i0} + Q_{it}^{\eta_i} \qquad \eta_i > 0 \ (i = \alpha, \ \beta)$$

$\lambda_{i0}$ is the level of technology $i$ at time 0 (the time when the decision is being made on which technology to use). $\eta_i$ is the *improvement elasticity* of technology $i$ and is assumed to be constant. In the light of this, *A2* implies:

$$(2) \quad \eta_\beta > \eta_\alpha$$ [6]

We make the following assumptions concerning factor endowments available to the sector:

*A3 The stream of conventional factors and research resources available to the sector throughout the planning horizon is exogenously given.*

*A4 The quantity of research resources available to the sector remains constant throughout the planning period.*

Assumption *A3* characterizes the type of model developed below. In contrast to the usual method of minimization of costs for a given output, we assume that the sector maximizes output (more precisely, cumulative output) for a given stream of production factors exogenously available throughout the period. In the former case, factor prices are exogenous to the firm, while its behavior determines the quantity and structure of resources employed; in the present model, factor prices may be considered to be determined by the central economic authorities in such a way as to ensure that the resources available to the sector will actually be employed.[7] *A3* also implies that the amount of capital investment in the sector is independent of sector performance, either in the short run or in the long run.[8]

The final assumption of the model concerns what we have termed 'the rigidity of tech-

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[3] I.e., the isoquants of technology $\beta$ in Figure 1 intersect to the left and above the isoquants of technology $\alpha$.

[4] $Q_{it}$ could be the engineer-hours used during the period from 0 to $t$ to improve technology $i$; the research resource itself would be engineers.

[5] Equations (1)–(6) are similar in structure to those appearing in Teubal, 1975.

[6] The gap between $\eta_\beta$ and $\eta_\alpha$ arises, *inter alia*, from the possibility of enjoying other countries' improvements in imported technology. The actual transfer may involve costs due to the purchase of know-how or to imitation and adaptation of foreign improvements through a domestic research effort. We shall however disregard such costs in this analysis.

[7] These factor prices do not necessarily coincide with the factor prices of the economy as a whole. For example, the economy's factor prices may lead the sector to choose technology $\alpha$, while the longer time horizon of the government may make technology $\beta$ the best choice from its perspective. Thus, the government may wish to subsidize capital in such a way that the sector will choose a higher capital-labor ratio which, in the context of this model, increases the relative private desirability of $\beta$.

[8] An improved model should recognize (a) that some factors are less variable than others in the short run (say, fixed capital compared to unskilled labor); and (b) that fixed capital investment is to a great extent dependent on sector performance. One could view the present model as prescribing the optimum choice of technology under different time patterns of factor availabilities to the sector, without attempting to specify which will be the actual one. The actual stream of factors available to the sector could then be regarded as one devised from an optimum plan for the economy as a whole as indicated at the end of this section.

nology.'

*A5 At time* 0, *the decision is made to choose either technology* $\alpha$ *or technology* $\beta$ *for the whole period.*

The concept of malleability of capital has been introduced in the various putty-clay models of growth. In these models, old capital (the stock) cannot be redirected to a new purpose or used in different factor proportions from those originally chosen; new capital (the flow) can. In our model, we assume that even new capital can be used only in the technology already chosen. We think this is a fairly reasonable assumption because of (a) the costs of retraining labor to work with a new technology; (b) other relatively fixed costs such as overheads or the infrastructure needed to introduce a new technology; and (c) vested labor interests.[9]

The rigidity of technology makes it impossible for the industry to adapt itself at each stage to existing factor proportions, and makes it necessary to take a long-run view when choosing among technologies. Let $k_0$, $k_t$ and $R$ be the initial capital-labor ratio of the sector, the ratio at time $t$, and the quantity of research resources, respectively. Let $L_t$ be the labor force available to the sector at $t$. $y_{it}$ will be the *current* output of the sector at $t$, and $Y_{it}$ will be the *cumulative* output between 0 and $t$ (both under technology $i$). $f_i(k_t)$ denotes the unit-technology level of output per head. Assumptions $A4$ and $A5$ imply:

