INDUSTRY GROWTH AND FOREIGN TRADE
——A STUDY OF JAPAN'S STEEL INDUSTRY*——

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I

Japan has demonstrated the rapid economic growth since the late nineteenth century. It may be difficult to deny the important role played by foreign trade in her economic growth process. For she has lacked important raw materials for manufacturing, the leading sector in her economic development, and she has had to import them in exchange for the export in their fabricated form. But the inter-relationship between economic growth and trade seems to leave much to be analyzed.

Firstly it should be noted that Japan has not experienced a balanced economic growth in the sense of the uniform rate of growth in all industries and constant pattern of trade, but she has experienced drastic changes both in her industrial structure and in the commodity composition of her exports and imports. In the start of her development she exported raw silk and tea in exchange for textiles. Manufacturing production started in textiles to substitute for imports and the share of capital goods and textile materials increased in her total imports. Since the turn of the century, textiles, especially cotton textiles, grew up to be her main export item, while the domestic products of heavy manufactures, metals, machinery and chemicals, rapidly took place of imports of those commodities. This was accelerated in the nineteenthirties and until World War II the import substitution in heavy manufactures was almost completed and some of them was even to be exported to the neighbourhood countries. After the recovery from the destruction due to World War II, the heavy manufactures have led the rapid growth of Japan's economy and her exports to the world market. Their share in manufactures exceeded a half of production in 1960 and of exports in 1962. Metal ores and mineral fuels have become two main items of Japan's imports.

Changes in industrial structure and trade pattern have been inter-related with each other. The shifts both from the primary products to light manufactures and from light manufactures to heavy manufactures occurred first in imports and then in production followed by the similar shifts in exports. There underlies the growth of each manufacturing industry from import to import-substituting production and finally to export promotion. This pattern of industry growth was given a poetic expression "Ganko-keitai-teki Hatten"

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(Flying wild-geese pattern of industry growth) by Professor Kaname Akamatsu over thirty years ago.[1] This has been empirically substantiated in many of Japan's major manufacturing industries and has often been mentioned in the studies of Japan's economic growth.[2]

This pattern of industry growth and trade may at first appear to be self-evident and requiring no further investigation. But why has this pattern of growth started earlier in one industry than in the other? Why has one industry succeeded in import-substitution and export promotion more quickly than the other? Why has a third industry failed to follow this pattern of growth? These are not selfevident and should be given a theoretical explanation and its empirical verification. Under what conditions is the growth of an industry preceded by imports and followed by exports and what factors determine the speed of import substitution and export promotion?[3]

The aim of this paper is to give an answer to this question with special reference to iron and steel industry, the leading sector of Japan's heavy manufactures. Historical review of the growth process of Japan's iron and steel industry is given in the next section, and in Section III a hypothesis is presented to explain the mechanism of industry growth and trade mentioned above, and is formulated in a model form. Based on this theoretical formulation an econometric analysis is attempted in the last two sections.

II

Iron and steel industry has three production processes; iron-making process where pig-iron is refined from iron ore and coke in blast furnace; steel-making process through which pig iron is changed to ingot of steel at open-hearth furnaces or converters; and finally milling and casting processes where ingot is fabricated into various types of steel products (bars, shapes, rods, plates, pipes, rails, etc.). Output of ingot in the second process is often used to measure the growth of the industry in either international or intertemporal comparison, but Japan's trade of ingot has been almost negligible relative to its production. It can be safely concluded that they have been traded mostly in the form of pig-iron and steel products, and domestic output of ingot is mostly input into the domestic production of steel products.

This is partly attributed to some technical reasons but partly reflects unbalanced growth between iron-making process on one hand and steel-making and milling processes on the other. This was reflected in the pre-war firm structure of the industry. Before World War II the integrated operation of the three processes were undertaken only in the government-

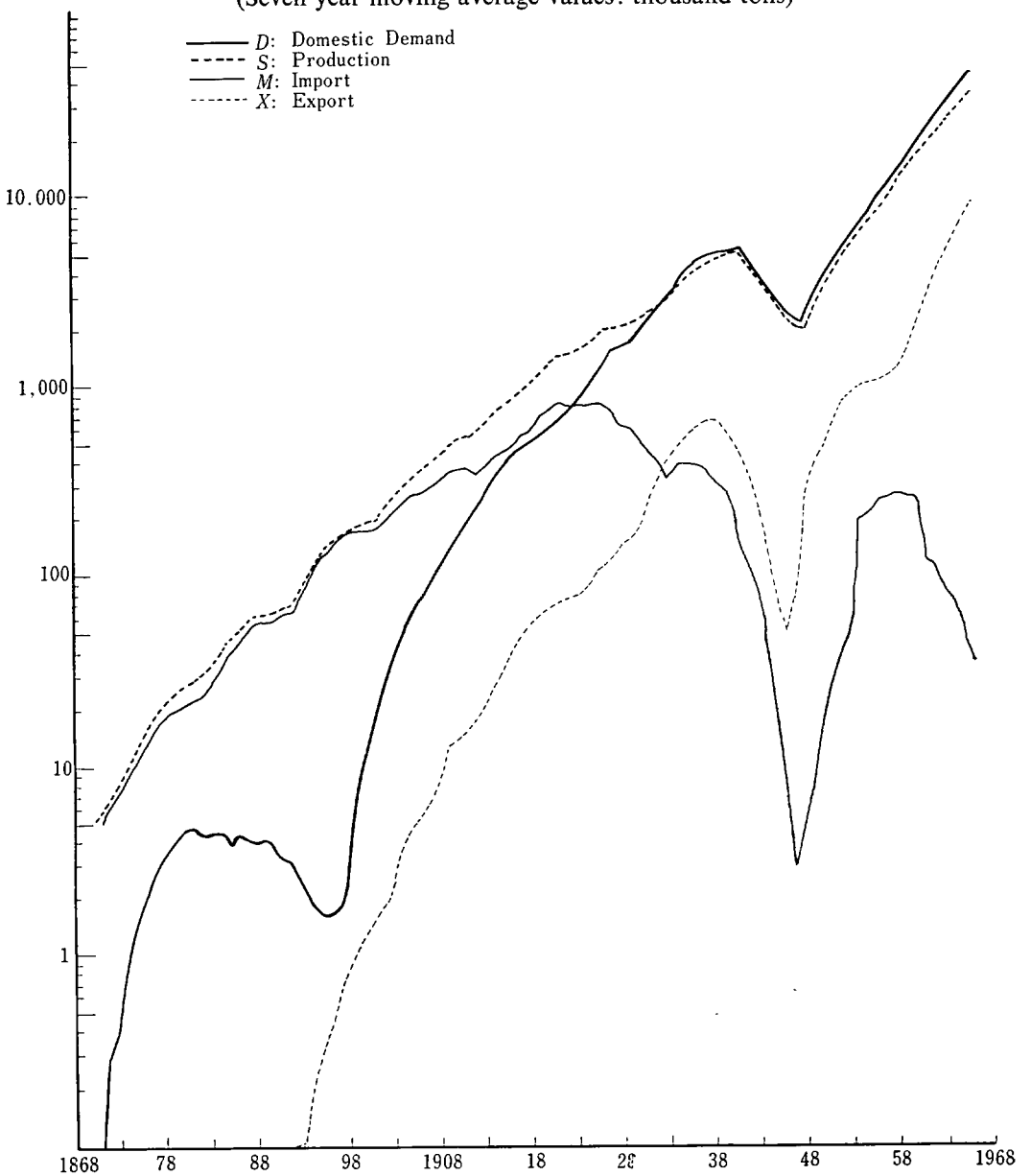
[1] See Kaname Akamatsu, "A Theory of Unbalanced Growth in the World Economy", *Weltwirtschaftliches Archiv*, Bd. 86 (1961), Heft 2, and "A Historical Pattern of Economic Growth in Developing Countries", Institute of Asian Economic Affairs, *The Developing Economies*, No. 1 1962.

