PRODUCTIVITY GROWTH IN JAPAN (1951-1980): AN INPUT-OUTPUT ANALYSIS

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Abstract

A new approach to cost structure analysis by the use of input-output methods is proposed and applied to the investigation of post-war technological progress in the Japanese economy. The analysis is based on seven comparable input-output tables for 1951-1980. The methodology employed has two key steps. First, the input coefficients (a_{ij}) are divided into two distinct components, one representing inputs of materials that are embodied in the product of the industry, and the other representing inputs of capital goods to replace capital "consumed" in the production process. The second step is to determine the corresponding indirect labor contributions (for "materials" and capital). Thus, total labor requirements for each sector are divided into three components: direct labor, labor embodied in purchased materials, and labor embodied in capital depreciation. The reduction of the total labor requirements for 18 industries from 1950 through 1980 is then disaggregated into direct labor savings, material savings, and capital savings components. The relative importance of these three cost-saving elements is analyzed from the viewpoint of long waves.

Foreword

The analysis of main directions of post-war technological progress plays an important role in investigations of diffusion processes for new technologies. Each new technology is reflected differently in terms of productivity growth or labor, material, capital savings. It may be inferred that the rate of diffusion of any technology depends on the existing situation in an economy from the resources use view point.

The Japanese case chosen by the authors is very interesting not only because of the unusually rapid economic growth that occurred, but because the growth process seems to have involved several distinct phases or "cycles".

In this paper new analytical techniques, utilizing a series of comparable input-output tables, are applied. The method reveals relations between economic growth, structural changes and cost reduction, as well as dynamics and interdependencies of the three types of technological progress (labor-material-capital savings) for 18 industries and the Japanese economy as a whole.

The work was started at Novosibirsk and largley completed at IIASA; it is of interest to a larger audience. Hence we offer it as an IIASA working paper, in the Technology-Economy-Society Program, with which Prof. Tchijov is currently associated.

R.U. Ayres
Deputy Program Leader
T E S

Introduction

Assuming that cost decrease is the other face or inverse value of productivity increase, one of the possible measures of technological progress is change in the structure of costs. Such changes are due to the uneven impact of new technologies on the different elements of product costs, namely direct labor, capital and purchased materials. In principle, it is possible to determine three different types of technological progress: labor-saving, capital-saving and material (purchased on-capital input) saving. In reality, any new technology or technological progress as a whole changes all the three elements (or factors) of cost, but historically it is also possible to determine the periods when one or other of them dominated.

1. Methodological Approach

In our investigation we have used 7 input-output tables of Japan for 1951, 1955, 1960, 1965, 1970, 1975, 1980 [1-3]. All the tables were aggregated to an 18-sector level and reestimated into 1970 prices [5]. Thus we have a time series of completely comparable input-output tables. Total direct and indirect labor inputs to sector j can be expressed as follows:

$$b_j = \sum_i a_{ij} b_i + l_j \tag{1}$$

where

b_j, b_i - total labor requirement coefficients;
l_j - direct labor requirement coefficient;
a_{ij} - input-output coefficients.

If we divide a_{ij} into two parts:

$$a_{ij} = \alpha_{ij} + \beta_{ij} \quad , \tag{2}$$

where α_{ij} reflects the use of materials produced by a i-th industry and embodied in the outputs of the j-th sector, while

β_{ij} reflects the consumption of capital goods produced by the i-th sector per unit of production by the j-th industry.[1]

In order to estimate β_{ij} it is necessary to disaggregate capital consumption (depreciation) allowances for each industry into their elements, viz. fixed capital goods, disaggregated back to the industry-of-source. Of the 18 sectors in the I-O tables, five are capital producers, namely construction, general machinery, electrical machinery, transportation equipment, and agriculture. We also subdivide capital assets into the following types:

(1) houses,
(2) complete structures,
(3) machines and equipment,
(4) ships,
(5) other transportation equipment,
(6) instruments and fixtures,
(7) land improvement,
(8) plants and animals,
(9) incomplete construction.

The output of types of capital by source sector is shown in Table 1.

Table 1. Industrial classification transformation

Source Industries	Types of capital assets produced
Construction	1, 2, 9
General manufacturing	3
Electrical machinery	6
Transportation equipment	4, 5
Agriculture	7, 8

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[1] There are some publications where the problem of "live-labor" and "dead-labor" inputs is discussed (for example A. Racz' or M. Ejdelman's papers in [8]). The capital-input matrices are described by W. Leontief [9], or by I. Ozaki and M. Shimizu in [10]. But the first examples did not consist of statistical verifications, and the second ones dealt with the production (not cost) analysis.

We utilized experts' estimates [7] of life-time for different types of fixed capital assets as follows:

33 years -	for houses and constructions;
11 years -	for industrial equipment;
5.7 years -	for transportation equipment;
8 years -	for perennial plants and animals in agriculture.

As a result we estimated the allocation of capital consumption allowances in each industry ($\overline{\underline{O}}_j$) (see Table 2) based on the use of the real I-O structure for 1967 [6] and the above assumptions about average capital life-time.

Table 2. Allocation of capital consumption allowances, %

Consuming Ind.* / Prod. Ind.*	Material Production (2-3,17)	Agriculture (1)	Transportation and Communication (16)	Non-material production (14,15,19)
3	30	27	27	50
10	43	40	40	-
11	7	7	6	12
12	20	20	27	37
1	-	6	-	-
	100	100	100	100

*Numbers of industries correspond to the list in Table 3.