$$(3)\quad Q_{it}=Rt, \qquad i=\alpha \text{ or } \beta$$

$$(4)\quad y_{it}=\lambda_{it}L_t f_i(k_t). \qquad i=\alpha \text{ or } \beta$$

By substituting (3) into (1) and (1) into (4) we obtain

$$(5)\quad y_{it}=[\lambda_{i0}+(Rt)^{\eta_i}]L_t f_i(k_t),$$

$$(6)\quad Y_{it}=\int_0^t y_{it}dt.$$

$A5$ implies that technology $\beta$ will be chosen if and only if

$$(7)\quad Y_{\beta T}-Y_{\alpha T}>0$$

*Case 1: Constant capital-labor ratio*

We first consider the case where $k$ remains constant throughout the planning period (from 0 to $T$), i.e. $k_t=k_0$, and where both $K$ and $L$ grow at a positive and constant rate $g$. Let $m_t$ be the difference between output per unit of labor in technology $\beta$ and output per unit of labor in technology $\alpha$ at time $t$:

$$(8)\quad m_t=\lambda_{\beta t}f_\beta(k_0)-\lambda_{\alpha t}f_\alpha(k_0).$$

We may now rewrite inequality (7) for preferring technology $\beta$ as:

$$(9)\quad V=\int_0^T m_t e^{gt}dt>0.$$

Before stating the necessary and sufficient conditions for (9) it is useful to analyze the

[9] A good example of the long-range decision which has to be made with respect to technology is the case of the green revolution now taking place in southeast Asian countries. It turns out that the new high-yield varieties of rice need a whole set of complementary new factors, ranging from fertilizers and pesticides to investment in land improvement and canalization for irrigation. The new varieties also have a shorter growth cycle period and make multiple crops possible. This has a far-reaching effect on transportation and marketing systems with respect to the distribution of seed and other inputs and the collection, storage, and sale of output. It also involves the training of farmers in the new methods and changes in their work schedule. Vested labor interests have often contributed to the conservation of obsolete technologies. For example, one reason for the decline of the British shipbuilding idustry was the opposition of the riveters union to the introduction of the welding system, causing a delay in the introduction of the new technology.

function $m_t$ and how it varies through time. From (8) and (1) we get:

$$(10) \quad m_t = m(k_0,\ Rt) = m_0 + [f_\beta(k_0)(Rt)^{\eta_\beta} - f_\alpha(k_0)(Rt)^{\eta_\alpha}]$$

where

$$(11) \quad m_0 = \lambda_{\beta 0} f_\beta(k_0) - \lambda_{\alpha 0} f_\alpha(k_0).$$

Differentiating $m_t$ of (10) with respect to time we get:

$$(12) \quad t\frac{\partial m}{\partial t} = \eta_\beta f_\beta(k_0)(Rt)^{\eta_\beta} - \eta_\alpha f_\alpha(k_0)(Rt)^{\eta_\alpha}$$
$$= \eta_\alpha[m(k_0,\ Rt) - m_0] + (\eta_\beta - \eta_\alpha) f_\beta(k_0)(Rt)^{\eta_\beta}.$$

It is clear from (12) that $m > m_0$ implies that $\partial m/\partial t > 0$. Moreover, a sufficient condition for this is

$$(13) \quad \frac{\eta_\beta}{\eta_\alpha} > \frac{f_\alpha(k_0)}{f_\beta(k_0)}.$$

In what follows, we assume (13) to be the case, hence

$$(14) \quad \frac{\partial m}{\partial t} > 0$$

i.e., that $m_t$ is an increasing function of $t$ for all $t$.

*Proposition 1*: *A sufficient condition for technology $\beta$ to be preferable to technology $\alpha$ is that it be more productive in a static sense at $t=0$, i.e., that $m_0>0$.*

The proof follows from (14) and (9). Proposition 1 implies that the desirability of choosing the "less dynamic" technology ($\alpha$) can only arise when $m_0<0$, i.e., when its static productivity at time zero exceeds that of the more dynamic technology. This implies that the capital-labor ratio $k_0$ should be lower than a critical level $k^*$ which satisfies the following relation:[10]

$$(15) \quad m_0 = 0 = \lambda_{\beta 0} f_\beta(k^*) - \lambda_{\alpha 0} f_\alpha(k^*).$$

The condition $m_0<0$ is necessary but not sufficient for choice of $\alpha$. The actual choice will also depend on the levels of $k_0$, $g$, and $R$. We now proceed to show how changes in $g$ and in $R$ affect this choice.

