THE PRODUCTION FUNCTION FOR MANUFACTURING IN JAPAN

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I. *Introduction*

Since the first empirical derivation of the Production Function in 1928, there have been accumulated a plenty of achievements by P. H. Douglas and others. *The Theory of Wages*, 1934 and "Are There Laws of Production?" *American Economic Review, March*, 1948, both written by P. H. Douglas, can be taken as two main summaries of the results of measurements hitherto accomplished.

In Japan, Prof. Ohkawa[1] has obtained a satisfactory results in respect to the computation of agricultural Production Function, but satisfactory computations are still lacking in relation to the manufacturing sector. This small article, rewritten from my work[2] published in 1949 in Japanese, aims to compute the cross-section Production Function for Japanese manufacturing. Reference should be made to the recent work of the Institute of Economic Research of the Tōyō Bōseki (Oriental Cotton Spinning Company Ltd.),[3] which attempts particularly to compute the Cobb-Douglas Function in the cotton spinning industry under the direction of Prof. Iemoto.[4]

While the statistical results are embodied in a considerable volume, there have arisen many animated controversies around these computations. Durand[5] emphasized the necessity of dropping the inflexible assumption $k+j=1$ of Douglas. At the outset, Douglas' formula took the following form, $P=bL^{k}C^{1-k}$, where P, L, C means production, labor, and capital respectively, and b, k are the constants to be determined from the data. Durand insisted on the use of a formula $P=bL^{k}C^{j}$. There was also the

[1] Kazushi Ohkawa, *The Theory and Measurement of Food Economy* (in Japanese, Tokyo, 1945).

[2] M. Shinohara. *Employment and Wages* (in Japanese, Tokyo, 1949).

[3] *The Relative Contribution of Labor and Capital to Production,* — On the Measurement of Douglas Function in relation to the Japanese Cotton Spinning Industry.

[4] Hidetaro Iemoto, "To Foster Douglas' Production Function" (in Japanese), *Riron Keizaigaku* (*The Economic Studies Quarterly*), Jan., 1951.

[5] David Durand, "Some Thoughts on Marginal Productivity, with Special Reference to Prof. Douglas", *Journal of Political Economy*, Dec., 1937.

idea that we should follow cross-section studies rather than time-series studies, because time series data involve the influence of time trend such as the effects of technological changes etc.[6] These two criticisms were positively accepted by Douglas, and his later works followed these lines.

One may mention a third criticism made by Mendershausen,[7] which I think the most important one and, in a sense, fatal to the Cobb-Douglas Function. Mendershausen emphasized the statistical impasse which is called "multicollinearity". Theoretically, I cannot find any proper answer to such criticism, and cannot agree even with the vigorous defense of Prof. Iemoto[8] which was recently developed systematically.

Although I am in a degree a theoretical nihilist on this point, yet I venture to compute the Production Function as if I were a confirmed Douglasian. There exist sufficient data that k or $\frac{k}{k+j}$ was in a close agreement with the actual relative share of wage- and salary earners. My chief concern is that there could not be the close correspondence above mentioned in Japanese Manufacturing, what with monopoly enterprises and exploited workers having few unions in the prewar period. Although some computed the relative share of labor which almost perfectly agrees with k or $\frac{k}{k+j}$, I think there is something erroneous in such a calculation. My alternative calculations show that, although labor's share was much less than $\frac{k}{k+j}$ or k, the intertemporal movements of both were parallel, with the exception of upgrades of the trade cycle, during which the degree of monopoly would be lessened.

Starting as a Douglasian, I shall add another contribution to the already accumulated results of the Cobb-Douglas Function. Whether these results are statistically significant or not, particularly in the light of multicollinearity, is not dealt with in this tentative work. A test in this regard would need another work.

II. *Why we adopt the Cross-Section Method?*

We adopt here the method of cross-section study. The reasons why we did not follow the time-series analysis are as follows:

First, in the time-series analysis, the product P involves other influences from time trends, such as technological changes, besides those from labor L and Capital C. Consequently, in order to avoid historical disturbances,

[6] David Durand, *op. cit.*

[7] Horst Mendershausen, "On the Significance of Prof. Douglas' Production Function", *Econometrica*, April, 1938.

[8] H. Iemoto, *op. cit.*

it is quite likely we may prefer the cross-section or inter-industry analysis at any particular time.

The second reason derives mainly from statistical materials. As regards product P in terms of time series, we can do no other than use the index of industrial production. But the index of production based on fixed weight would have great shortcomings, particularly in periods like the 1930's and 1940's when the industrial structure under-went a sharp change, the production of heavy industries such as machinery and metals expanding, whilst the production of light industries, e.g., the textile industry, declining.

Thirdly, P, L, C from 1933 on, made a parallel change, so that the parameters k and j in the production function are destined to become indeterminate. If we venture to compute them, it is highly probable that a few random errors would determine the values of k and j. In this case the menace of multicollinearity naturally falls upon the time-series analysis. Our tentative calculation along the time-series studies did not indicate a satisfactory result, e.g., in many cases k or j took minus values.

Such being the case, our preference of the cross-section method is inevitable. Fortunately, the statistical data of P, L, C between industries or groups classified as to size of factories by number of production workers, are available from "Census of Manufactures" (Kōgyō Tōkeihyō), by the Ministry of International Trade and Industry but we cannot deny that the cross-section method too has difficulties, e.g., how much significance the regression curves which are fitted, have in spite of the characteristic differences between industries. Nevertheless, such difficulties would be unavoidable in all research work to some degree.

