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FACTOR PRODUCTIVITY AND INTERNATIONAL COMPETITIVENESS: A COMPARATIVE STUDY OF THE U.S. AND JAPANESE STEEL INDUSTRIES

The Ohio State University PH.D. 1981

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FACTOR PRODUCTIVITY AND INTERNATIONAL COMPETITIVENESS: A COMPARATIVE STUDY OF THE U.S. AND JAPANESE STEEL INDUSTRIES

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By
Yew-ky Kim, B.S., M.S., M.A.

* * * * *

The Ohio State University
1981

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FIELDS OF STUDY

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Studies in International Trade

Studies in Econometrics

Studies in Mathematical Economics and Economic Theory

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LIST OF ABBREVIATIONS

AISI: American Iron and Steel Institute

BOF: Basic Oxygen Furnace

CC: Continuous Casting

COWPS: Council on Wage and Price Stability

EC (9): European Community 9 Countries

ECE: Economic Commission for Europe, The United Nations

ECLA: Economic Commission for Latin America, The United Nations

EF: Electric Furnace

FTC: Federal Trade Commission

IISI: International Iron and Steel Institute

JISF: Japan Iron and Steel Federation

J-K: Jishu-Kanri

MT: Metric Ton (= 2,204.6 pounds)

N/A: Not Available

NT: Net Ton (= 2,000 pounds)

OECD: Organization for Economic Cooperation and Development

OH: Open Hearth

OTA: Office of Technology Assessment

PHB: Putnam, Hayes and Bartlett

PPM: Part Per Million

VRAs: Voluntary Restraint Agreements

CHAPTER I

INTRODUCTION

The Problem

The U.S. steel industry has received a great deal of attention in recent years from government policy-makers, industry analysts, academia as well as from the general public. The main reason for that attention has been the decline in the international competitiveness of U.S. steel producers relative to foreign steel producers, especially those of Japan.

In 1950, the U.S. share of world raw steel production was 46.7%, and that of Japan only 2.6%. Since then Japan's share has increased steadily, reaching 6.4% in 1960, 15.7% in 1970, 17.1% in 1973, and 15.7% in 1976, while the U.S. share declined almost continuously since 1950, reaching 16.9% in 1977. (See Table 27.)

Until 1958, the U.S. had been a net exporter of steel mill products, exporting 3 to 6% of its net industry shipments. Since 1959, the U.S. has been a net importer of steel mill products. Imports as a percent of apparent domestic consumption increased from 6.1% in 1959 to 17.8% in 1977. (See Table 28.)

U.S. imports of steel mill products by country of origin also experienced some dramatic changes. The share of Japan in U.S. imports increased from 18% in 1960 to 56% in 1976, and that of the European Community (EC 9 countries) decreased from 62% in 1960 to 22% in 1976, while the share of the rest of the world remained stable, ranging from 10 to 22%. (See Table 29.)

Voluntary Restraint Agreements (VRAs) were in effect between the U.S. and Japan, and the U.S. and EC for three years beginning with 1969 and were renewed until 1974 with some revisions.[1]

On the other hand, the U.S. share in Japanese exports increased from about 7% in 1956 to 36.4% in 1959, reaching a peak of 52.6% in 1968 and declining from then on to 21.7% in 1977. (See Table 30.)

Japanese exports as a percent of production increased from 13.3% in 1959 to 38.5% in 1977. (See Table 31.)

The increased U.S. imports captured the Carter Administration's attention and in 1977 the Inter Agency Task Force, headed by the Under Secretary of the Treasury

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[1] The U.S. State Department negotiated with the governments of Japan and the European Community, and reached agreements commonly known as Voluntary Restraint Agreements. Under VRAs, steel imports from Japan and the European Community were limited to 5.75 million metric tons each in 1969, with an annual increase of 5% in 1970 and 1971. VRAs were renewed until 1974 and the United Kingdom was included.