The data in Table 2 mean that, for instance, the capital allowances ($\overline{\underline{O}}_8$) for industry No. 8 will be reflected as flows of capital goods (x") as follows:

$$x''_{3,8} = 0.30\ \overline{\underline{O}}_8$$

$$x''_{10,8} = 0.43\ \overline{\underline{O}}_8$$

$$x''_{11,8} = 0.07\ \overline{\underline{O}}_8$$

$$x''_{12,8} = 0.20\ \overline{\underline{O}}_8$$

This method permits us to develop a matrix of capital input flows (x''_{ij}) and to add it to the original matrix of material flows (x'_{ij}):

$$x_{ij} = x'_{ij} + x''_{ij} \qquad (3)$$

The corresponding material input, capital input and total material plus capital input (α_{ij}, β_{ij} and a_{ij}, respectively) coefficients can then be deduced as shown below:

$$\beta_{ij} = x''_{ij}/x_j \qquad \text{estimated as above} \qquad (4)$$

$$\alpha_{ij} = x'_{ij}/x_j \qquad \text{from I-O tables} \qquad (5)$$

$$a_{ij} = \alpha_{ij} + \beta_{ij} \qquad \text{new I-O coefficients} \qquad (2)$$

Thus we have transformed the capital consumption row usually given in the third quadrant of the I-O table) into distinct capital and materials input-output coefficients.

In the early post-war Japanese economy, imports traditionally provided a significant fraction of intermediate inputs. In 1955-1980 the share of crude materials and fuels oscillated from 56 to 66% of total import value. It is clear that imported materials and fixed capital had their own original costs which differed from the Japanese ones. To exclude the influence of imports we need "to purify" the I-O tables. The most reasonable approach is based on import subtraction from the I-O matrix, element by element. But there are only 2 import matrices in the Japanese statistics (for 1970 and 1980) and we had to develop an approximate algorithm for the other years.[2]

If $M_{i,t}$ is a volume of imports of products of the i-th industry, $x^d_{i,t}$ is a volume of this industry's domestic production (all in year t), the share of domestic production in the total i-th product consumed in the economy will be the following:

$$d_{i,t} = x^d_{i,t}/(x^d_{i,t} + M_{i,t}) \qquad (6)$$

---

[2] There are different approaches to import exclusion from input-output relationships for an analysis of domestic costs of production. These are described, for instance, in [11]. We preferred to test one of them for our purposes.

For convenience we used a rather strong assumption, namely that for a given year t the import share is the same for different product destinations (e.g. as "materials" or as "capital"). Moreover, the allocation of imports to materisl vs. capital may vary from one year to another.

The modified flows, exluding imports, will be for each I-O table:

$$x^{d}_{i,j} = x_{i,j} \cdot d_i \qquad (7)$$

where x_{ij} is taken from (3) where the subscript t (for time) is dropped.

In order to prove the applicability of this method we compared two matrices of domestic flows. The first was estimated from the official import statistics for 1970 and the second was estimated for the same year by using the proposed method.

The correlation coefficients for these two vectors estimated for each industry (from the 1st to the 18th) were more than 0.99 except for one case (transportation and communication) where the coefficient was 0.92. These results can be treated as evidence of the acceptability of the procedure.

The results of the various procedures described above yielded a set of reconstructed input-output tables where the flows of products were purified to exclude imports, and divided into material and fixed capital consumption. It then becomes possible to construct the coefficients of total labor requirements (b), with 3 components: direct labor requirements (l), material-embodied labor requirements (b^m) and capital-embodied labor requirements (b^c). If A is a matrix of direct material and capital requirements and A^m is a matrix of direct material requirements, b and its components will be defined as follows:

$$b = l(E - A)^{-1} \qquad (8)$$

$$b^c = l(E - A)^{-1} - l(E - A^m)^{-1} \qquad (9)$$

$$b^m = l(E - A^m)^{-1} - l \qquad (10)$$

$$b = l + b^m + b^c \qquad (11)$$

The shares of direct labor, material-embodied labor and capital-embodied in the total cost of each product will be defined, respectively:

$$S_l = \sum_j l_j x_j / \sum_j b_j x_j \qquad (12)$$

$$S_m = \sum_j b_j^m x_j / \sum_j b_j x_j \qquad (13)$$

$$S_c = \sum_j b_j^c x_j / \sum_j b_j x_j \qquad (14)$$

Using the above classification, we can define three types of technological progress for each period. We now proceed to estimate the impacts of these three components on the total reduction in labor inputs per unit output, period by period.

2. Technological Progress, Economic Growth and Structural Changes

The data obtained for the output growth as well as for the direct and total labor requirements reduction are shown in Table 3. It is obvious that the uneven growth took place in the Japanese economy both from the viewpoint of factor-savings and from the viewpoint of industrial structure. The accelerated output growth of the 1950's and 1960's was followed by a period of less rapid growth in the 1970's. A similar tendency was observed in labor requirements (direct and total).

Let us analyze two interrelated hypotheses. The first one is that the post-war technological progress resulted in a decrease of the range of labor-intensity among the sectors (in total labor requirements) starting at the beginning of the 1950's. The second hypothesis suggests that industries with the highest labor intensity at the beginning tended to decrease their labor requirements most rapidly, that is industries starting from a higher level of labor intensity experienced bigger decreases.