III. *Statistical Data*

In the cross-section study, the data of "Census of Manufactures" is available in two manners. One is the method in which the formula $P=bL^k C^j$ is fitted among various industries or firms, and another is the method in which this formula is fitted among groups of firms classified as to size by number of production workers. Although the former has been used by Douglas and others, the latter was adopted in our analysis. There is not a particular reason for this adoption, but we are sure that, while according to the classification merely made by industries various scales of factories are mixed into the respective industries on the one hand, the comparison among relatively homogeneous factories as to number of workers becomes possible in the case of the classification by the scales of factories on the other hand. The latter has the drawback that the number of samples are limited to 9, but involves the advantage mentioned above.

These data were attached as an appendix to the end of this article.

The exposition of these data is as follows:

(1) The figures mentioned as products P are not net amounts but gross amounts which include the value of materials, fuels, electricity and gas used as well as depreciation charges, etc. If the ratio of net products to gross products is not uniform among the various scales of factories, the use of gross products by these factories enhances the inaccuracy by so much.

(2) The workers L in this case were defined as the number of manual or production workers, excluding clerical and technical staff. There is no special reason for this definition.

(3) As for capital C, we fail to find the fixed and liquid capital in money values in "Census of Manufactures". There are included, however, statistics of the number and actual horse power of prime movers, with classifications of used and idle horse power. In our computations, we regarded as capital this actual horse power in use. This procedure may have some defects, but the prevalent procedures which use as capital the fixed and liquid capital in money terms, present more difficult problems, such as the valuation of capital and the inclusion of idle equipment. Our method has no such disadvantages.

(4) The figures of P, L, C used are those excluding the gas and electricity industries. The reason why these are excluded are the following two:

(a) The products enumerated in "Census of Manufactures" in relation to gas and electricity are limited to by-products. (b) As actual horse power in the electricity industry in the 1930's amounts to about 50% of all industries, we may arrive at a better result if we limit the range of studies to the manufacturing industries.

(5) As far as 1941 is concerned, we avoid computations consciously, because we found great errors in the figures on actual horse power of prime movers in operation. Table 1 shows that while from 1940 to 1941 the number of prime movers did not change too much, actual horse power revealed significant changes in some industries; veneer 100 fold, paper 60 fold, cotton spinning, and iron refining and basic ferrous manufacturing 7 times. These inconsistent figures show the unreliability of horse power statistics in 1941.

Table 1. Apparent Errors in "Census of Manufactures"

Scale of factories	Industries	Number of prime movers in operation		Horse power of prime movers in operation	
		1940	1941	1940	1941
Production Workers 1000 and over	Iron refining and basic Ferrous manufacturing	31,417	33,985	H.P. 1,400,254	H.P. 10,216,907
	Paper	1,634	2,517	86,722	5,157,482
Production Wokers 200–500	Cotton spinning	10,993	11,142	83,944	556,127
	Veneer	210	284	1,322	142,221
	Chemical industry	18,013	18,447	336,817	674,286

There seems to be a further error in the figures of the metal industries in 1934, and therefore we did not compute the production function in that particular industry, but the calculation of parameters of manufacturing as a whole in the same year was made with the idea that the errors in the component part will not too much influence the aggregate figures.

(6) We compute k and j during 13 years, 1929–42, except 1941, in relation to the whole manufacturing. As to individual industries, however, we have chosen 5 years, 1931, 1934, 1936, 1939 and 1942, and have limited ourselves to 4 industries, i.e., textiles, metal, machinery and equipment, and chemicals.

(7) The object of our study are *private* factories employing five or more workers. It does not include those under government or public management.

(8) Data of P, L, C are classified as to size of factories by number of employed manual workers, and the number of samples is only 9 respectively. But, as referred to already, the defect of the small number of samples may be compensated by the advantage that each group consists of comparatively homogeneous factories with regard to the number of employed workers.

IV. *The Production Function for the Whole of Manufacturing*

Gross products, production workers and actual horse power of prime movers in use representing P, L, C, respectively, which are all classified by scale of factories, let us fit the next formula

$$P = bL^k C^j.$$

and obtain the coefficients of partial elasticity of production with respect to labor ($k=\frac{\partial \log P}{\partial \log L}$), as well as with respect to capital ($j=\frac{\partial \log P}{\partial \log L}$). If this production function is a homogeneous function of the first degree, we obtain $1=\frac{\partial P}{\partial L}\cdot\frac{L}{P}+\frac{\partial P}{\partial C}\cdot\frac{C}{P}$, and therefore, $P=\frac{\partial P}{\partial L}\cdot L+\frac{\partial P}{\partial C}\cdot C$. If the prices of factors of production are equal to the values of their marginal productivities, the value of products will be all distributed among factors and leave no residual part. The value of products will be distributed among labor and capital according to the relative proportion of k and j. In the case of increasing and decreasing returns in turn, the relative shares of production factors will correspond to the proportion of $\frac{k}{k+j}$ and $\frac{i}{k+j}$. These are nowadays too well known.