Anthony M. Solomon, was created and a Trigger Price Mechanism was established.[2]

Many authors have examined the competitiveness of the U.S. steel industry in the international market, focusing on various issues such as 'cheap foreign labor', government subsidy, dumping, environmental regulations and others. These studies include the works of Kawahito [1972], Council on Wage and Price Stability (COWPS) [1975], [1977], Putnam, Hayes and Bartlett (PHB) [1977], [1978], Federal Trade Commission (FTC) [1977], Mueller and Kawahito [1978], [1979], Tarr [1979], and Office of Technology Assessment (OTA) [1980].

Among these, the COWPS study [1977] and the FTC study [1977] are probably the most comprehensive studies in that they examined various aspects of the U.S. steel industry problem. The PHB study [1978] tried to demonstrate that Japanese steel producers were engaged in dumping, but this issue was refuted by Tarr [1979] and other studies, especially by Mueller and Kawahito [1979]. Most of the studies concluded that the difference in employment costs

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[2] A Trigger Price Mechanism sets the minimum prices for all basic steel mill product imports. Imports below the minimum could trigger an investigation into possible dumping charges, which could lead to imposition of heavy penalty duties on the imports.

between the U.S. and foreign countries, especially Japan, is the major factor influencing the competitiveness of the U.S. steel industry.

With respect to technological aspects of the problem, Adams and Dirlam [1966], Ault [1973], and Baumann [1974] have argued that U.S. steel firms have not adopted new technology very rapidly, and thereby suffered a relative decline in technical efficiency vis-à-vis firms in other countries. This view was challenged by McAdams [1967], and Huettner [1974], and by the U.S. steel industry.[3] The OTA study [1980] is one of the major studies dealing with the technology problem rather extensively.

However, these studies have dealt mostly with the adoption of new technologies such as basic oxygen furnace, electric furnace, and continuous casting processes, which make up only a fraction of the total cost of production. Moreover, those studies have relied heavily on descriptive methods without clearly explaining the linkages between the relevant variables. Virtually no work has been done using a formal model.

Plan of the Study

The purpose of this study is, first, to find out the nature of technological changes in the U.S. and Japanese

---

[3] See Langenberg [1978], p. 6, for example.

steel industries and explain why the steel industries of the two countries have experienced the observed patterns of technical changes. Secondly, we wish to examine whether or not the observed patterns of technical changes significantly influenced the flow of steel trade between the two countries. Thirdly, we attempt to test the Kennedy-Weizsäcker theory and Fellner-Hicks-Ahmad theory of induced bias in invention with respect to the steel industries of the U.S. and Japan. According to Kennedy [1964] and Weizsäcker [1966], the shares of individual inputs in the total cost determine the direction of technological progress, while Fellner [1962], Hicks [1964], and Ahmad [1966] have argued that relative factor prices play an important role in determining the direction of technological progress. The outline of the study is as follows:

In chapter II, the long-run trends in U.S. comparative advantage in steel production are examined. For this purpose, we compare the performances of the major steel producing countries of the world in terms of raw steel production, exports, and imports. Various statistics dating back to the 1920's will be examined.

In chapter III, we develop a formal model which will be used to determine the nature of technological changes which took place in the U.S. and Japanese steel industries, and also to estimate total factor productivity growth of the steel industries of the two countries. Production functions employing factor-augmenting technical change with constant returns to scale are utilized. The effects of technical changes are captured by decomposing the relative change in the unit cost of production into two components: change in the unit cost due to changes in factor prices and change in the unit cost due to technological progress.

In chapter IV, we present the results of our estimation based on the theoretical model developed in chapter III. Rates of factor-augmenting technical changes are estimated and a comparison is made between the U.S. and Japanese steel industries by calculating the index of total factor productivity growth. Regression analysis is used to test whether or not the difference in total factor productivity growth has any significant effects on the flow of steel trade between the two countries. We will also examine the two major theories of bias in induced innovations, the Kennedy-Weizsäcker theory and the Fellner-Hicks-Ahmad theory, for the steel industry.