To test the first hypothesis we estimated the changes over time of the relation between a standard deviation and a sample average (S/Y) for total labor requirements. The results (see Figure 1) show that, as technological progress (productivity growth) in the Japanese economy led to a reduction of the total labor requirement in all industries, the differences from the

Table 3. Dynamics of direct and total labor requirement coefficients (number of employees per 1 mil. yen)

Industries	DIRECT								TOTAL								Output Growth
Years	51	55	60	65	70	75	80	1980/ 1951	51	55	60	65	70	75	80	1980/ 1951	1980/ 1951
1. Agriculture	3.9	2.9	2.3	1.8	1.4	1.0	0.8	0.207	4.5	3.8	3.0	2.3	1.8	1.2	1.0	0.230	1.73
2. Mining	1.8	1.6	1.2	0.6	0.2	0.1	0.1	0.056	3.7	2.7	1.9	1.0	0.5	0.4	0.3	0.072	3.65
3. Construction	0.5	0.6	0.6	0.4	0.2	0.2	0.2	0.460	1.1	1.4	1.6	1.0	0.6	0.6	0.5	0.395	7.91
4. Food	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.258	2.0	2.8	1.9	1.3	0.9	0.7	0.5	0.236	5.40
5. Textile	1.1	0.8	0.6	0.5	0.4	0.3	0.3	0.234	6.1	4.0	2.0	1.5	1.0	0.7	0.5	0.085	6.55
6. Paper	0.8	0.6	0.4	0.3	0.2	0.1	0.1	0.125	5.1	3.4	1.8	1.2	0.7	0.4	0.4	0.073	16.53
7. Chemicals	0.9	0.5	0.3	0.2	0.1	0.1	0.1	0.069	4.9	2.8	1.4	0.8	0.4	0.4	0.2	0.045	21.92
8. Primary metals	0.4	0.3	0.3	0.2	0.1	0.1	0.1	0.143	4.9	1.6	1.3	0.8	0.5	0.3	0.2	0.045	15.62
9. Fabricated metal products	1.2	1.3	1.0	0.6	0.3	0.3	0.2	0.198	3.0	2.3	1.8	1.0	0.7	0.6	0.4	0.131	22.81
10. Non-electrical machinery	0.7	0.6	0.4	0.3	0.1	0.1	0.1	0.085	2.3	1.7	1.3	0.9	0.5	0.4	0.2	0.091	30.43
11. Electrical machinery	1.6	1.2	0.5	0.4	0.2	0.2	0.1	0.050	4.7	2.8	1.6	1.1	0.6	0.4	0.2	0.041	150.24
12. Transportation equipment	1.1	0.8	0.4	0.3	0.2	0.1	0.1	0.072	3.8	2.0	1.4	0.9	0.5	0.4	0.3	0.066	47.40
13. Other manufacturing	0.9	0.8	0.7	0.5	0.3	0.3	0.2	0.268	2.6	3.6	2.4	1.5	0.9	0.6	0.5	0.182	9.32
14. Trade	2.3	2.0	2.0	1.2	0.7	0.6	0.5	0.208	3.3	2.6	2.4	1.5	0.9	0.8	0.6	0.174	14.89
15. Finance, real estate	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.237	0.7	0.7	0.4	0.4	0.3	0.3	0.2	0.297	20.20
16. Transportation, communication	1.5	1.2	0.9	0.7	0.4	0.2	0.2	0.147	2.9	2.2	1.4	1.	0.7	0.5	0.4	0.140	15.01
17. Public utilities	0.5	0.4	0.2	0.2	0.1	0.1	0.1	0.130	1.6	1.4	0.8	0.6	0.4	0.3	0.2	0.135	11.82
18. Services	0.8	0.6	0.7	0.6	0.5	0.5	0.4	0.443	2.5	1.1	1.1	1.	0.8	0.8	0.5	0.218	5.70
Change in total, %	-	-27	-23	-30	-40	-19	-19	-	-	-26	-27	-33	-38	-21	-29	-	