Table 2.

	log b	k	j	$k+j$	$\frac{k}{k+j}$
1929	0.8091	0.7322	0.2210	0.9532	0.7681
1930	0.7118	0.7376	0.2205	0.9581	0.7699
1931	0.7412	0.7843	0.1627	0.9470	0.8282
1932	0.5111	0.7503	0.2471	0.9974	0.7523
1933	0.9235	0.4988	0.4296	0.9284	0.5373
1934	1.1040	0.4596	0.4361	0.8957	0.5131
1935	0.7526	0.5392	0.4261	0.9653	0.5586
1936	0.5229	0.5771	0.4320	1.0091	0.5719
1937	0.9723	0.5215	0.4165	0.9380	0.5560
1938	0.6707	0.6298	0.3700	0.9998	0.6299
1939	0.8527	0.6368	0.3406	0.9774	0.6515
1940	1.3087	0.6200	0.2841	0.9041	0.6858
1941	—	—	—	—	—
1942	1.3055	0.6201	0.3106	0.9127	0.6598

The results of our computations are shown in Table 2. The graphical representation of actual and theoretical values of log P was made in Chart 1.

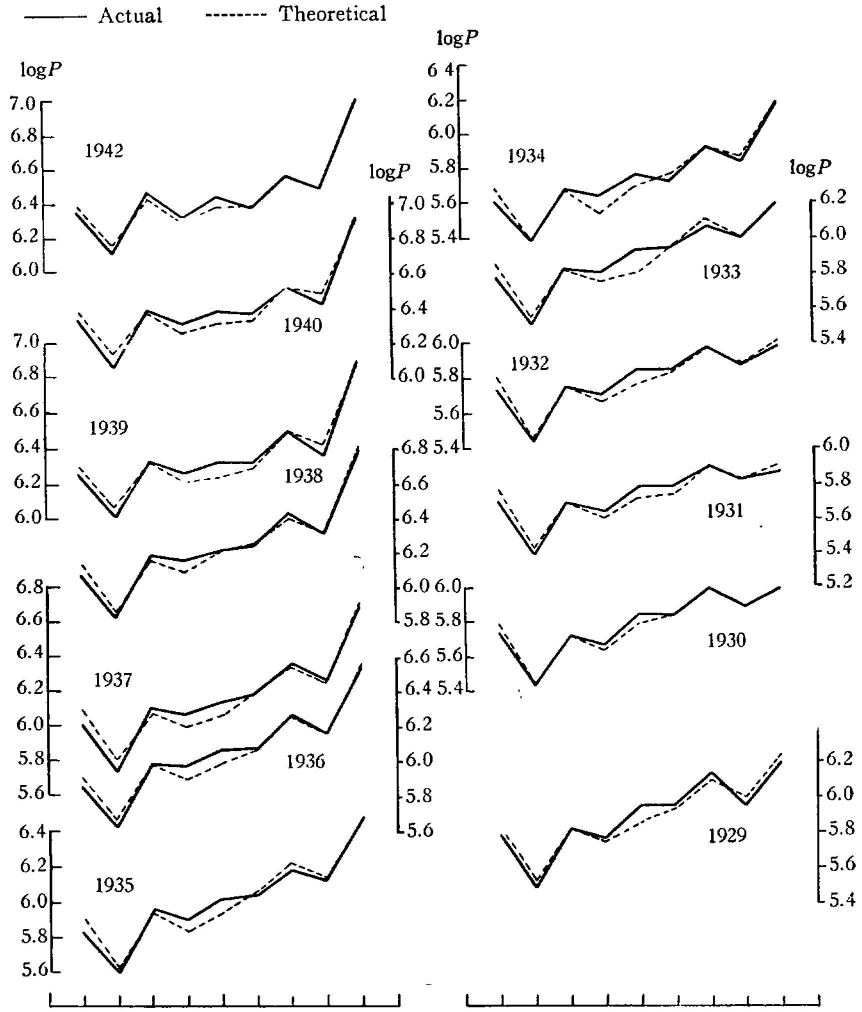
As seen from Chart 1, the deviations of theoretical and actual values of log P are very trivial. In 1930, when the correspondence between the two appears to be most intimate, the coefficient of multiple correlation amount to 0.9817, and even in 1933, when the deviations appear to be largest, the coefficient remains at 0.9717. Consequently, we can say the coefficients of multiple correlation during these 13 years will range from 0.97 to 0.98.

We can analyze the results as computed as follows:

(1) While in smaller scale and larger scale factories the theoretical values of log P are larger than the actual values, the theoretical values are smaller in the intermediate scale of factories than the actual values. According to the research work of the Statistical Bureau of Cabinet in 1931, however, the ratio of net products to gross products was 33.23% in smaller scale factories, 29%, in intermediate scale factories, and 35.85% in larger scale factories. Therefore, if we use net products as P in place of gross products, we may apparently derive better results, thus reducing the gap between the theoretical and actual values of log P.

(2) There remains another problem, i. e., whether the parameters k and j in the production function will actually coincide with the relative shares of labor and capital. There are two famous estimates on the relative sharing of income from Japanese manufacturing. One is that of

Chart 1. Theoretical and Actual Values of log P



Ш. ЛИФ [9] to which Japanese Marxian economists frequently refer, —— to the effect that the highest rate of exploitation (or surplus value) during the thirties in Japan amounted to 380%. This means the ratio of capitalist income to labor income $(\frac{S}{V})$ is 3.8 and the labor's share is 28%. Another is that of Dr. Hijikata,[10]—— which states that labor's share in the

[9] Ш. ЛИФ, ВОЙНА И ЭКОНОМИКА ЯПОНИИ, 1940 (Japanese Translation, p. 284).

[10] Dr. Hijikata, *The Structure of National Income* (in Japanese, Tokyo, 1933), Chapter 5.

manufacturing income (the proportion of wages and salaries) was 78% in 1926–28, 76% in 1929, and 79% in 1930.