[2] See Masao Baba and Masahiro Tatemoto, "Foreign Trade and Economic Growth in Japan", Klein and Ohkawa ed. *Economic Growth: The Japanese Experience since the Meiji Era*, 1967, and Miyohei Shinohara, *Growth and Cycles in the Japanese Economy*, 1962, pp. 57-59 and Benjamin Higgins, *Economic Development, Principles, Problems, and Policies*, 1968, pp. 623-625.

[3] Our viewpoint is similar to that of 'product cycle theory' developed by R. Vernon and others. But the crucial difference between the two is that the latter is concerned with the process of growth and transmission abroad of a new industry from a leading country's point of view whereas the former deals with it from a following country's viewpoint. See R. Vernon, "International Investment and International Trade in the Product-cycle", *Quart. Jour. Econ.*, May 1966.

owned Yawata Iron Works and one private firm, and the rests, including major 'zaibatsu' firms, were steel-making and milling firms dependent on imported pig iron. The fact that iron-making was handicapped by high cost import of iron ore and big capital requirement for large optimum scale of production seems to let private firms specialize in the steel-

FIG. 1. GROWTH PATTERN OF STEEL PRODUCTS
(Seven year moving average values: thousand tons)



making and milling processes. Taking these characteristics into consideration let steel products as a whole represent the industry in the following analysis. For comparison, however, frequent reference will be made to the growth pattern of pig-iron.

Fig. 1 shows the growth of domestic production (S), imports (M), exports (X), and (apparent) domestic demand (D) over the past hundred years. Domestic demand for steel products is defined as

$$D \equiv S + M - X$$

and it represents the demand by the residents for steel products both domestically produced and imported.[4] Seven-year moving average values are plotted in order to depict the relationships between the growth trends of four variables. Fig. 1 exhibits the typical pattern of growth with successful import substitution and export promotion. Steady growth of the industry started in 1901 when the government-owned Yawata Iron Works commenced operations. It should be noted that there had already existed a fairly large domestic market for imported steel products. Yawata was already equipped with integrated facilities of iron-and steel-making at the time of its establishment, but it took Yawata nine years to be able to run with profit. Both the deficits over the period and the expansion investments were financed by government expenditure. Until 1910 major zaibatsu firms followed Yawata but they were equipped only with open-hearth furnace and milling facilities and dependent on either Yawata or imports for the supply of pig iron. Domestic production expanded rapidly in this period.

World War I spurred the industry to another rapid expansion. Price and profit hike due to the stoppage of imports from Europe and tax exemption under Iron-Manufacturing Encouragement Act (1917) induced the entry of medium-and small-scale firms into the industry. Production grew up rapidly to exceed imports in 1923, after then imports turned downward, and was exceeded by exports in 1934. Rapid growth of production and exports was resumed after the recovery from the destruction of World War II and even accelerated in the post-war period of high rate of investment and technological transfer. Table 1 shows average annual rates of growth of domestic demand, production, imports and exports for each period.

TABLE 1. AVERAGE ANNUAL GROWTH RATES OF STEEL PRODUCTS (%)

	1900–1914	1914–1923	1923–1938	1952–1966
Domestic Demand	10.1	8.9	7.6	15.9
Production	26.3	11.0	12.9	16.5
Import	6.5	7.6	−5.7	—
Export	23.7	13.4	15.1	18.9

* Figures are calculated from the seven year moving average values of four variables in 1900, 1914, 1923, 1938, 1952, 1966.

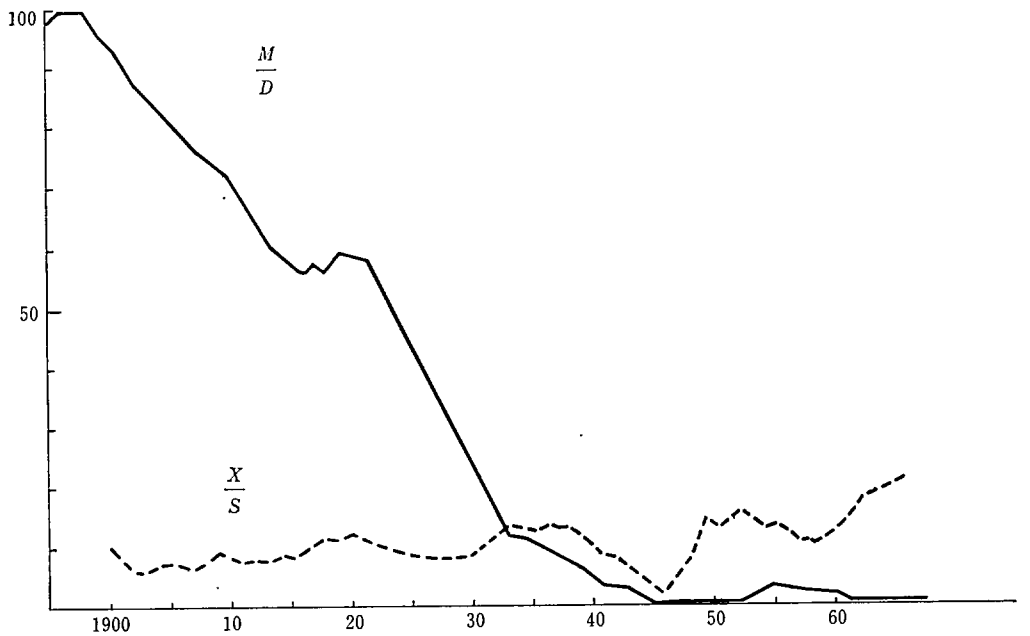
It is interesting to see the interwar period more closely from our viewpoint of industry growth. Being suffered both from the over-expanded capacities and severe competition with cheap imports after World War I, the industry forced rationalization and cost-down to the complete import substitution. It also benefited from government support of all possible