In chapter V, we discuss various factors which can explain our empirical results. The role of government with respect to the steel industry is examined. Various aspects of government involvement such as subsidies, price controls, environmental regulations, and others are examined. Also other factors which could affect the competitiveness of the steel industries will be carefully investigated. Those factors include: adoption of technologies, labor-management relations, the use of computers, and others.

In chapter VI, we conclude our study with a summary description and some policy implications together with suggestions for future research. The significance of the present study is that it is one of the first attempts to quantify the situation in the steel market, and also that the technique developed in this study can be applied to an analysis of international competitiveness in other industries.

CHAPTER II

LONG-RUN TRENDS IN U.S. COMPARATIVE ADVANTAGE IN STEEL PRODUCTION

In this chapter, we attempt to assess the relative long-term position of the U.S. steel industry in the world market. To do this, we will examine various statistics including raw steel production, exports, and imports dating back to the 1920's and compare the changes in the average shares decade by decade.

Raw Steel Production

We compared ten-year average shares of raw steel production by the major steel producing countries in the world for the period 1920-1976, except for 1939-1943, for which period no data are available. First, we turn to the U.S.-Japan comparison.

During the 1920's, the U.S. maintained about a 50% share of world raw steel production, while the Japanese share was only 1.67%. Over the 1930's, the U.S. share declined to less than 35%. On the other hand, the Japanese share increased to 4.53%.

The 1940's statistics were greatly affected by the events of World War II. For the period 1944-50, the

Japanese share of raw steel production decreased to 1.84%, and that of the U.S. increased to 53.03% from 34.26% in the 1930's.

The decade of the 1950's is considered a period of recovery from World War II. For this period, the Japanese share of raw steel production increased to over 4% from 1.84% in the 1940's, while the U.S. share decreased slightly to 37.07%.

If we look at the raw steel shares of the U.S. and Japan for the 1960's and 1970's, Japan's share accelerated its increase to almost 11%, while that of the U.S. drastically declined to about 25% in the 1960's; Japan's share continued to increase and surpassed 16% and the U.S. share fell to lower than 20% over the period 1971-1976.

The average shares of the major steel producing countries' raw steel production as a percent of the world raw steel production are shown in Table 1. (See also Table 32 for annual data.) The U.S. and Japanese shares of raw steel production in the world are shown in Figure 1.

During the 1920's, the German share was, on the average, close to 16% and about the same level was maintained in the 1930's, but it experienced a drastic decline during the World War II period. After World War II, it recovered a little during the 1950's. However, the recovery was not sufficient to keep Germany at about the same share of raw