If Dr. Hijikata's estimate is correct, k or $\frac{k}{k+j}$ would approximately coincide with labor's share, —— that is to say, $\frac{k}{k+j}$ in 1929 and 1930 was 0.7681 and 0.7699, while labor's share was 76% and 79%. Thus Hijikata's estimate is much higher than Ш. ЛИФ's estimate which seems to me fantastically low. Are both estimates wrong? Or which is wrong?

We find that in Ш.ЛИФ's calculation, labor income (V) does not include salaries income and that in the calculation of net income ($V+S$) expenses on fuels, electricity, gas etc., are not excluded, thus producing an excessively high rate of exploitation and a labor share which is much too low. On the other hand, it was recently suggested by Prof. Yuzo Yamada [11] that in Hijikata's estimate there was an overestimate of employees which was the basis of his calculation of labor income. Dr. Hijikata's statistical procedure depends upon other figures than "Census of Manufactures". He estimated wages and salaries as well as entrepreneur and capitalist income respectively from separate sources, thus obtaining a total manufacturing income by summation of these covering all manufacturing, including establishments employing fewer than 5 workers.

If these two estimates are both questionable, we lose the appropriate criterion with which k or $\frac{k}{k+j}$ is to be compared. We are, therefore, compelled to recompute the relative shares of labor on the basis of "Census of Manufactures", introducing some modifications.

The results are summarized in Table 3. If these results are correct, the estimate of Ш. ЛИФ would be an under-estimate and that of Hijikata an over-estimate. It should be noted that labor's share in the Japanese manufacturing was very low compared with other countries, and this fact was likely the basis of the very rapid rate of capital accumulation and production experienced in the prewar period.

In Chart 2, $\frac{k}{k+j}$ as well as k are compared with labor's shares $\frac{W}{Y}$. This graph seems to indicate the following three points:

(a) $\frac{k}{k+j}$ or k is larger than $\frac{W}{Y}$ during all years in question. This appears to be the consequence of lower wages having been paid than the marginal productivity of labor. The fact that labor unions before and during the war were extremely weak or negligible has perhaps enhanced the monopolistic attitude toward labor.

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[11] Yuzo Yamada, *The Estimated Data on National Income in Japan* (in Japanese, Tokyo, 1951), pp. 76–77.

Table 3.

(Unit : *Million Yen*)

	Gross product a	Expenses on raw materials, fuels, etc.[1] b	Gross income c [a−b]	Depreciation charges[2] d [a×4%]	Other expenses[3] e [a×5%]	Net income f [c−d−e]	Wages payroll g	Salaries payroll[4] h [g×20%]	$\frac{g+h}{f}$
1929	7,739	4,415	3,324	310	387	2,627	747	149	34.1%
1930	5,945	3,864	2,081	239	297	1,545	641	128	49.8
1931	5,196	3,286	1,910	208	260	1,442	549	110	45.7
1932	5,970	3,623	2,347	239	299	1,809	560	112	37.1
1933	7,857	4,972	2,885	314	393	2,178	636	127	35.0
1934	9,359	6,056	3,303	374	468	2,461	777	155	37.9
1935	10,816	7,052	3,764	433	541	2,790	863	173	37.1
1936	12,236	8,138	4,098	489	612	2,997	964	193	38.6
1937	16,328	11,222	5,106	653	816	3,637	1,144	229	37.8
1938	19,620	12,769	6,851	785	981	5,085	1,433	287	33.8
1939	24,793	14,727	10,066	992	1,240	7,834	1,947	389	29.8
1940	27,093	15,831	11,262	1,084	1,355	8,823	2,279	456	31.0
1941	30,458	17,224	13,234	1,218	1,523	10,493	2,532	506	28.9
1942	32,039	17,000	15,039	1,282	1,620	12,137	2,919	584	28.9

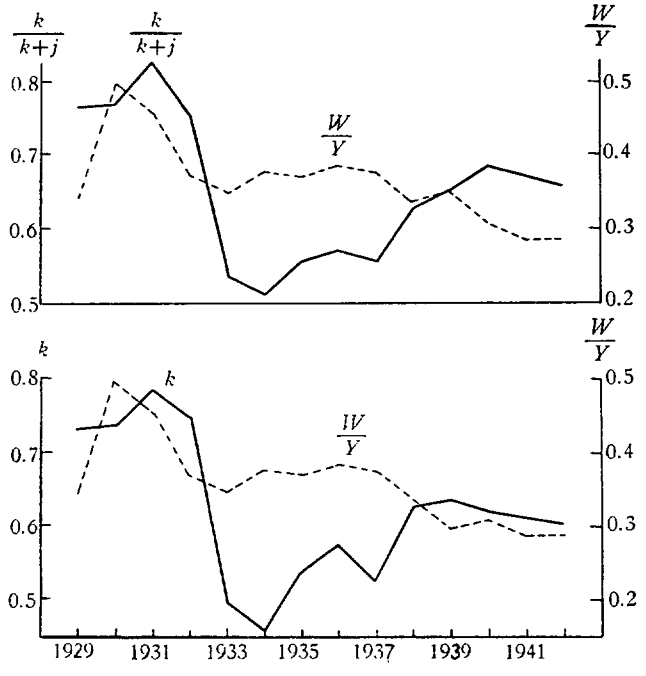
[1] Expenses on raw materials, fuels, etc. include expenses on electricity and gas supplied from other firms. The latter computation is based on the estimate of the average unit price.