[4] Data on steel products come from Committee for Iron and Steel Statistics, *Hundred Year Statistics of Japan's Iron and Steel Industry*, March 1970.

sorts, which included raises of tariff (1921, 26), tax-exemption to steel-making firms, subsidies to the production of steel for ship-building (1921), the formation of cartels, and finally the establishment of Japan Iron Manufacturing Company (1932). (See Table 2)

Cartels were formed by category of steel products, in each of which Yawata took initiative in maintaining prices of domestic products as low as those of imports. The last one was the merger of Yawata with six inefficient zaibatsu firms. 43 percent exchange depreciation in the early 1932 had an effect equivalent to raise of tariffs on imports and subsidy to exports. Import dependence (M/D), declined rapidly from 60 percent to less than 10 percent in the inter-war period. (See Fig. 2).

FIG. 2. IMPORT DEPENDENCE AND EXPORT-PRODUCTION RATIOS OF STEEL PRODUCTS (%)



On the other hand exports of steel products in early years seem to have been mainly re-exports and before World War II exports were mostly those to Japan's domains (Korea, Taiwan, Manchuria and the main part of China), It was after World War II that Japan's steel products began to be exported to the world market at competitive prices. Post-war growth of steel production is characterized by the rapid investment and introduction of new technology developed abroad. Eight big firms with integrated iron and steel-making facilities took parts in the race of building new plants of larger scale and equipped with new technology. It enables the cost down relative to American and European competi tors, and the exports of steel products have grown rapidly to American and Southeast Asian markets. Both domestic demand and exports have increased far more rapidly than before

TABLE 2. GOVERNMENT POLICIES PROTECTING IRON AND STEEL INDUSTRY

Before 1900	Experimental operations in government-owned small scale foundries.
1901	Yawata (government-owned) Iron Works commenced operations.
1911	General Revision of Customs Tariff Act. (1.67 yen per ton of pig-iron and 15 percent *ad valorem* equivalent rate on steel products).
1917	Iron-Manufacturing Encouragement Act (tax exemption for iron-manufacturing firms).
1921	The first amendment to Iron-Manufacturing Encouragement Act (enlarged tax exemption). Change in tariffs on steel products from specific duties to *ad valorem* ones. (15 percent *ad valorem* rate).
1926	The second amendment to Iron-Manufacturing Encouragement Act. (subsidy to pig-iron production; 3~6 yen per ton). Raise of customs tariff on steel products (18 percent *ad valorem* rate).
1926~31	Formation of cartels by category of steel products under government support.
1932	Raise of customs tariff on pig-iron (6.00 yen per ton).
1934	Establishment of the Japan Iron Manufacturing Company (the merger of Yawata with six zaibatsu firms. Eighy-two percent of its stock shares was held by the Finance Minister. It produced 96 percent of pig-iron and 44 percent of steel products in Japan).
1937	Iron-Manufacturing Enterprise Act (support for integrated iron-and-steel making firms; A change to production expansion policy for war time economy).
1951~52	Government aids to the reconstruction of iron and steel industry. (Tax exemption to induce private firms' investments).
1951~55	Government bank's loan to the First Rationalization Project.

Note on tariffs on steel products:

Specific duties were levied on some categories of steel products and *ad valorem* ones on other categories and they were changed several times from one to the other. Tariff figures in the table are expressed in *ad valorem* rates or their equivalents since specific duties differed much in different categories but their *ad valorem* equivalents were relatively uniform.

Until 1911 tariffs on most of steel products remained as low as 7.5 percent *ad valorem* equivalent rate under Tariff Agreement in 1899, and they were raised twice as high in 1911. *Ad valorem* equivalent of specific duties decreased considerably during the post World War I years of high level of domestic and import prices of steel products, and the change from specific to *ad valorem* rate in 1921 had the similar effects to the raise of tariffs. In 1926 some *ad valorem* rates were changed back to specific duties, which were raised by 35 percent in 1932 in response to the increase in import price due to currency depreciation. *Ad valorem* tariffs of around 15 percent were levied on steel products in the post World War II years until the Kennedy Round Tariff Reduction in 1967.

Ad valorem equivalent of specific duty on pig iron import was 5.0 percent in 1911 and 17.6 percent in 1932 respectively.

the war and accelerated the growth of production by 3~5 percent above pre-war levels. Export-production ratio has increased steadily since late 1950's.

On the contrary, the growth of pig iron production was much slower. They succeeded in the production of pig iron at blast furnace for the first time in 1887, and almost half of domestic demand was already supplied domestically in 1900. But the import of pig iron has increased in pace with its domestic production, and import dependence declined only by 10% for the inter-war period. During the pre-World War II period (1900~1936) domestic demand for pig iron increased at the annual average rate of 9.7 percent, in pace with that of steel products, whereas its imports and production increased at 8.6 and 10.7 percent respectively. Exports of pig iron still remain negligible even in recent years. How

has such an unbalanced growth between pig iron and steel products resulted?

It is partly explained by the fact that zaibatsu firms had already started the production of pig iron near the deposits of iron ore and coke in Manchuria and Chosen during World War I and imported them for further fabrication. Dependence on the production in Manchuria and Chosen amounted to 18~20 percent both during World War I and in 1930's. Slow import substitution of pig iron is partly explained by the facts that Japan was handicapped by the lack of iron ore and coke and continued to be suffered from the competition with cheap imports from India during 1920's on one hand, and on the other that there existed a large group of steel-making firms mainly dependent on imported pig iron and they resisted the raise of tariff on pig iron until 1932.

The comparison of these situation for pig iron production with those for steel production enables us to make clear the condition for successful and rapid import substitution of steel products.

III

Historical review of the growth of steel industry in the previous section gives us a clue to the mechanism of successful import substitution and export promotion in an industry.

The factors behind this mechanism may be summarized as follows.

(A) It requires, first of all, steady reduction in production cost in response to the expansion of production for the industry as a whole. Cost reduction tends to lower the price of domestic product relative to import price and world price, thereby making possible import substitution and export promotion.

(B) Growth of domestic demand is also required to induce investment and output expansion in the industry. Foreign trade adds to the demand growth through import substitution and export promotion.