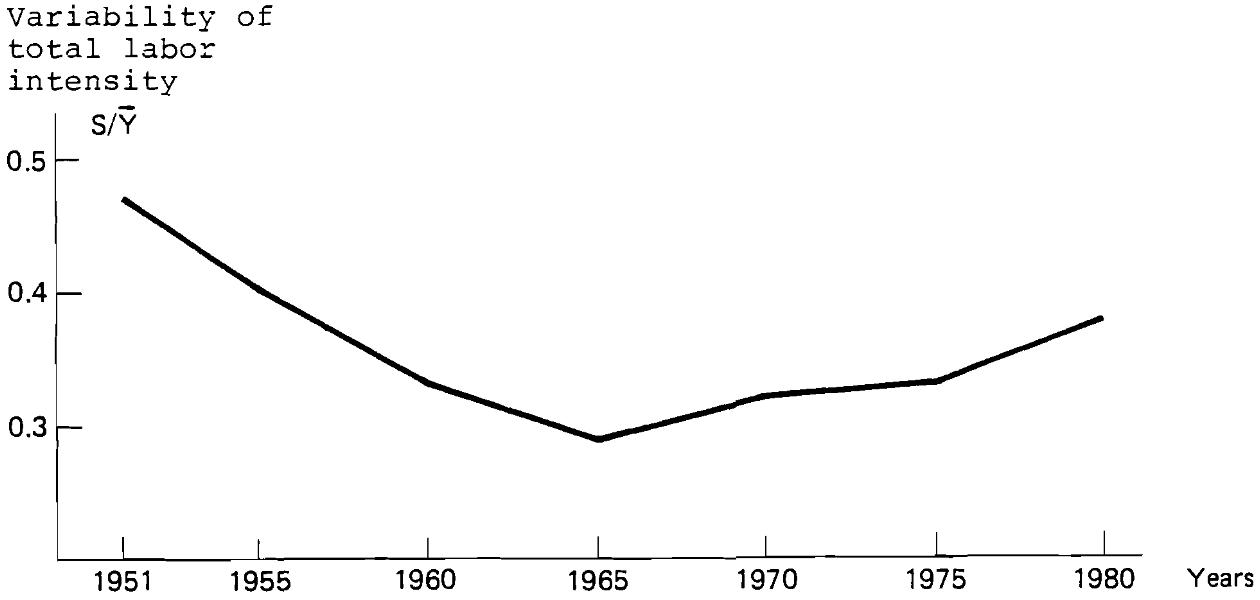


Figure 1. The trend in labor intensity variability (measured as the ratio of standard deviation to sample average $-S/\bar{Y}$).

most labor-intensive to the least labor intensive declined sharply during 1951-1965, but subsequently increased.

We tested the second hypothesis for the total labor requirements, estimating the correlation between decrease rates and the starting levels of the variables in 1951. These estimates were made for 17 industries (No. 2-18 in Table 3). The results, displayed in Figure 2, show that this hypothesis is generally valid, when total labor requirements are considered.

If we compare the growth rates for industrial outputs with the decrease rates for the total industrial labor requirement coefficients we can find a certain relationship between them. Higher reductions in the cost of production usually correspond to higher production growth rates. The total rank correlation coefficient of these two variables for 17 industries was (0.65). Thus it is not unreasonable to distinguish "dynamic" industries (like electrical and nonelectrical machineries, transportation equipment and chemicals) and "mature" industries (like agriculture).

For example, output in electrical machinery increased by a factor of 150 in 1951-1980, in transportation equipment by 47 and in nonelectrical machinery - by 20. At the same period total labor requirements in these industries decreased by a factor of 24, 15 and 11, respectively. On the other hand, output in agriculture increased only by a factor of 2, and total labor requirements declined by a factor of 4. One can conclude that there is a certain interdependence between the rate of output growth and the rate of cost (total labor requirements) reduction, see Figure 3. Nevertheless during the post-war period we found big differences in this relationship from one period to another. Let us compare the interpolated regression between the rate of total labor requirement reduction (TLR) and changes in industrial outputs (IO), see Figure 4. The dynamics of the slope coefficient reflects a tendency to decrease from 0.37 for the first period up to 0.22 for 1965-1970 and a lack of such a relationship in 1970-1975. Then the coefficient increased again in 1975-1980. This tendency is followed by T-values decrease up to unsufficiency of the relationship in 1970-1975 and its increase in 1975-1980.

Thus we can observe certain tendencies in long-term trends of variables reflecting waves in technological progress. The