[2] The rate of depreciation charges was estimated on the basis of Analysis of Financial Status of the Japanese Industry by the Mitsubishi Institute of Economic Research.

[3] Other expenses denote expenses on insurance, storage, advertising, carriage and other miscellaneous expenses. The estimate rate 5% is derived from "Research on Manufacturing Concerns", 1932, by the Ministry of Commerce and Industry.

[4] Salaries payroll rate 20% was estimated from Hijikata, *The Structure of National Income* (In Japanese, Tokyo, 1933), p. 234, Table 14.

Chart 2.



(b) If, however, the recovery period of the trade cycle, 1933–37 is separately considered, k and $\frac{W}{Y}$ will indicate parallel movements during the remaining 9 years. That k rather than $\frac{k}{k+j}$ indicates closer covariation with $\frac{W}{Y}$, may be a verification that the results of increasing or decreasing returns as a whole will be imputed to the capitalist's side.

(c) Thirdly, it may be said that cyclically k or $\frac{k}{k+j}$ was more responsive to short-run economic fluctuations, as far as the range of the observed period is concerned. It is, of course, difficult to explain why the parallel movements of k and $\frac{W}{Y}$ were lacking during the prosperity phase 1933–37. But the theory that the degree of monopoly decreases during the upswing of cycles,[12] may explain why the difference between k and $\frac{W}{Y}$

[12] Joan Robinson, "Review of R. F. Harrod, The Trade Cycle", *Economic Journal*, Dec., 1936.
M. Kalecki, *Essays in the Theory of Economic Fluctuations* (London, 1939), Chap. 1.

was narrowed during this period.

At any rate k and labor's share do not coincide. There are strong forces at work, however, which will in the long run make the movements of k and labor's shares parallel. Nevertheless, these long-run tendencies were disrupted in the prosperity phase cyclically. Moreover, these parallel movements do not amount to perfect coincidence. The differences (k minus $\frac{W}{Y}$) had the tendency to be eventually 0.3 from the observation of 9 years 1929–32 and 1938–42. This seems to be long-term level of the degree of monopoly prevailing during these years in Japan.

V. *Production Functions for Particular Industries*

We shall commence our next task, the measurement of Production Functions for four industries in Japanese manufacturing. The data used is, as before, "Census of Manufactures". Using the figures on P, L, C classified as to size of factories by number of manual workers, k and j would be computed in relation to the four manufactures, —— textiles, metals, machinery and equipment, and chemicals. Table 4 contains these results, almost everyone of which is a fairly good fit, but the textile industry indicates the best fit.

As already mentioned, we avoided computation as regards the metal industry in 1934, because of a few errors in the data. At any rate, if the figures of Table 4 are economically significant, the following observations will be possible.

Table 4.

	Textile industry		Metal industry		Machinery and equipment industries		Chemical industries	
	k	j	k	j	k	j	k	j
1931	0.4499	0.3708	0.5317	0.3628	0.5201	0.2967	0.3931	0.3385
1934	0.5610	0.5892	—	—	0.5137	0.4785	0.2927	0.3966
1936	0.8187	0.3651	0.5517	0.5759	0.4425	0.4749	0.3054	0.3811
1939	0.5485	0.3031	0.5242	0.5339	0.0726	0.7879	0.2304	0.5486
1942	0.8320	0.1845	0.2586	0.6596	−0.5980	1.3095	0.2774	0.4162

The bottom of the depression in the thirties in Japan was in 1931, and thereafter came a sharp rise. From 1937 on, ensued the wartime economy, and the stage of full employment was reached in 1939 or 1940. Henceforth, in order to accelerate the rapid expansion of munition industries, a radical reallocation of human resources from non-munition industries took place, and there was an increasing scarcity of manpower in the textile industry, etc., and a relative scarcity of equipment compared with labor in the metal and machinery industries etc.

In the textile industry k was gradually larger, and j, on the contrary, became smaller year by year. This was a necessary consequence of the superfluity of capital equipment and the accelerated scarcity of labor. In the machinery and equipment industry, on the other hand, k was close to zero in 1939, and turned into minus value in 1942. This fall was more severe compared with k (0.2586) of 1942 in the metal industry. The chemical industry seems to have stood in an intermediate position between the machinery and textile industry.

It is not necessary, however, that k and j in the four manufacturing industries indicate close covariations with the actual relative shares respectively. In the war-time period in particular, wages were controlled, so that the relative scarcity of labor and capital could not be reflected directly into relative shares as would have occurred under perfect competition.

We have no accurate data in preparation which indicates the actual course of the relative shares of these industries. However, we can attempt the following approximation, by examining the process of wages in each industry or the changes of the inter-industry wage structure.

Chart 3.

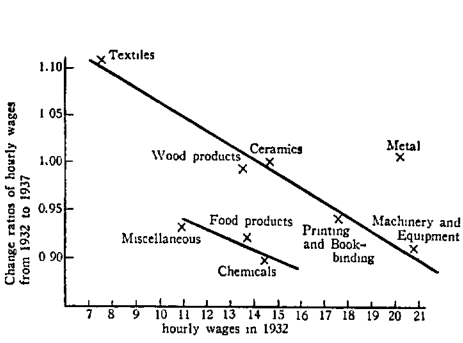
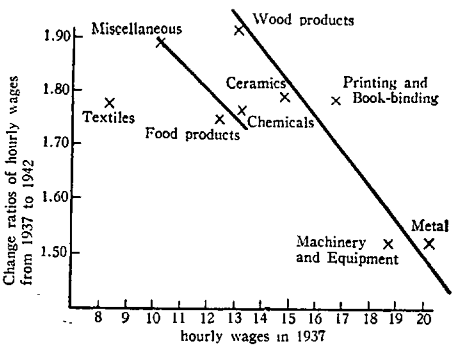


Chart 4.