(C) Government protections accelerates the process of demand growth $\longrightarrow$ output expansion $\longrightarrow$ cost reduction $\longrightarrow$ import substitution and export promotion for the industry. They include such typical policies of industry protection as tariffs and subsidies on one hand and more direct but less apparent instruments such as tax exemption and preferencial purchasing policies. In the case of steel industry, furthermore, the government-owned Yawata initiated and led the growth of the industry.

These are hypotheses for the mechanism of successful industry growth and trade. Both (A) and (B) were indispensable for the mechanism to work and (C) was also important for most of Japan's heavy manufacturing industries. A model is formulated to include the hypotheses and tested by empirical data. It is built in order to trace the long-run growth trend of the industry let alone short-term fluctuations around it.

Four behavior equations and an equilibrium condition are needed to determine the equilibrium values of five endogenous variables for a given set of values of exogenous variables in each year. In Equation (1) the domestic income variable determines the level of domestic demand for steel products. The former is represented by the total output of industry which uses steel products as input but in the case of consumer goods it is represented by per capita gross domestic expenditure or consumption expenditure. The level of domestic demand is also influenced by the demonstration effect in the course of adapting a new product to domestic market. Demonstration effect may well be formulated as a

A MODEL OF INDUSTRY GROWTH AND TRADE

(1) Domestic Demand: $D=D(Y, L)$
$D'_Y>0,\ D'_L>0$

(2) Import: $M=M(D, P, PM)$
$M'_D>0,\ M'_P>0,\ M'_{PM}<0$

(3) Export: $X=X(Z, P, PZ)$
$X'_Z>0,\ X'_P<0,\ X'_{PZ}>0$

(4) Price: $P=P(S, PO, W)$
$P'_S<0,\ P'_{PO}>0,\ P'_W>0$

(5) Equilibrium condition: $D=S+M-X$

SYMBOLS:
- D: Domestic demand
- S: Production
- X: Export
- M: Import
- Y: Domestic income variable
- Z: Foreign income variable
- L: Demonstration effect (monotone increasing function of time)
- P: Price of steel products
- PM: Import price of steel products (including tariff)
- PZ: World price of steel products
- PO: Import price of iron ore
- W: Wage rate of metal workers

monotone increasing function of the length of time from the introduction of the product to the domestic market, which can be assimilated by growth curve, increasing at increasing rate at first and then at decreasing rate and finally approaching to a satiety level. The length of time during which the demonstration effect reaches satiety level differs in different commodities. It will be shorter for synthetic products for which domestic market has already adapted to their natural substitutes.

The level of import is determined in Equation (2) by import price relative to domestic price for a given level of domestic demand. Steady reduction of domestic price relative to import price promotes import substitution, and imports will decline in absolute volume when the price effect more than offset the income effect (increase in domestic demand).

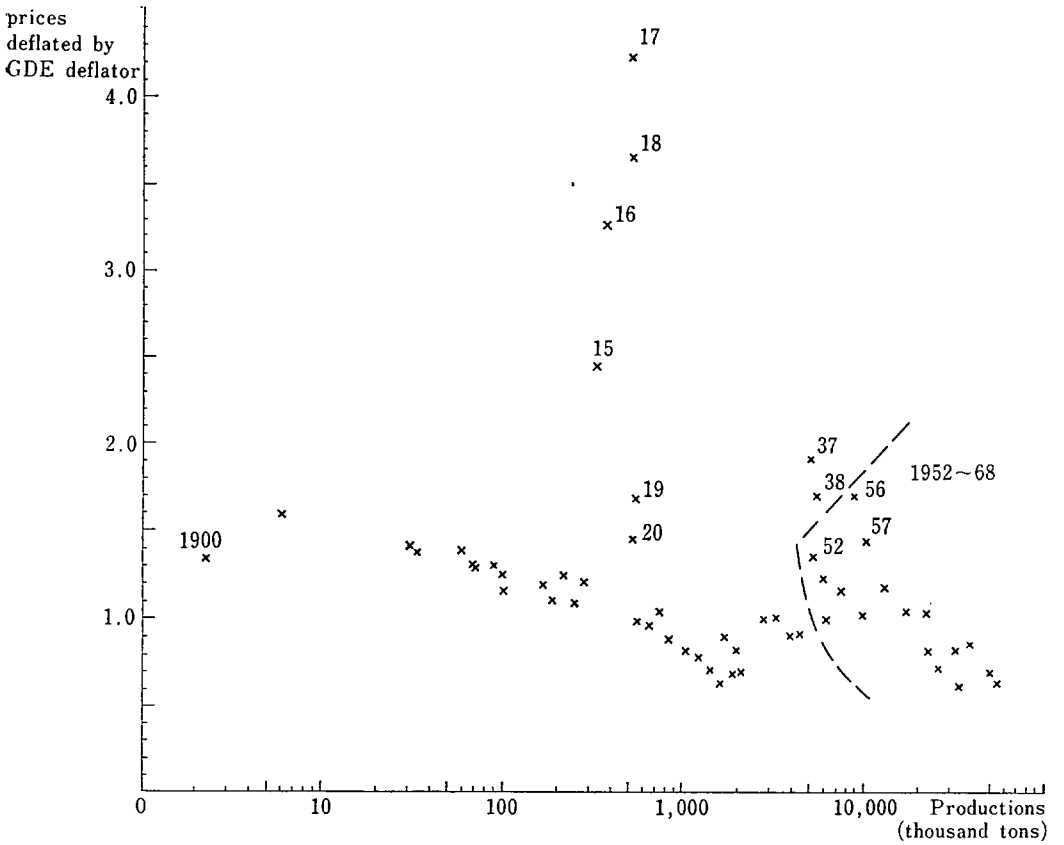
When domestic price declines enough relative to world price of the product, the export of domestic product starts and it grows as the results of both the growth of foreign income variable and the steady decline in domestic price relative to world one (Equation (3)).

Price equation (4) represents the relationship between domestic price (cost) and total output of an industry. This is the basic relationship in our model and needs explanation in detail.

Equation (4) gives a negative correlation between domestic price and the total output of the industry, which was widely observed in the growth processes of main industries in Japan. It may well be called "long-run decreasing cost of an industry".[5] Fig. 3 shows this relationship for steel products. Except during World War I and late 1930's, there is

[5] Industry long-run decreasing cost curve is not new to students of international economics. It is introduced for the justification of infant industry protection. But few studies have attempted to analyze factors causing it on empirical data.

FIG. 3. THE RELATIONSHIPS BETWEEN PRICES AND PRODUCTIONS OF STEEL PRODUCTS



depicted a negative correlation between price and total production. The price is deflated by GDE deflator in order to get rid of inflationary trend which was characteristic of Japan's economic growth. We have introduced this observed relationship into our model but what theoretical explanation can be given to it ?