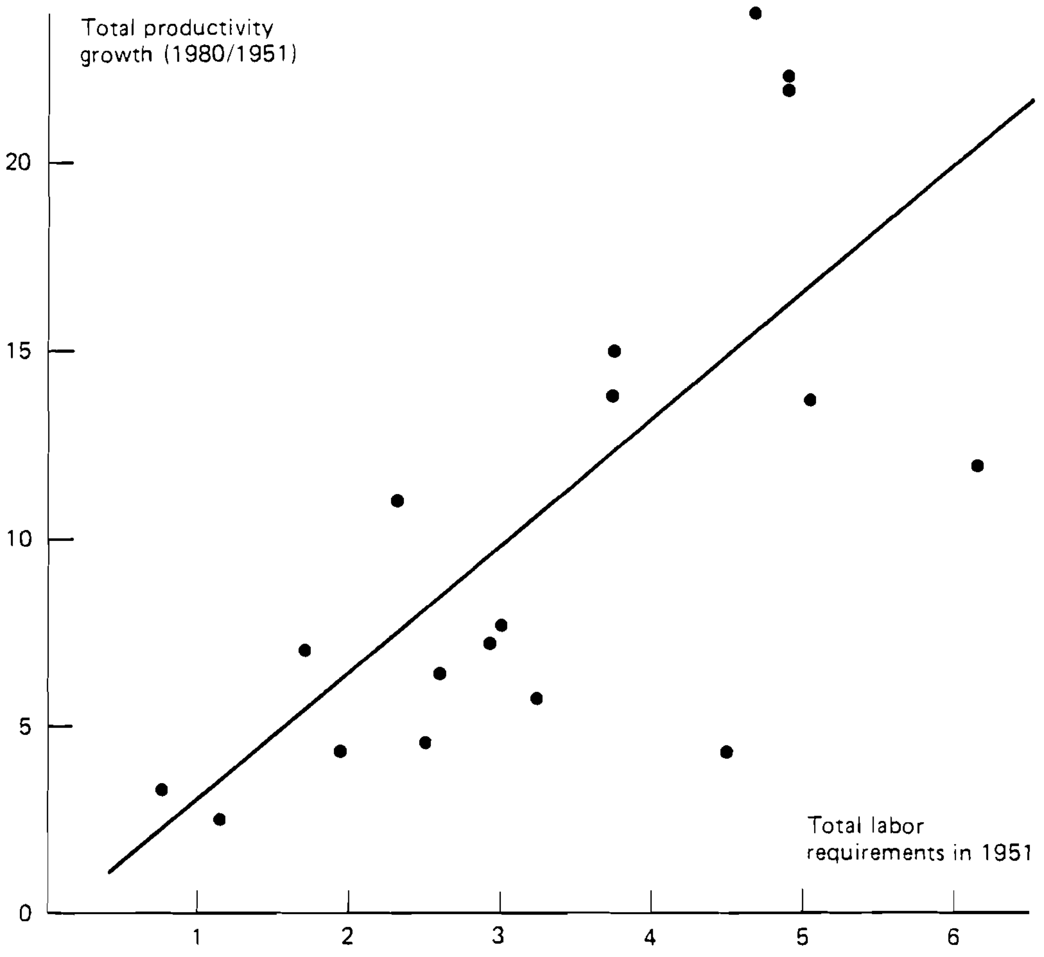


Figure 2. Productivity growth versus starting value of total labor requirements.

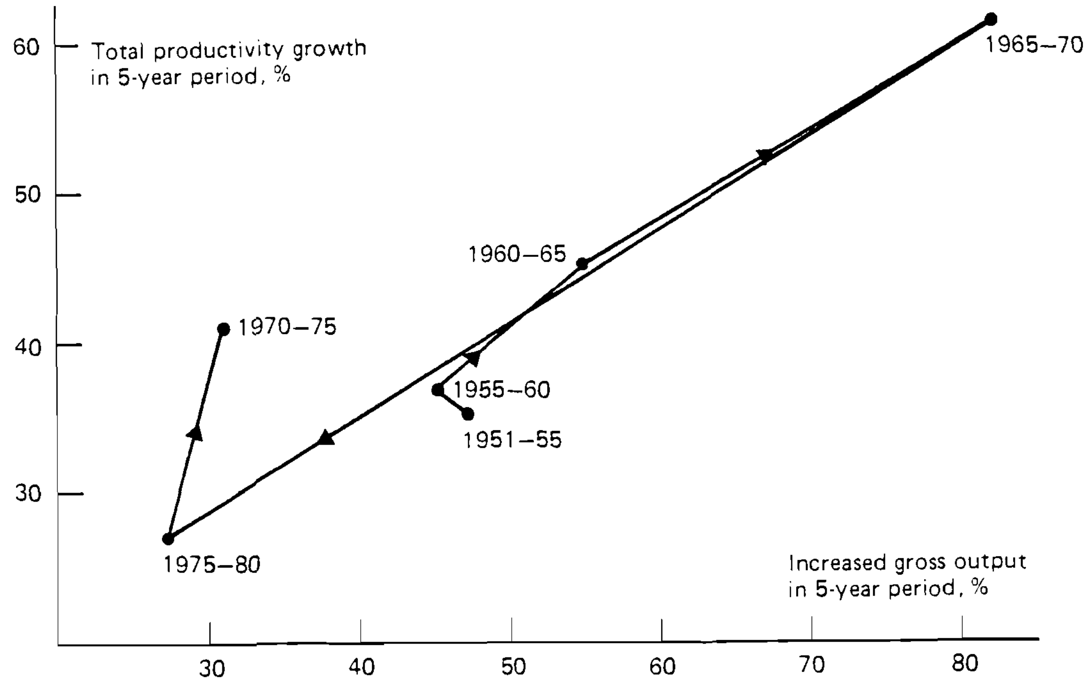


Figure 3. Productivity growth versus output changes.

Fig.4 Correlation between 5-year changes in industrial output (IO) and in total labor requirements (TLR),%