In Chart 3, the hourly wages of 1932 in each manufacturing industry are represented by horizontal coordinates and their change ratios from 1932 to 1937 by vertical coordinates. In Chart 4, the hourly wages of 1937 and their change ratios from 1937 to 1942 are depicted in the same manner. These two charts are confiled from my separate study[13] of the inter-

[13] M. Shinohara, "Interindustry Wage Structure in Japan" (in Japanese), *Keizai Kenkyu* (*The Economic Review*), July, 1951.

industry wage structure, and these charts reveal the higher the level of wages in each industry, the lower the rates of wage increases in the upswing of the business cycle, and vice versa, —— i. e., that the wages of unskilled workers are more responsive to cyclical fluctuations than the wages of skilled workers. We could not obtain a single regression curve, but it deserves to be emphasized that in Chart 3 as well as in hart 4, both regression lines have almost the same industries scattered along them,—— the metal industry is the only exception in Chart 3, and the textile industry is the only exception in Chart 4.

By making a comparison between Chart 3 and Table 4 we find an interesting connection between relative changes of hourly wages and the behavior of k in each industry. Although in Table 4 the coefficients k of 1932 and 1937 are not computed, we assume that we can roughly compare the figures of 1931 and 1936 in Table 4 with the results in Chart 3 between 1932 and 1937. We can there see a high rank correspondence between changes of k and inter-industry wage changes.

	Textile industry	Metal industry	Machinery and equipment industry	Chemical industry
k in 1931	0.45	0.53	0.52	0.39
k in 1936	0.82	0.55	0.44	0.305
relative changes of hourly wages from 1932 to 1937	1.11	1.01	0.91	0.90

In the same way, inter-industry wage changes between 1937 and 1942 can be compared with the behavior of k from 1936 to 1942. In this case too, there is a strong rank agreement between changes of k and the alteration of inter-industry wages.

	Textile industry	Metal industry	Machinery and equipment industry	Chemical industry
k in 1936	0.82	0.55	0.44	0.305
k in 1942	0.83	0.26	−0.60	0.28
relative changes of hourly wages from 1937 to 1942	1.77	1.53	1.52	1.75

However, the above is merely a relation between the changes of hourly wages and the behavior of k. It was not considered in terms of comparison with the value productivity per man-hour. It is the relative share or $\frac{\text{Average hourly earnings of all employees}}{\text{the net output per man-hour}}$ that must be compared with k. Consequently, we try to examine the correlation between wages per man-hour and net output per man-hour. The former are not the average earnings of both wage-earners and salary-earners, but we can by such a comparison test the parallel changes of k and their ratios. The tentative graphical representation of wages per man-hour and net output per man-hour, indicates that in general during the downswing and the early phase of recovery, they are under a negative correlation. But exclusive of the years of negative correlation, we can compute the following relations from the residual positively correlated parts of the data.

Machinery and equipment industry (1935–42)	$Y= 0.2798+0.5443X$	……(1)
Metal industry (1933–42)	$Y=-0.1365+0.7407X$	……(2)
Chemical industry (1934–42)	$Y=-1.0019+1.0483X$	……(3)
Textile industry (1932–33, 1938–42)	$Y=-0.4433+0.8966X$	……(4a)
(1938–41)	$Y=-1.1956+1.3500X$	……(4b)

, where Y = hourly wages, X = productivity per man-hour.

Inasmuch as wages and productivity are in terms of current value, it is quite likely that a spurious correlation will be involved owing to the changing value of money. But an examination of the parameters given in the regression equations of the four industries, will reveal the relation between changes of productivity and those of wages, i. e., the alteration of the relative shares.

The reason why two equation are fitted in the textile industry only are as follows : i. e., the regression curve of that industry is particularly curvilinear and the scatter point 1942 exceptionally deviates to the right from the regression, in spite of the fact that almost straight lines are valid in respect to other industries. Therefore, if we fit a straight line through the other scatter points, excluding 1942 and 1933–34, we obtain a linear form, so that the dominant tendencies during war time will be more illuminating.

The rank of coefficients thus obtained from (1)-(3) and (4b) equations perfectly coincide not only with the rank of k in 1942, but also with the ranks of rates of alteration of k from 1936 to 1942.

VI. *Conclusion*

The above results, as a matter of fact, were not tested by bunch maps. I believe some of the cases above computed will be statistically insignificant owing to multicollinearity. Consequently, it might be somewhat hasty to draw conclusions from our computed results.

However, anyone will confirm the long-run parallel between k and the relative share of labor and capital in the light of our analysis already conducted, notwithstanding the non-existence of a perfect coincidence. If I had been an enthusiastic Douglasian, I would have defended the theoretical validity of the Cobb-Douglas Function on the ground of those empirical findings, but I am not confident enough to do so.

Be that as it may, it is worth while to keep in mind that the relative shares of labor in Japanese manufactures were considerably lower than k computed. This fundamental fact reflects not only the extremely monopolistic position of private enterprise as compared with the body of laborers, but also the special characteristics of the past Japanese economy in which the farm area, having a lower standard of living than the urban districts, supplied cheap labor to the latter. These circumstances enabled business firms to realize a high rate of capital accumulation, which fostered the prominent tempo of production expansion pointed out by Colin Clark.