The " industry long-run decreasing cost " seems to be the complex result of various factors. Among them the following factors seem to be significant.

(1) The expansion of total output of an industry is generally accompanied by enlarged scale of production plant (measured in productive capacities). In the process of an industry expansion there will be both entry of new firms to the industry and establishment of new plants by existing firms, thus an increase in the number of plants. But more important is the fact that the newer the plant the larger is its optimum scale of production, and that the larger the optimum scale the lower is the unit cost of production.

It may be the case that new plants of small or medium scale are established during the years of persistent excess demand and price increase. But as the excess demand is slackened and price decreases down to the previous level, these inefficient plants will be eliminatd through competition. This happened in fact in the steel industry during and after World War I. If the market is competitive enough, the unit production cost in the most efficient

new plant tends to dominate the market price in the long run and inefficient old plants will be scrapped and replaced by more efficient and larger plants. Cost reduction due to large-scale production seems to be one of the main factors for the industry long-run decreasing cost.

A new plant of larger scale makes it possible to reduce production costs in various ways. (a) Although there will be little room for saving material cost since raw materials are used in proportion to the level of output, a larger scale plant causes the reduction in the cost of construction, energy and labor per unit of production by some geometric law.[6] Production capacity of an blast furnace increased steadily from 160 tons per day in 1901 to 500 tons in 1930 and to 1000 tons in 1937, and more than 3000 tons in 1965. This is also the case for open-hearth furnace in steel-making. (b) Larger scale production made possible automatic and continuous operations of production processes, thereby leading to the reduction of cost per unit production. A good exmple is given by " hot strip mill " in steel making which has become profitable only in larger scale production and replaced old fashioned " pull-over mill '. (2) Industry long-run decreasing cost is partly explained by learning effects in production, which includes improvements in production equipment and in management system as the result of the accumulation of production experiences, and improvement in skills of production workers and so on. In order to expand a newly introduced industry the foreign technology must be learned quickly and the cost reduction due to the learning effect is very important in the early stages of industry growth. This learning effect may increase not in proportion to the level of output but to the accumulated output from the beginning. It took several years for Japanese iron- and steel-making firms to adapt foreign technology to iron ore and cokes of the type available in Japan.

(3) Cost reduction is accelerated by the repercussion of external economies which the industry gives to the related industry. Machinery production in Japan benefited much from the growth of steel industry, which in turn gains from successful domestic production of steel-making machinery in 1930. The industry has also benefited from development of automatic control system in the post World War II years.

We have listed three possible factors which seem to have brought about steady cost reduction in steel products. Relative contribution of each factor differs much in different industries and in different stages of an industry growth. In the case of steel industry learning effect was the most important in the early years of its establishment and the scale economy and external effect were important in 1920's and the post World War II years.

It is not easy to anaylse quantitatively the industry long-run decreasing cost because of the unavailability of reliable data on capacities and input-output relationships in steel-making and what we can do is to introduce this observed relationship as the combined effect of various factors. Increase in material cost and labor wages in Equation (4) tend to offset the cost reduction mentioned above.[7]

[6] See John Haldi and David Whitcomb, "Economies of Scale in Industrial Plants", *Jour. Pol. Econ.*, Aug. 1967, Vol. 75, No. 4.

[7] Fogel and Engerman presented a short-run equilibrium model in which a set of equilibrium price and quantity are determined by the intersect of short-run demand and supply curves for each year and short-run demand and supply curve shift rightward by domestic income and productive capacities respectively. This approach was tried in the earlier draft of this paper, but finally the present model was adopted because of data requirements. Reliable data on productive capacity over the whole period is not available for Japan's steel industry. See R. W. Fogel and S. L. Engerman, "A Model for the Explanation of Industrial Expansion during the Nineteenth Century; with an Application to the American Iron Industry", *Jour. Pol. Econ.*, May-June 1969.

Let us make sure the dynamic property of our model. The mechanism of industry growth is generated, first in demand side, primarily by the growth of domestic income variable assisted by demonstration effect in domestic market and the growth of foreign income variable. Steady growth of domestic demand induces output expansion which is accompanied by the reduction in unit cost and market price, which in turn leads to import substitution and export promotion for a given level of import and world prices of the product and input prices, thereby adding to the growth of domestic demand.[8] Exogenous changes in these price variables affect such a growth mechanism. One of these changes comes from government protection given to the industry. Tariffs on import raises import price and accelerate import substitution of the product.

One theoretical question remains. How can we assure that we always move along the industry long-run decreasing cost curve? We always move down along the curve under two following assumptions. One is that firms foresee the demand growth correctly and expand their production exactly and without time lag in response to it. The other is that the productive capacity is divisible so that firms can produce any level of output at minimum cost. Actual growth process of steel products is characterized by cyclical fluctuation along its steady growth trend, which may appear to be unfavorable evidence for the two assumptions. But except for the World War I years and late 1930's, both of which were characterized by persistent excess demands for steel products in unusual external environments for Japan, it may be assumed that the industry almost moved along the curve with some random divergences from it. Governmental support to the industry through government-owned firm and preferential purchasing policy contributed to the growth of industry in respect of the first assumption.

IV

The hypothesis and the model built on it in the previous section need to be tested by empirical data.[9] Our model is applied to actual data separately for pre-World War II period excluding the years of persistent excess demand (1900～1914, 1921～1936), and for the post World War II years (1952～1968). Simulations of growth process under alternative policy assumptions are attempted for each period. This section describes the results of testing and simulation for the first period, and next section those for the second period respectively.

Four behavior equations are estimated in log-linear form by two stage least squares methods for the period of 1900～1914 and 1921-1936. The result is summarized in Table 3. Let us check them in turn.

The growth of domestic demand is explained fairly well by the domestic income variable

[8] Differentiation of Equations (1)-(5) with respect to time t enables us to derive a system of log linear equations in growth rates of variables, and the linear equation system is solved for equilibrium growth rate for each endogenous variable. We can prove that under a few plausible assumptions the model generates a path of successful import substitution and export promotion, but that for small values of $\lambda_1(=S/D)$ the model tends to move in the other direction. See my "Industry Growth and Foreign Trade——A Theoretical Approach" (in Japanese), *Hitotsubashi Ronsō* Vol. 66, No. 6 (Dec. 1971).