*Proposition 2*: *An increase in the constant rate of growth of conventional factors ($g$) will, if $V \geq 0$, increase the relative desirability of the more dynamic technology ($\beta$).*

*Proof*: Let $t^*$ be the time at which the static efficiencies of the two technologies are equalized, i.e.

$$(16) \quad m(k_0,\ Rt^*) = 0.$$

In the more general case, $T$ will exceed $t^*$, so we may decompose $V$ of (9) into two integrals of opposite sign as follows:

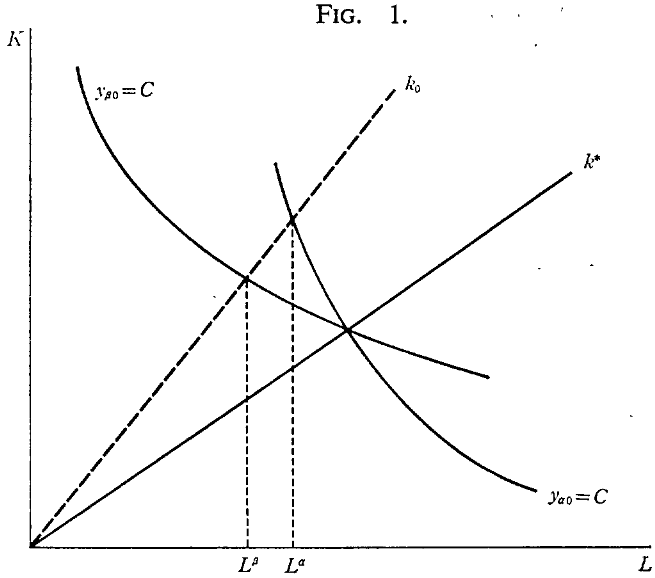
$$(17) \quad V = V_1 + V_2$$

where

$$V_1 = \int_0^{t^*} m(k_0,\ Rt)e^{gt}dt < 0,$$
$$V_2 = \int_{t^*}^{T} m(k_0,\ Rt)e^{gt}dt > 0.$$

[10] Graphically, $k^*$ is the capital-labor ratio of the intersection of the two period-zero isoquants representing a common output level, one for each technology. In Figure 1 both isoquants stand for a common period-zero output level $C$. Output per head under technology $i$ is given by $\lambda_{i0} f_i(k_0) = C/L^i$ ($i=\alpha$ or $\beta$). $L^i$ is the quantity of labor required to produce $C$ units of output under technology $i$ with the ratio $k_0$. Thus $k_0>k^*$ implies $L^\alpha > L^\beta$ and $m_0<0$.

FIG. 1.




$V_1(V_2)$ is negative (positive) since all the $m_t$ for $t<t^*(t>t^*)$ are negative (positive). Differentiating (17) with respect to $g$ we obtain:

$$(18)\quad \frac{\partial V}{\partial g}=\frac{\partial V_1}{\partial g}+\frac{\partial V_2}{\partial g}$$

where

$$\frac{\partial V_1}{\partial g}=\int_0^{t^*} m(k_0, Rt)te^{gt}dt>t^*\int_0^{t^*} m(k_0, Rt)e^{gt}dt=t^*V_1,$$

$$\frac{\partial V_2}{\partial g}=\int_t^{T} m(k_0, Rt)te^{gt}dt>t^*\int_{t^*}^{T} m(k_0, Rt)e^{gt}dt=t^*V_2.$$

From (17), (18) and the above expressions we obtain

$$\frac{\partial V}{\partial g}>t^*(V_1+V_2)=t^*V.$$

It follows that

$$(19)\quad \frac{\partial V}{\partial g}>0 \text{ if } V \geqq 0.$$[11]

*Proposition 3*: *An increase in the quantity of research resources* ($R$) *will increase the relative desirability of the more dynamic technology,* $\beta$.