Other institutional factors than the marginal productivity would evidently have exerted a strong influence upon the distribution of income in Japan, but it cannot be denied that the influence of productivities of factors also was not negligible. This is a conclusion at which I have finally arrived as an optimistic Douglasian, but I am obliged to cast serious doubts as to the statistical validity of these results. The failure to eliminate the above duality is a dilemma difficult enough to overcome.

Appen-

(Whole Manufacturing)

Statistical data of *P, L, C*

Scale of factories by number of manual workers	(Unit)	5—10	10—15	15—30
1929 Value of gross products	million yen	620	306	660
Manual workers	thousand	198	92	186
H. P. in use of prime movers	thousand H. P.	149	76	178
1930 Value of gross products	million yen	533	270	528
Manual workers	thousand	206	92	180
H. P. in use of prime movers	thousand H. P.	167	71	151
1931 Value of gross products	million yen	506	249	499
Manual workers	thousand	211	94	175
H. P. in use of prime movers	thousand H. P.	169	74	146
1932 Value of gross products	million yen	550	275	564
Manual workers	thousand	220	99	194
H. P. in use of prime movers	thousand H. P.	169	77	145
1933 Value of gross products	million yen	591	326	660
Manual workers	thousand	232	108	212
H. P. in use of prime movers	thousand H. P.	173	81	158
1934 Value of gross products	million yen	651	380	773
Manual workers	thousand	254	122	250
H. P. in use of prime movers	thousand H. P.	183	87	185
1935 Value of gross products	million yen	665	396	913
Manual workers	thousand	258	134	273
H. P. in use of prime movers	thousand H. P.	186	92	202
1936 Value of gross products	million yen	714	422	966
Manual workers	thousand	263	150	305
H. P. in use of prime movers	thousand H. P.	176	101	209
1937 Value of gross products	million yen	1,004	554	1,305
Manual workers	thousand	317	165	325
H. P. in use of prime movers	thousand H. P.	247	125	241
1938 Value of gross products	million yen	1,183	666	1,581
Manual workers	thousand	322	172	341
H. P. in use of prime movers	thousand H. P.	271	131	267
1939 Value of gross products	million yen	1,752	1,045	2,161
Manual workers	thousand	437	252	430
H. P. in use of prime movers	thousand H. P.	296	177	336
1940 Value of gross products	million yen	2,158	1,148	2,476
Manual workers	thousand	451	237	429
H. P. in use of prime movers	thousand H. P.	328	180	353
1941 Value of gross products	million yen	2,264	1,342	2,935
Manual workers	thousand	388	219	415
H. P. in use of prime movers	thousand H. P.	345	202	432

The above figures exclude the electricity and gas industries.

dix I.

classified by scale of factories

30—50	50—100	100—200	200—500	500—1000	1000 over
583 147 163	879 193 212	888 190 471	1,376 247 1,174	884 206 709	1,542 360 1,322
468 139 139	711 194 212	703 190 458	976 244 863	774 189 718	982 240 886
439 139 136	610 186 191	616 172 327	822 239 626	679 195 731	740 233 800
511 152 141	694 192 183	701 190 321	949 234 547	750 189 527	974 256 718
643 168 150	853 209 203	870 200 327	1,277 267 615	1,009 209 474	1,626 267 847
711 189 163	926 233 221	865 217 340	1,378 258 669	1,136 230 569	2,449 403 1,548
804 210 166	1,047 255 238	1,147 238 451	1,559 283 816	1,360 244 545	2,924 465 1,903
958 242 188	1,103 262 269	1,196 246 467	1,852 313 835	1,472 256 730	3,484 547 2,298
1,198 255 210	1,383 263 280	1,541 260 626	2,356 344 945	1,870 275 735	5,118 723 3,266
1,487 276 250	1,659 274 538	1,802 291 636	2,735 375 1,019	2,094 303 947	6,403 852 3,488
1,840 316 297	2,140 314 347	2,155 311 518	3,235 411 1,281	2,387 331 1,172	8,080 971 3,760
2,075 304 303	2,428 324 408	2,340 305 523	3,388 405 1,371	2,727 348 1,356	8,363 1,027 4,340
2,173 275 351	2,774 319 521	2,436 276 711	3,714 400 1,310	3,131 312 1,167	11,271 1,306 4,772

Appendix II.

(Four particular industries)