[9] Data of steel products are taken from Committee for Iron and Steel Statistics, *Hundred Years Statistics of Japan's Iron and Steel Industry*, Ministry of Industry and Commerce, *Statistics of Iron Manufacturing*. Prices (domestic, import and world) of round bars are taken as the representative of steel products because of the availability of long run time series data. U.S. market price is used for world price.

and demonstration effect. Production index of total manufacturing on one hand and the sum of net products of mining and manufacturing and construction on the other are taken as the income variable, respectively, but production index of machinery gives better estimation than either of the alternatives. Machinery production and metal manufactures compose demand for steel products and the sum of the two will improve the estimates but data is not available for this alternative. Demonstration effect, on the other hand, is assimilated by a truncated exponential function of time. Alternative values are applied to the coefficient of time and the value of 0.1 gives the best estimation.

Import function is estimated correctly. Its domestic demand elasticity is .45 and price elasticities are 1.4 and −1.4 for demestic price and import price respectively. Low value

TABLE 3. GROWTH PATTERN OF STEEL PRODUCTS: 1900∼1914, 21∼36

Estimations (Figures in parentheses show *t*-values of estimates)

(1) Domestic Demand

$$\log D = 6.6967 + .8511 \log Y + 1.0804 \log L$$
$$\qquad\qquad (12.02) \qquad (1.72)$$
$$\bar{S} = .1610 \quad \bar{R}^2 = .9741 \quad DW = 1.57$$

(2) Imports

$$\log M = 4.4806 + .4494 \log D + 1.3779 \log PP - 1.4317 \log PPM$$
$$\qquad\qquad (3.37) \qquad (2.30) \qquad (5.87)$$
$$\bar{S} = .2936 \quad \bar{R}^2 = .7152 \quad DW = 1.80$$

(3) Exports

$$\log X = -1.0181 + 1.7015 \log Z - 6.4112 \log PP + 2.0700 \log PPZ$$
$$\qquad\qquad (3.47) \qquad (6.29) \qquad (3.36)$$
$$\bar{S} = .6904 \quad \bar{R}^2 = .8701 \quad DW = 1.12$$

(4) Price

$$\log PP = 1.1994 - .0910 \log S + .1800 \log PPO$$
$$\qquad\qquad (4.79) \qquad (1.23)$$
$$\bar{S} = .1332 \quad \bar{R}^2 = .7011 \quad DW = .96$$

Final Tests

	D	*M*	*X*	*S*	*PP*
Root Mean Square	3729.5	2317.75	576.41	3070.90	0.11
Von-Neuman Ratio	0.45	0.57	1,10	0.34	0.87

Symbols

D: Domestic Demand
S: Production
X: Export
M: Import
} of steel products (hundred tons)

Y: Production index of machinery
Z: World production of ingot of steel
L: Demonstration effect ($\equiv 1-\exp[-0.1(t-1890)]$); t : year, $t=1$ for 1900

PP: Price of steel products
PPM: Import price of steel production including tariff
PPZ: World price of steel products
PPO: Import price of iron ore
} deflated by GDE deflator

of domestic demand elasticity is worth noticing. This means that when domestic demand for steel products increase by one percent demand for imported steel products increases only by less than a half of it. Is there any specific explanation for such a low elasticity of demand? It should be remembered here that a large part of domestic demand for steel products came from government for military production and railroad construction. Therefore a plausible explanation for the low elasticity is that there existed a strong preferential purchasing policy by the government for domestically produced steel products.

This explanation appears to be more plausible when we compare the estimation of Equation (2) with that for pig iron. (1900～1936).

$$\log M = -.09 + \underset{(45.54)}{.9093} \log D + \underset{(1.11)}{.1800} \log PM/P.$$
$$\bar{R}^2 = .9836 \quad DW = 1.68$$

Domestic demand elasticity for pig iron import is twice as large as that for steel products. As we mentioned in the previous section, a large group of steel-making firms depended on imported pig iron and import demand for pig iron increased almost in proportion to the growth of domestic demand.

Estimation of export function gives support to rapid growth of exports before World War II. World production of ingot of steel, which is a proxy variable for the world consumption of steel products, grew annually at 2.9% for the period of 1900–36, and it induced a 4.9(=2.9×1.7) percent growth of Japan's exports. The rest of export growth (around 10 percent. See Table 1 in Section II) is attributed to price effects, that is, the decline in domestic price and the rise in world price. Of course it can not be denied that preferential purchasing in Japan's domain contributed to some part of this export growth.

Price equation gives a statistically significant negative relationship between price and production but the coefficient of material cost is less significant. Wage variable is eliminated since its coefficient is not significant statistically with wrong sign.

Partial test of our estimation (standard error of residual $\bar{S}$, coefficient of determination $\bar{R}^2$, and Durbin Watson ratio DW) shows a relatively good fit of our model to actual data. But it may be worthwhile to see whether our model generates the process of import substitutuon and export promotion over the whole period when only exogenous variables and initial values of endogenous variables are given. This can be seen in final tests in Table 3 and Fig 4 and 5.[10] Estimations in Fig 4 and 5 do not follow every up and down of observations but they trace the rapid growth of domestic production, import substitution and export promotion, and steady decline in domestic price. We mentioned in the preceding pages to the effect of government policy on the process of industry growth and trade. Here we can analyze the effect of two of them, import tariffs and preferential purchasing policy.

[10] For final tests and simulations it is necessary for endogenous variables to be expressed in reduced form, that is, linear equations of exogenous variables. In our model each behavior equation is in log-linear form and equilibrium condition (5) is replaced by its approximate formula in long linear form so that the model is solved easily for each endogenous variable.

$$\Delta \log D_t = \lambda_{1 \cdot t-1} \Delta \log S_t + \lambda_{2 \cdot t-1} \Delta \log M_t - \lambda_{3 \cdot t-1} \Delta \log X_t$$

where

$$\lambda_{1 \cdot t-1} = (S/D)_{t-1},\ \lambda_{2 \cdot t-1} = (M/D)_{t-1},\ \lambda_{3 \cdot t-1} = (X/D)_{t-1}$$

Values of $\lambda_i (i=1, 2, 3)$ changed greatly over the period and λ_i values of the previous year are used iteratively. Furthermore, values of 1902 are taken as initial values for final tests because the model generates the movement in the wrong direction for small values of λ_1. See footnote 8 in page 51.

Which had a larger effect on import substitution of steel products in Japan, import tariffs or preferential purchasing policy? The answer may be found in Fig. 6. Simulation 1 traces the values of import and production in case import tariffs is not levied over the whole period at all. Simulation 2 traces the similar values in the absence of preferential purchasing policy.[11] In Simulation 1, import price (including tariffs) is lowered by the tariff and imports shift upward and domestic production downward over the whole period. In Simulation 2 imports increase in proportion to domestic demand and domestic production shifts downward by the corresponding amounts. It should be noted that the effect of preferential purchasing policy is almost three times as large as that of import tariff. However, in either case, import follows the pattern similar to that of estimations, that is, it grows slowly at first and turns downward in mid 1920's, which demonstrates import substitution through price effects. Thus the production values in both cases approach to the estimations because of the rapid decline of import share.