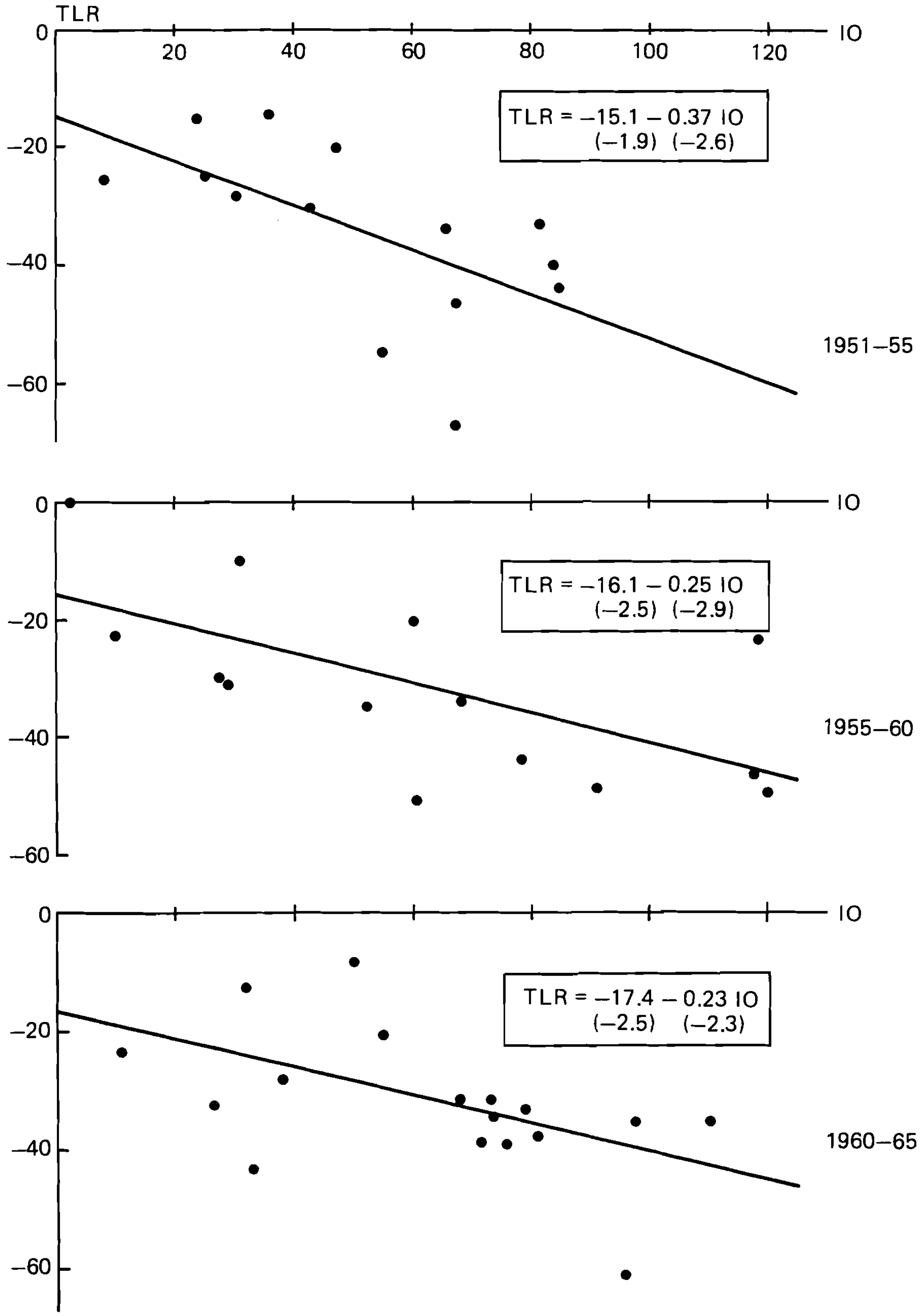
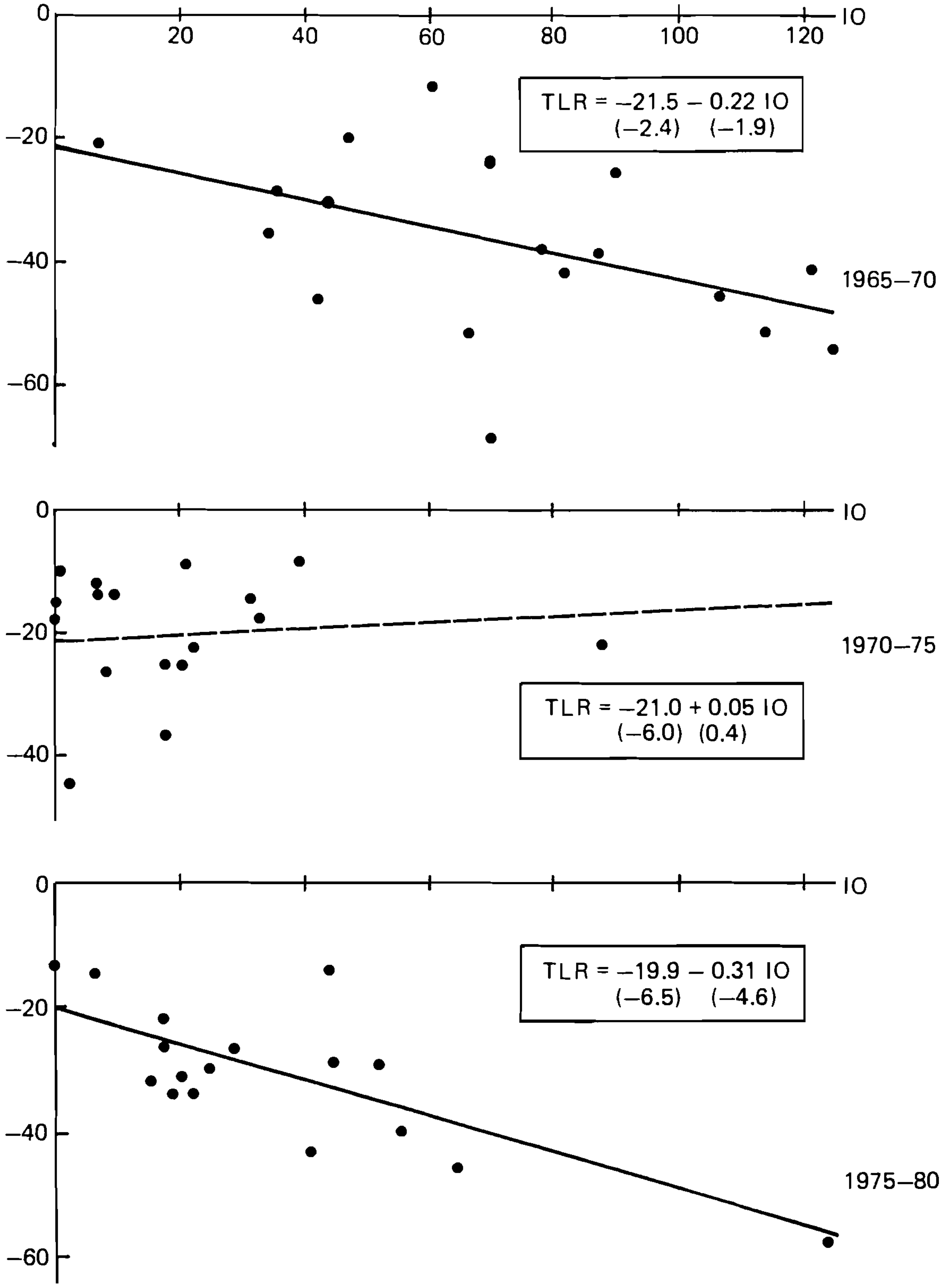