*Proof*: Differentiating $V$ of (9) with respect to $R$ we obtain:

$$(20)\quad \frac{\partial V}{\partial R}=\int_0^{T} \frac{\partial m_t}{\partial R} e^{gt}dt.$$

From (10), (14) we have

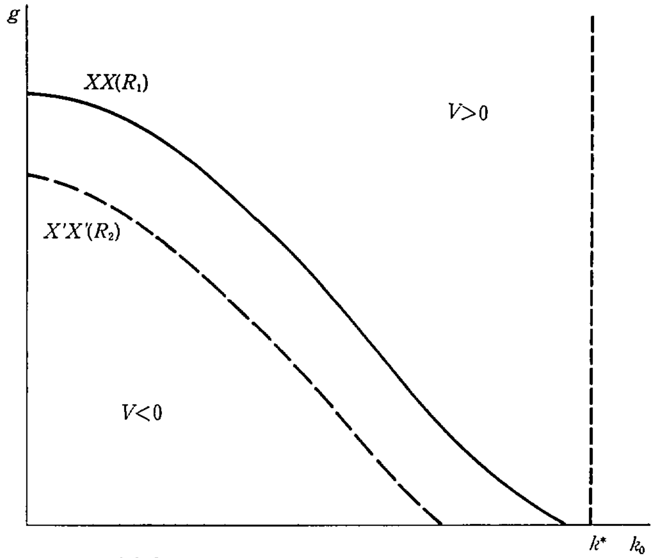
$$R\frac{\partial m_t}{\partial R}=t\frac{\partial m_t}{\partial t}>0$$

[11] $\partial V/\partial g>0$ is also consistent with $V<0$, i.e. the relative desirability of the more dynamic technology may increase as a consequence of an increase in $g$, even when technology $\alpha$ is preferred. Note in particular that when $V=0$, namely when the desirability of the two technologies is equal, an increase in the rate of growth of conventional factors increases the desirability of the capital-intensive technology.

which introduced into (20) proves the proposition.

*Propositions 1–3* may be represented in Figure 2 where the $XX$ schedule represents combinations of $g$ and $k_0$ for which technology $\alpha$ and $\beta$ are equally desirable. An increase in $R$ from $R_1$ to $R_2$ will shift this schedule downward to $X'X'$.[12]

FIG. 2.




*Case 2*: *Increasing capital-labor ratio.*

We may now ask what happens when we allow capital to grow faster than labor. Let the production functions be of the Cobb-Douglas form. Then we can write

$$f_\beta(k)=k^b, \qquad f_\alpha(k)=k^a$$
$$1>b>a$$

Let $g>0$ be the rate of growth of labor and $h>0$ the rate of growth of $k\equiv\frac{K}{L}$. Then

$$k_t=k_0e^{ht}$$

and

$$m_t(k_0e^{ht})=\lambda_{\beta t}(k_0e^{ht})^b-\lambda_{\alpha t}(k_0e^{ht})^a$$

It may be useful to express $m_t(k_0e^{ht})$ in terms of $m_t(k_0)$ (the $h=0$ case). Let us write the following difference

$$m_t(k_0e^{ht})-m_t(k_0)$$
$$=\lambda_{\beta t}[k_0^b(e^{ht}-1)]-\lambda_{\alpha t}[k_0^a(e^{ht}-1)]$$
$$=m_t(k_0)(e^{ht}-1)$$

From this it follows that

$$(21)\quad m_t(k_0e^{ht})=e^{ht}m_t(k_0)$$

Since $m_t\,(k_0e^{ht})=0$ when $m_t(k_0)=0$, $t^*$ is not affected by $h$. To understand the effect of $h$ on the relative desirability of $\beta$ (i.e. on $V$ of (17)) we again can express $V$ as equal to $V_1+V_2$, after substituting $m(k_0, Rt)$ by $m(k_0, e^{ht})$.[13] Differentiating each with respect

[12] Figure 2 reflects the fact that a decrease in $k_0$ favors technology $\alpha$. This follows from assumption *A1*.