V

In the post World War II years a rapid growth of domestic demand and exports led the growth of steel production. Import substitution had already been completed before World War II and imports of steel products fell to negligible level in this period and is eliminated from our estimation. Equation (1), (3) and (4) in the model are estimated on data of this period by statistical technique similar to that in previous section. The results are summarized in Table 4.

Estimation of domestic demand is very similar to that for the pre-war period. Demonstration effect is eliminated from the equation because values of $\log L$ are close to zero in this period. Estimates for both income elasticity and constant term differ little from those for the pre-war period. We have got a stable relationship for demestic demand over

TABLE 4. GROWTH PATTERN OF STEEL PRODUCTS: 1952–1968

Estimations:

(1) Domestic Demand

$$\log D = 6.2531 + \underset{(40.19)}{.8137} \log Y$$

$$\bar{S} = .0755 \quad \bar{R}^2 = .9902 \quad DW = 1.97$$

(2) Export

$$\log X = .0289 + \underset{(3.68)}{2.2711} \log X - \underset{(1.64)}{1.4337} \log PP/PPZ$$

$$\bar{S} = .4070 \quad \bar{R}^2 = .8376 \quad DW = .69$$

(3) Price

$$\log PP = 5.9651 - \underset{(1.43)}{.4043} \log S + \underset{(.38)}{.3437} \log PW$$

$$\bar{S} = .1731 \quad \bar{R}^2 = .6298 \quad DW = 1.86$$

[11] Simulation 1 is computed on the assumption that tariffs was not imposed so that import price is lowered by the same amount as tariff and initial values of imports and production are adjusted to this change in price. Simulation 2 is computed on the assumption that domestic demand elasticity is .90 instead of .45 in parallel with that for pig iron.

Final Tests

	D	*X*	*S*	*PP*
Root Mean Square	19051.01	16518.72	18044.54	0.22
Von-Neuman Ratio	1.72	0.48	1.00	1.25

Simbols

D: Domestic demand
S: Production
X: Export
} of steel products (hundred tons)

Y: Production index of machinery

Z: World production of ingot of steel

PP: Price of steel products
PPZ: World price of steel products
PW: Wage rate of metal workers
} deflated by GDE deflator

the two periods.

Different estimates are obtained for export function between pre-and post-war periods. Income elasticity increased and price elasticity decreased in the latter period. World consumption of steel products has grown faster in the post war period, and Japan's export has grown more than twice as fast as it, let alone favorable price effect. Environment for Japan's export of steel products have changed much after the war. She has been exporting mainly to Southeast Asian and North American markets in place of East Asia before the war. Her exports concentrate in such types of steel products as plates and sheets for which world demand is rapidly increasing and the supply capacity of European and American competitors is limited. These seem to explain the high income elasticity mentioned above.

Japan's steel industry has also gained shares in world market from cost (price) decline relative to its European and American competitors. This will be tested in simulation below.

Price equation has less success because of volatile fluctuations in mid-fifties, but price elasticity with respect to output has increased four times as high as before the war. This reflects the result of high investment in large scale plants equipped with newly developed technology since late fifties. On the other hand the coefficient of material price has turned out to be not significant and of wrong sign, and that of wage level to be of correct sign but not significant statistically either.

Final tests in Fig. 4 and 5 show that our model has succeeded in tracing the growth trends, apart from fluctuations around them of major variables of steel products for the post war period. Fig. 7 illustrates a simulation in the post war development of steel industry. As we mentioned above, the rapid export growth is one of the main features of post war development of the industry and it is partly explained by high income elasticity and partly by relative price decline. Simulations in Fig. 7 trace values of exports and production in the absence of relative price decline.[12] The growth of export is slowed down to 11.0% (see Table 1) but it does not change the strong growth trend of production.

[12] Simulations are computed on the assumption that world price has fallen in parallel with that of Japan so that the relative price remains constant.