Figure 4 (continued)



trends of total and direct labor requirements, the changes in labor-intensity variability among sectors (see Figure 1), and the changes in relationships between economic growth and cost reduction (productivity increase) (see Figure 4) show that the first part of the 1970's may have been a turning point in long-term waves, connected with technological progress.

3. Three Types of Technological Progress

If the total labor requirements are disaggregated into three components - labor, material and fixed capital inputs (see equations (12-14)), then technological progress expressed in terms of productivity increase or total labor input reduction can be divided into three distinct types: direct labor saving, material-embodied labor saving and capital savings.

By using the method described in the first section and the 7 input-output tables for the post-war Japanese economy we can compare the relative importance of these three types of technological progress in different periods (see Table 4).

It is obvious that at any time during the post-war period (1951-1980) technological progress combined all the three types. But in each period one type usually dominated. Indirect material-embodied labor saving took place in all periods, becoming dominant in 1955-1965. The direct labor-saving type of technological progress played a growing role and accounted for the biggest share of total cost reduction in 1965-1970. The most important period of capital-saving on total cost (or labor requirements) reduction took place in the most recent period 1975-1980.

The first period (1951-1955) of technological progress belonged to the labor and material saving types. In 1955-1965 material-embodied saving dominated, but the role of labor saving was growing and in 1965-1970 direct labor saving took the first place among these types of cost reduction. In 1970-1975, when the first post-war energy crisis occurred, material-embodied labor saving became more important again. Finally, 1975-1980 was the only period when capital saving dominated.

TABLE 4

Rate of cost elements changes, % (L-labor, M-material, C-fixed capital inputs, *maximum reduction)

No. of Industry	1951-1955			1955-1960			1960-1965			1965-1970			1970-1975			1975-1980		
	L	M	C	L	M	C	L	M	C	L	M	C	L	M	C	L	M	C
1	-24*	+44	+39	-20	-29	-36*	-25*	-24	+7	-19	-21*	-4	-32	-35*	-18	-17	-15	-20*
2	-12	-41*	-30	-22	-48*	+5	-52*	-49	-11	-61*	-42	-21	-39*	+13	-22	-29	-33	-39*
3	+24	+21	+57	-10*	+24	+43	-30	-40*	-12	-38*	-38	-12	0	-18*	-8	-4	-31	-48*
4	-35*	+58	+75	-20	-32*	-31	-6	-34*	+2	-27	-31*	-17	-9	-31*	-5	-20	-35	-45*
5	-26	-37*	-10	-28	-57*	-45	-17	-33*	+3	-27	-34*	-24	-19	-39*	-18	-10	-34	-46*
6	-28	-36*	-8	-34	-50*	-22	-32	-40*	+5	-42	-44*	-40	-13	-60*	-45	-23*	+26	0
7	-41	-44*	-27	-41	-54*	-8	-43	-48*	-11	-47	-51*	-45	-11	-24*	+4	-25	-37	-51*
8	-33	-71*	-60	-4	-28*	+20	-37	-40*	-13	-47*	-47	-33	-22	-35*	-13	-14	-31	-52*
9	+12	-44	-54*	-24	-25*	+11	-43*	-42	-12	-39*	-37	-26	-6	-25*	-6	-28	-34	-38*
10	-20	-34*	-11	-39*	-17	+8	-17	-37*	-17	-55*	-43	-34	-15	-21*	-10	-45	-47	-53*
11	-24	-48	-52*	-63*	-29	+45	-22	-43*	-23	-46*	-46	-40	-21	-37*	-10	-47	-55	-61*
12	-24	-55*	-54	-46*	-25	+66	-41*	-38	-13	-38	-41*	-32	-13	-22*	-18	-43	-45*	-31
13	-10*	+68	+68	-15	-41*	-33	-35	-42*	-3	-42*	-42	-31	0	-40*	-21	-27*	-24	-26
14	-11	-43*	+5	-3	-41*	+17	-37*	-25	-22	-46*	-45	-27	-13*	-3	-11	-23	-40	-38*
15	-34*	+25	+46	-32	-63*	-50	0	-2*	+21	-24*	-16	-17	-38*	+31	-6	+13	-50*	-21
16	-22	-36*	+2	-27	-49*	-18	-24	-38*	-12	-34	-42*	-35	-44*	+36	-32	-8	-26	-42*
17	-24*	-12	+8	-41	-59*	+3	-26	-30*	-4	-39	-42*	-41	-18	+6	-24*	-22	-24	-54*
18	-25	-71*	-51	+14	-13*	+2	-10	-22*	+17	-25*	-22	-11	+2	+1	+6	-24	-33	-50*
number of asterisks	5	10	2	4	13	1	5	13	0	10	8	0	4	12	1	2	2	14
average	-27	-27	-9	-23	-32	-10	-30	-36	0	-40	-38	-22	-19	-26	-14	-19	-35	-50