[13] Since we are interested in analysing the effect of change in $h$ with $R$ remaining constant, we neglect the dependence of $m$ on $R$.

to $h$ we obtain

$$\frac{dV}{dh}>t^*(V_1+V_2)=t^*V$$

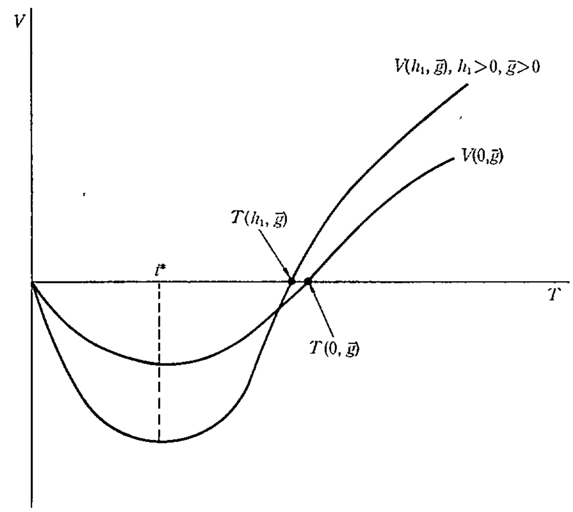
This enables us to visualize the $V$ function for various levels of $h$ and $g$ as in Figure 3.

The condition for choosing $\beta$ when $h=0$ was $T>T_0$, while the condition for choosing it when $h>0$ is $T>T_1$ where $T_1<T_0$. This means that if, for a given $T$, technology $\beta$ is chosen under the condition $g=\bar{g}$, $h=0$, it will be chosen *a forteriory*, for $g=\bar{g}$, $h>0$. Likewise, if $\beta$ is chosen for $h=\bar{h}$, $g=0$, it will also be chosen for $h=\bar{h}$, $g>0$.

*The general equilibrium solution*

In the preceding analysis we assumed that the flow of resources is given to the sector, and found that for every vector of conventional resources (given variables $R$, $\eta_\alpha$ and $\eta_\beta$) there is

FIG. 3.




a technology ($\alpha$ or $\beta$) which maximizes output over the planning horizon. However, the allocation of resources among the sectors of the economy is a problem which has to be solved endogenously within the model. A detailed analysis of the multi-sector model lies outside the scope of this manuscript and will be left for future research. Here we present only an outline of the problem in the two-sector context.

Let us assume the existence of two sectors, a traditional sector ($A$) and a modern sector ($M$) and two available technologies, $\alpha$ and $\beta$. At $t=0$ these two secotors differ in the absorptive capacity of modern (capital intensive) technology, due to factors such as a difference in scale, managerial talents, information and the product composition. We assume that the flow of conventional resources ($K_t$, $L_t$) for $0\leq t\leq T$ is given for the economy. Let $Y^j_{iT}$ be the accumulated output of sector $j$ under technology $i$ for the planning period ($j=A, M$; $i=\alpha, \beta$). Under these assumptions technology $\beta$ should be chosen for the $M$ sector and technology $\alpha$ for the $A$ sector if $Y^A_{\alpha T}+pY^M_{\beta T}>Y^A_{rT}+pY^M_{sT}$ $((r, s)=(\alpha, \alpha), (\beta, \beta), (\beta, \alpha))$ where $p$ is the price of the goods produced by the $M$ sector in terms of the goods produced by the $A$ sector. We assume $p$ to be exogenously given.

Note that the choice of technology is interrelated with the question of factor allocation. Thus, the choice of technology $\beta$ for the $M$ sector and $\alpha$ for the $A$ sector may cause not only a static inefficiency within the former but will also usually reduce the output of the latter (relative to a choice of $\alpha$ by the $M$ sector). Upon reflection, however, it becomes clear that the likelihood of such an inefficiency being overcome by future gains is greater the higher is the rate of growth of the economy's scale and of the capital-labor ratio, the higher the volume of research resources in the $M$ sector, and the wider the gap between $\eta_\beta$ and $\eta_\alpha$.

Since factor prices reflecting existing resource allocation do not assure the correct choice of technology according to society's long-run interest, the government can lead the two sectors to make the right choice by manipulating prices in such a way that each sector faces different factor prices.

## II *Japan's Economic Development in the Light of the Model*

Let us apply our theoretical model to the case of the Japanese economy. As mentioned before, it has been shown that the nature of technological change in Japan has been in the capital-using direction. Our interpretation, in the light of the model, is that the Japanese have introduced these technologies ahead of the time called for by available factor proportions, and thus reaped the benefits of utilizing a future-oriented technology. This strategy was justified because of changes in the capital-labor ratio in subsequent periods.[14]

Data on capital stock, employment and the capital-labor ratio are presented in Table 1. As seen in the table, total employment grew 1.75 times during this period, while capital stock grew 5.43 times. This caused a very substantial increase in the capital-labor ratio; in 1965, it was 3.11 times its 1920 level. In a change of this magnitude, quantity changes into quality; it reflects the transformation of the Japanese economy from labor abundance to labor scarcity.