FIG. 4. GROWTH PATTERN OF STEEL PRODUCTS: FINAL TEST

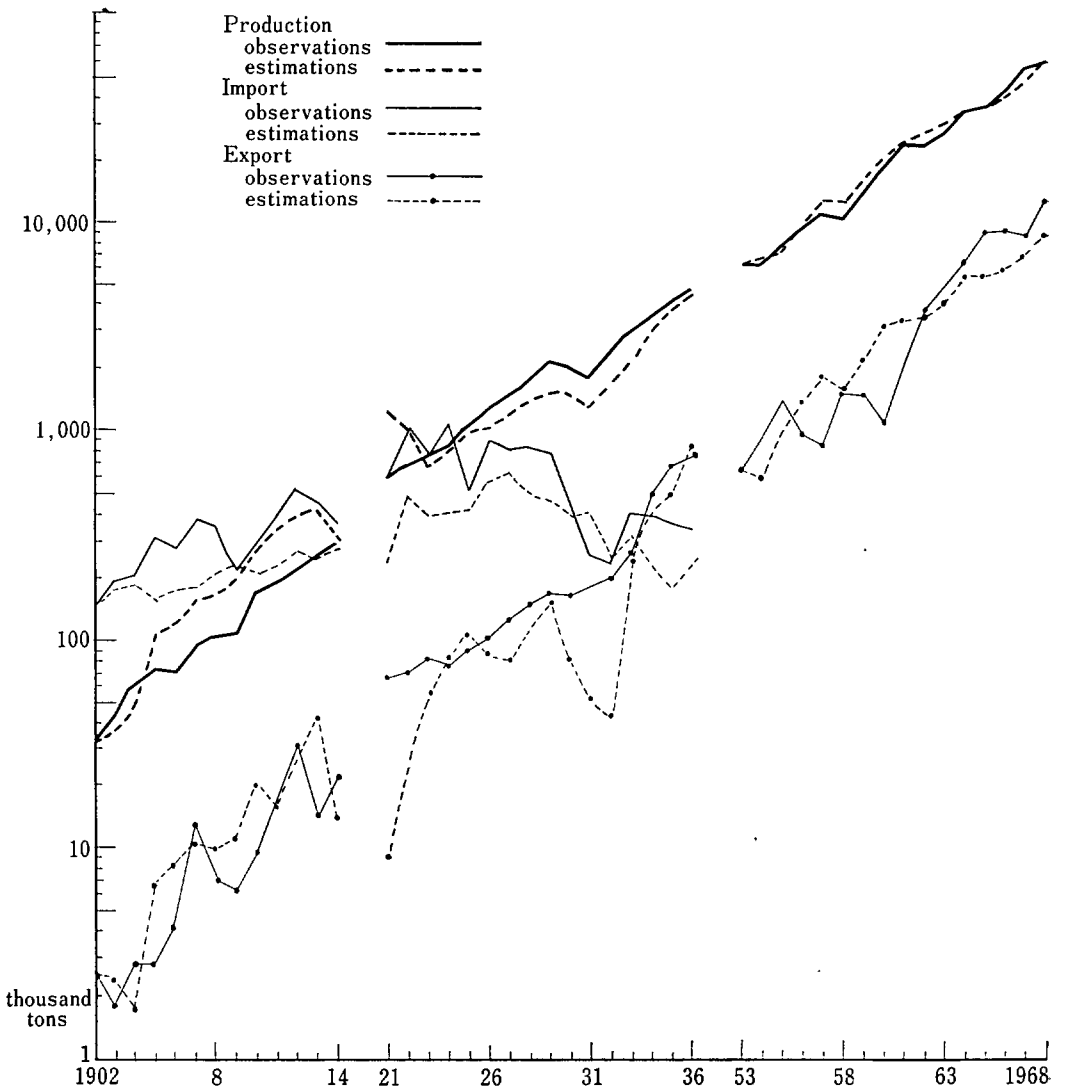


FIG. 5. PRICE OF STEEL PRODUCTS: FINAL TEST

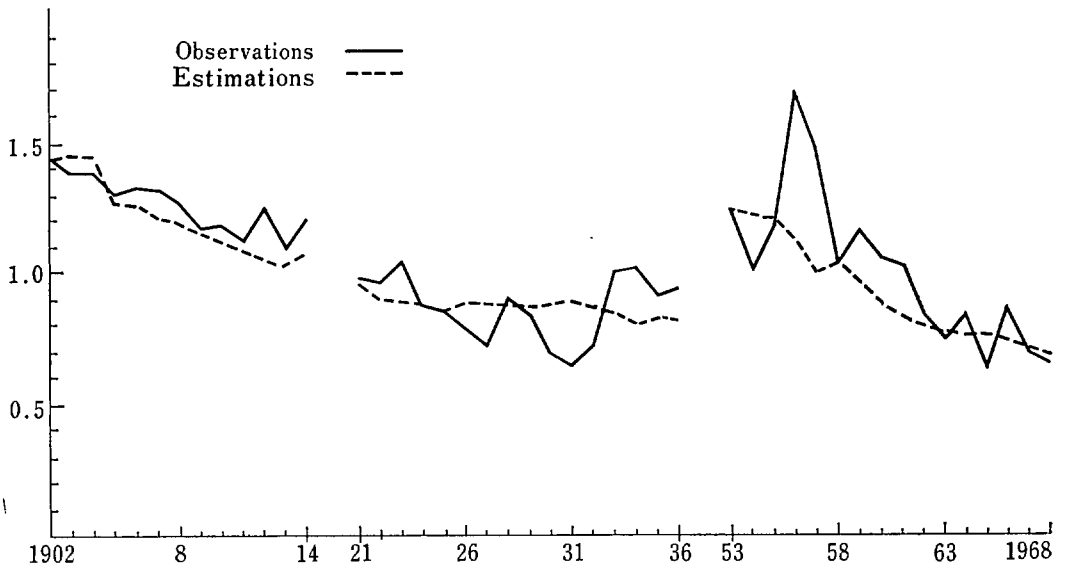


FIG. 6. PROCESS OF IMPORT SUBSTITUTION
(thousand tons)

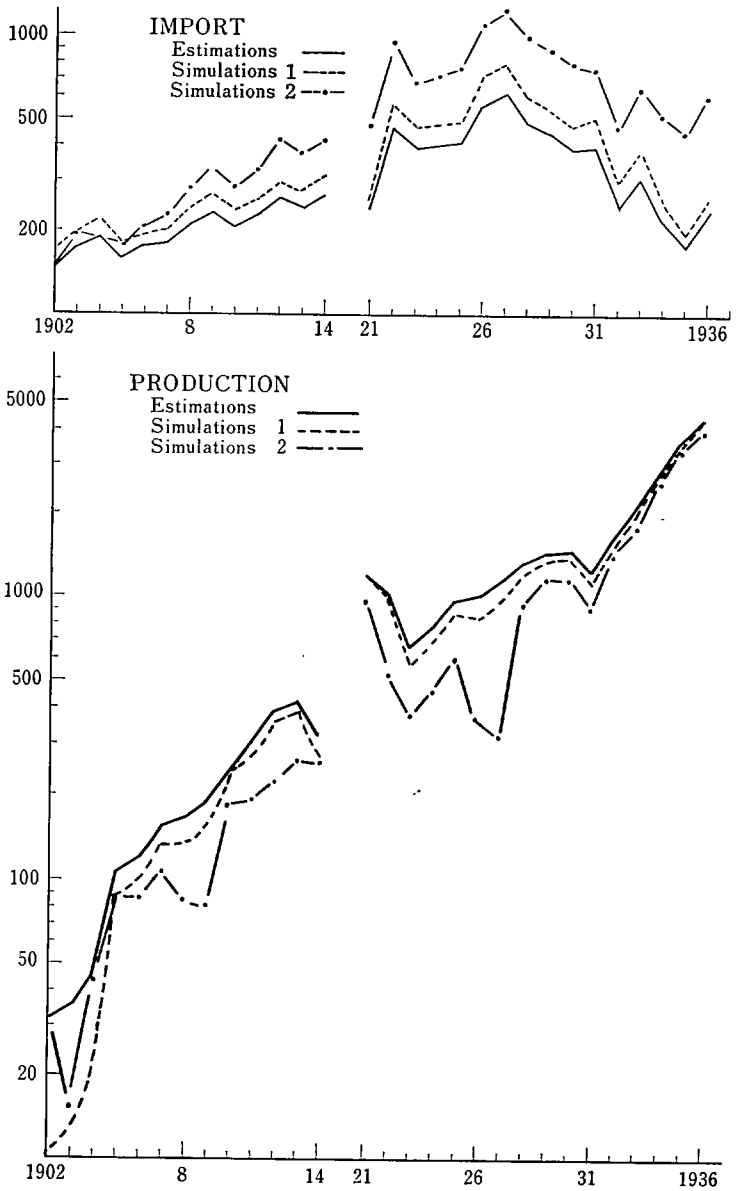


FIG. 7. PROCESS OF EXPORT PROMOTION (million tons)