Table 5. Structure of total cost of production, %

Cost Element	1951	1955	1960	1965	1970	1975	1970	1980/ 1951 ratio, %
Labor cost	44.7	44.5	46.5	47.3	46.2	47.4	53.3	119
Material cost	51.7	50.9	47.8	44.6	44.1	41.4	37.8	73
Fixed capital cost	3.6	4.6	5.7	8.1	9.7	11.2	8.9	245
Total	100	100	100	100	100	100	100	

As a result (see Table 5), the labor share in total cost grew in the 1950's, was stable in the 1960's up to 1975 and then grew again. The "material" share decreased during the whole period but with different rates and the "capital" share in total cost increased up to 1975 and decreased afterwards.

It is difficult to find oscillations in the shares movement looking at the table. But if we exclude time-trends, estimated regressionally, from the real values of the shares it is possible to find certain oscillations in deviations from the time-trends. The dynamics of such deviations is shown in Figure 5.

For the case of the material cost share one can determine the approximate period of oscillations which is equal to 20 years. The oscillations of the labor cost share look symmetrical to the first case, and it is difficult to determine the period for the case of capital cost share by using these limited data.

There were certain correlations between three types of technologcal progress in the industries. The comparison of the change rates (1951-1980) in labor (LR), material (MR) and capital (CR) savings is shown in Table 6.

For instance, the value of a direct labor requirement coefficient in agriculture in 1980 equals 21% of its value in 1951, the value of a material input coefficient in construction in 1980 equals 32% of its initial value, etc.

From the viewpoint of direct labor saving the best three industries were electrical machinery, mining and chemical, but

Figure 5. Deviations of shares of labor (L), material (M) and capital (C) costs in total cost from their time-trends, percent points (based on Table 5).

Table 6. 1951-1980 reductions in L, M and C (%) for 18 industries.

Industries	LR		MR		CR		Sum of
	Value	Rank	Value	Rank	Value	Rank	ranks
1. Agriculture	21	11	35	18	61	17	46
2. Mining	6	2	7	7	25	10	19
3. Construction	46	18	32	17	84	18	53
4. Food	26	16	22	15	54	15	46
5. Textile	23	14	5	4	17	4	22
6. Paper	13	6	5	5	25	9	20
7. Chemicals	7	3	3	3	17	3	9
8. Primary metals	14	8	3	1	11	2	11
9. Fabricated metal products	20	10	8	8	20	6	24
10. Nonelectric machinery	9	5	8	10	22	8	23
11. Electrical machinery	5	1	3	2	11	1	4
12. Transportation equipment	7	4	5	6	25	11	21
13. Other manufacturing	21	13	15	14	44	14	41
14. Trade	21	12	8	9	39	13	34
15. Finance and real estate	24	15	25	16	55	16	47
16. Transportation & communication	15	9	12	13	19	5	27
17. Public utilities	13	7	12	12	22	7	26
18. Services	44	17	10	11	28	12	40

the worst three were food, services and construction. From the material-embodied labor saving viewpoint the best ones were primary metals, electrical machinery and chemicals, and the worst ones were finance (plus real estate), construction and agriculture. And finally, from the capital saving viewpoint the best industries were electrical machinery, primary metals and chemicals. Finance, agriculture and construction can be regarded as the worst three.

On the whole the most progressive industries (minimum rank sum) in the Japanese economy were electrical machinery and chemicals. At the other extreme, construction and agriculture can be regarded as the least progressive industries.

The theoretical understanding of relationships between labor-material-capital savings (are they alternatives or complements?) might be aided by further analysis of the rank data shown in Table 6. The coefficients of rank correlation are as follows:

0.83 - between material and capital savings;

0.64 - between labor and material savings;

0.62 - between labor and capital savings.

This means that a growing saving of one factor usually leads to the same tendency in other factors and complementarity is stronger than competition.

The final topic concerns the reasons or determinants of predominance among one or other of the three types of technological progress. Of course, from the long-term viewpoint the relative prices of the three factors (labor, materials and fixed capital) as well as national availability of the resources are the important determinants of dominance of one or another mode of technological progress.

In 1960-1980 labor prices increased in Japan by 2 times, prices of materials by 2.5 times, and for capital goods by 1.6 times. This led to higher savings of material input and lower savings of capital input (see Table 5). The first real capital saving period took place in the second half of the 1970's. One of the reasons, presumably, was that capital goods prices and investment began to grow sharply in the 1970's, whereas prices had been relatively stable earlier.

The resources supply influenced these processes too. For example, "material"-saving dominated during the periods of the post-war reconstruction of the Japanese economy when it lost some colonial sources of raw materials. In 1970-1975, the period of a first severe energy crisis, a similar shift occurred. The 1965-1970 period emphasized direct labor-saving. This may be because the post-war flow of rural labor into the cities had largely come to an end, and the wage rate growth doubled. This would explain why labor-saving technological progress became dominant for a time.

It is possible to draw one final conclusion from the foregoing analysis of different types of technological progress. Besides long-term oscillations in the rate of technological progress as a whole the component elements of cost reduction--labor/material/capital savings -- have their own intermediate-term harmonics. These changes can be triggered by major external (international) market factors, such as the price of oil, or internal factors, such as demographic changes.

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