It remains to explain what were the means by which the introduction of capital-using technologies was achieved.

Since Japan has been characterised by a free enterprise economy (though with substantial intervention by the government) choice of technology depends to a large extend on relative prices of factors of production. The prices to which firms react were not those determined by a free play of market forces, but were heavily dependent on government intervention. The difference in relative factor prices to different sectors of the economy[15] is shown in Table 2. This table presents data on the wage-rental ratio between small and large firms during 1950–70. The price of capital is defined as the rate of interest paid by firms on their total debt, including bonds, short-term and long-term loans from financial institutions, plus the rate of depreciation. The average wage rate is the total compensation to employees divided by the number of employees. The dividing line between large and small firms is paid-up capital of ¥100 million.

[14] We do not address ourselves to the question whether the adoption of these technologies reflected superior insight on the part of the government or sheer luck. Here we are only interested in the *ex post* effects of this strategy.

[15] This aspect of the dual structure was analyzed in Miyazawa, 1961, p. 61.

TABLE 1: EMPLOYMENT, CAPITAL STOCK AND CAPITAL-LABOR RATIO 1920–1965

| Year | Total Employment (millions) | Capital Stock[a] (billions of yen at 1934–36 prices) | Capital-Labor Ratio (yen) |
|---|---|---|---|
| | (1) | (2) | (3) |
| 1920 | 27.2 | 37.5 | 1,379 |
| 1925 | 28.1 | 43.9 | 1,562 |
| 1930 | 29.6 | 51.1 | 1,726 |
| 1935 | 31.2 | 59.0 | 1,891 |
| 1940 | 32.5 | 71.3 | 2,200 |
| 1945 | 29.9 | n.a. | n.a. |
| 1950 | 35.6 | n.a. | n.a. |
| 1955 | 41.1 | 89.0 | 2,165 |
| 1960 | 44.6 | 123.2 | 2,762 |
| 1965 | 47.5 | 203.6 | 4,286 |

a Total gross reproducible capital stock.

*Source*: Column (1), Kazushi Ohkawa and Henry Rosovsky, *Japanese Economic Growth* (Stanford: Stanford University Press, 1973), pp. 310–311, Table 15. Column (2), 1920–40, *ibid.*, pp. 312–313, Table 16. 1955–65, calculated from *ibid.*, Table 16, using linked index of investment goods prices from Kazushi Ohkawa *et al.*, *Estimates of Long Term Economic Statistics of Japan since 1868* (Tokyo: Toyo Keizai, 1967), Vol. 8, p. 134.

TABLE 2: INTERFIRM DIFFERENTIALS OF WAGE, RENTAL AND $w/r$: 1956–70[a]

| Year | Wage Ratio[b] | Rental Ratio[b] | $w/r$ Ratio (1)÷(2) |
|---|---|---|---|
| | (1) | (2) | (3) |
| 1956 | 0.478 | 1.526 | 0.313 |
| 1957 | 0.553 | 1.449 | 0.382 |
| 1958 | 0.487 | 1.602 | 0.304 |
| 1959 | 0.477 | 1.550 | 0.308 |
| 1960 | 0.475 | 1.666 | 0.285 |
| 1961 | 0.559 | 1.519 | 0.368 |
| 1962 | 0.586 | 1.477 | 0.397 |
| 1963 | 0.597 | 1.526 | 0.391 |
| 1964 | 0.600 | 1.523 | 0.394 |
| 1965 | 0.613 | 1.417 | 0.433 |
| 1966 | 0.610 | 1.389 | 0.439 |
| 1967 | 0.623 | 1.425 | 0.437 |
| 1968 | 0.610 | 1.430 | 0·427 |
| 1969 | 0.588 | 1.395 | 0.422 |
| 1970 | 0.632 | 1.402 | 0.451 |
| Average 1956—1970 | 0.566 | 1.486 | 0.381 |

a Until 1959, calendar year; from 1960, fiscal year (April-March).

b Calculated as $\frac{\text{average wage (rental) in firms with capital of less than ¥100 million}}{\text{average wage (rental) in firms with capital of ¥100 million or more}}$

*Source:* Calculated from *Hōjin Kigyō Tōkei Nenpō* (*Annual Report of Corporation Statistics*).