Statistical data of *P*, *L*, *C* classified by scale of factories

Scale of factories by number of manual workers			5—10	10—15	15—30	30—50	50—100	100—200	200—500	500—1000	1000 over
1931	Textiles	*P*	115.2	56.6	142.4	118.6	181.8	185.5	296.0	374.7	455.9
		L	62.1	29.0	67.1	61.5	102.5	110.7	161.0	151.5	153.3
		C	26.0	11.3	31.5	26.2	42.2	52.9	120.5	180.9	396.5
	Metals	*P*	34.0	16.7	39.3	36.1	45.8	61.0	59.0	70.0	69.5
		L	13.5	6.9	12.8	9.0	8.9	8.3	8.7	8.0	8.2
		C	10.8	6.3	14.2	14.1	18.6	37.9	65.4	72.4	68.2
	Machinery and equipment	*P*	34.5	17.8	32.6	32.8	40.7	49.8	94.0	65.8	129.9
		L	19.7	9.0	15.2	12.4	13.1	13.5	18.1	16.0	41.6
		C	10.3	4,8	11.6	10.0	12.9	23.2	82.3	64.5	165.3
	Chemicals	*P*	50.6	31.1	77.3	63.2	132.8	123.4	173.1	102.5	62.5
		L	8.1	5.2	12.8	11.7	18.4	14.7	21.4	11.0	19.2
		C	19.1	8.8	22.4	26.6	54.1	78.5	197.8	197.0	56.5
1934	Textiles	*P*	142.9	89.8	212.2	191.5	264.8	267.7	377.0	566.4	1,055.5
		L	69.9	37.6	91.1	75.1	104.4	111.0	144.3	148.4	187.5
		C	30.7	16.6	39.2	31.1	43.8	41.5	82.9	183.7	362.8
	Machinery and equipment	*P*	47.4	30.0	77.4	68.6	85.3	108.0	119.2	138.3	405.1
		L	28.6	15.4	30.9	23.8	26.1	25.0	29.2	29.4	106.2
		C	12.6	6.7	14.0	12.1	23.4	21.5	36.2	53.5	244.7
	Chemicals	*P*	68.2	40.3	100.8	121.8	187.7	214.2	327.0	173.9	247.1
		L	10.2	6.5	16.2	17.1	23.1	22.2	26.1	19.0	51.9
		C	14.2	9.4	29.1	44.6	59.5	80.1	204.3	155.9	293.9
	Textiles	*P*	148.0	104.0	258.3	242.0	302.3	323.6	503.0	660.2	1,113.4
		L	68.5	44.6	105.5	89.8	107.8	108.1	156.3	151.9	195.3
		C	32.2	19.3	45.4	38.8	51.8	59.6	115.5	241.8	495.7

1936	Metals	P	54.4	46.4	135.9	139.1	120.6	157.8	230.3	217.6	1,106.8
		L	21.9	16.1	35.8	23.7	22.9	20.5	22.9	23.1	59.9
		C	14.5	10.9	27.8	29.0	34.9	38.9	84.4	128.1	764.3
	Machinery and equipment	P	56.0	42.5	100.2	104.8	130.4	134.4	238.6	207.7	701.8
		L	33.2	21.3	43.6	37.1	37.1	34.7	39.2	39.8	171.0
		C	15.9	9.3	20.0	18.8	25.9	29.4	41.2	63.3	374.9
	Chemicals	P	87.4	48.1	137.6	145.7	242.0	276.1	430.0	313.1	430.9
		L	11.2	7.1	20.4	20.1	25.6	26.1	37.6	28.2	97.2
		C	15.4	12.1	29.4	39.8	68.3	95.7	241.5	260.1	616.2
1939	Textiles	P	375.7	240.9	484.2	370.9	441.7	441.1	710.1	789.5	959.8
		L	120.2	69.7	125.3	89.9	95.2	102.0	151.8	153.8	159.4
		C	46.7	28.7	62.8	48.5	61.0	69.3	154.2	336.8	438.0
	Metal	P	157.2	122.2	304.8	301.6	255.2	282.9	472.1	520.6	3,164.3
		L	33.5	24.2	47.9	35.6	31.1	29.5	44.3	37.7	161.4
		C	28.6	23.2	53.4	51.0	48.1	65.6	140.9	218.3	1,323.2
	Machinery and equipment	P	177.6	149.2	372.8	370.7	445.7	425.2	571.1	475.7	2,604.1
		L	64.8	46.8	90.5	75.8	85.3	84.1	106.5	83.9	493.9
		C	37.3	27.5	55.7	55.8	60.6	75.4	105.1	97.3	758.5
	Chemicals	P	171.7	127.5	293.0	269.5	433.4	499.0	777.9	456.7	1,246.6
		L	23.2	16.7	30.6	27.6	31.7	38.8	54.0	37.0	137.5
		C	20.3	15.8	46.3	51.0	88.1	134.0	394.7	407.9	1,183.3
1942	Textiles	P	401.0	213.1	437.5	302.7	421.3	371.0	707.7	539.0	576.0
		L	89.6	47.2	88.6	59.0	76.3	68.1	124.8	90.8	90.8
		C	43.0	22.9	51.1	36.8	80.0	85.6	157.0	194.0	210.1
	Metals	P	190.6	143.8	361.8	274.0	335.9	288.4	536.7	624.1	4,276.7
		L	33.6	21.1	44.4	28.8	32.2	25.8	41.7	37.6	180.2
		C	44.4	28.3	69.0	60.3	75.7	80.8	183.5	173.5	2,114.1
	Machinery and equipment	P	319.2	227.5	633.2	586.6	730.3	692.3	991.0	1,164.3	5,237.5
		L	70.1	45.0	101.2	84.0	101.4	100.8	142.1	128.2	909.9
		C	49.5	33.1	83.1	79.3	110.8	112.1	175.7	184.1	1,350.4
	Chemicals	P	225.0	175.2	422.0	378.6	546.7	582.0	930.2	606.4	1,145.3
		L	21.8	15.5	32.7	26.1	36.0	34.9	49.2	38.6	118.3
		C	29.2	24.2	62.2	76.9	127.3	227.8	383.6	518.7	1,089.5

P = Value of gross products ; L = Number of manual workers ; C = Horse Power in use by prime movers.
Unit : P=million yen ; L=thousand men ; C=thousand H. P.