The wage of small firms was, on the average, somewhat less than 60 per cent of the wage of large firms. The ratio was lower in the 1950s and there is a clear trend of decreasing differentials. On the other hand, the rental ratio for small firms was about 50 per cent above that of large firms; though a decreasing trend can be traced, it is milder than that of wages.

Our main interest, however, is in the wage / rental ratio. The ratio for small firms was about one third that for large firms in the second half of the 1950s, and less than 40 per cent for the whole period. Having to pay that much more for labor relative to capital, large firms naturally preferred capital-using technologies over labor-using ones.

Moreover, as has been pointed out (Teranishi, 1974), small firms encountered difficulties in obtaining long-term credit from banks. Responses to a questionnaire sent to firms[16] show that whereas the desired and actual composition of credit are very close for large firms, there is a substantial gap between the two in the case of small firms. For example, firms with capital of ¥ 50 million to ¥ 100 million wanted to have 74.1 per cent of their credit in the form of long-term loans, but the actual share amounted to only 57.2 per cent.

Unfortunately, we cannot perform the same analysis for the prewar period because no data on the price of capital is available. Nevertheless, there are indications that the situation was quite similar, at least in the 1920s and 1930s. Concerning inter-firm wage differentials, it has been pointed out by Yasuba (1976), that significant differentials existed in 1909 and 1914 within light industries, though not in the traditional or heavy industries;[17] in 1932–33, the large gap was in modern heavy industry. Concerning capital, the evidence is of a more qualitative nature. It has been noted that there was a strong connection between banks and large firms, especially within the Zaibatsu groups, and that this relationship became stronger after the banking crises of the 1920s (Lockwood 1954, p. 60).

It is thus our contention that the factor-price difference explains why large Japanese firms ignored the country's factor endowment structure and introduced capital-using technologies.

## *References*

Beckmann, Martin J. and Sato, Ryuzo, "Aggregate Production Functions and Types of Technological Progress: a Statistical Analysis", *American Economic Review*, LIX (No. 1, March 1969), pp. 88–101.

Chenery, Hollis B., "Comparative Advantage and Development Policy", *American Economic Review*, LI (No. 1, March 1961), pp. 18–51.

Kiyokawa, Yukihiko, "Menkōgyō Gijutsu no Teichaku to Kokusanka ni Tsuite (On the Determination and Nationalization of Technology in the Cotton Spinning Industry)", *Keizai Kenkyū*, XXIV (No. 2, April 1973), pp. 117–137.

Lockwood, W.W., *The Economic Development of Japan* (Princeton: Princeton University Press, 1954).

Minami, Ryoshin, *The Turning Point in Economic Development: Japan's Experience* (Tokyo: Kinokuniya, 1973).

Miyazawa, Kenichi, "Shihon Shūchū to Nijū Kōzō (Capital Concentration and Dual

[16] The survey was made in 1968. Kinyū Seido Chōsakai Shiryō, *Kinyū Seido Chōsakai Tōshinshū* (*Reports of the Committee on Financial Structure*), (Tokyo, 1970), p. 107.

[17] This is the period when modern technology was introduced in the cotton-spinning industry. See Kiyokawa, 1973.

Structure)", in *Shihon Chikuseki to Kinyū Kōzō* (*Capital Accumulation and Financial Structure*), edited by Ichiro Nakayama (Tokyo: Tōyō Keizai, 1961).

Ohkawa, Kazushi and Rosovsky, Henry, *Japanese Economic Growth* (Stanford: Stanford University Press, 1973).

Teranishi, Juro, "Chōki Shikin Shijō to Tanki Kashidashi Shijō (Long-Term Capital Market and Short-Term Loan Market)", *Nihon Shōken Keizai Kenkyūshō*, No. 9 (July 1974).

Teubal, Morris, "Towards a Neotechnological Theory of Comparative Costs", *Quarterly Journal of Economics*, Vol. 89, No. 3, August 1975, pp. 414–431.