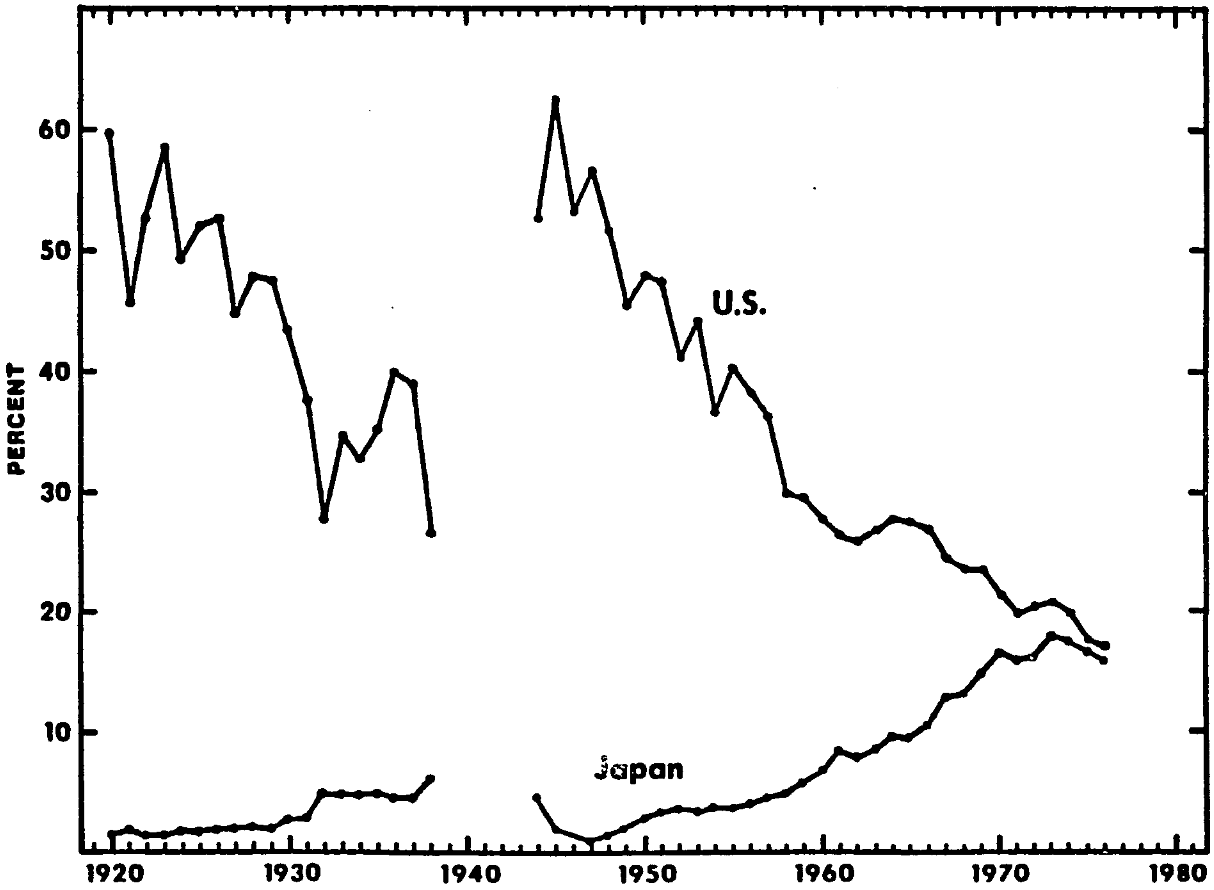

Figure 1

Share of Raw Steel Production in the World steel production as during the pre-World War II period. In recent years, its share declined steadily to below 10%.

The British share of the world raw steel production maintained the most stable pattern among the major steel producers in the world. Its average share for the 1920's was about 8.5%. It is one of the least affected countries from World War II. However, after World War II, its share has been almost continuously declining.

Table 1

Average Shares of Major Steel Producers in World Raw Steel Production (%)

Period	U.S.	Japan	Germany[a]	U.K.	U.S.S.R.
1921-30	49.38	1.67	15.74	8.47	2.55
1931-38	34.26	4.53	15.78	9.83	12.15
1944-50	53.03	1.84	5.71	9.70	11.84
1951-60	37.07	4.17	10.10	7.58	17.81
1961-70	25.36	10.97	9.34	5.60	20.62
1971-76	19.27	16.48	8.00	3.72	21.02

[a] Including W. Germany, E. Germany, and Saar

Source: Eurostat, Iron and Steel Yearbook, 1976, 1978
AISI, Annual Statistical Report, various years

The U.S.S.R. is another country whose steel production was not very much affected by World War II. The most significant increase in the average share came about over the 1930's and the 1950's. During the 1960's and the 1970's, it experienced a steady increase in the average shares, surpassing 20% of the world raw steel production.

We also compared the average shares of the major steel producing countries in the free world, excluding the Soviet Union. The rationale for such an observation would be that the Soviet Union is not actively engaged in steel trade with the rest of the world. Figures excluding the U.S.S.R. show roughly the same pattern of fluctuations as the shares in the total world production. The average shares of the major steel producing countries' raw steel production relative to total free world production are shown in Table 2. (See also Table 33 for the annual data.)

Table 2

Average Shares of Major Steel Producers in Free World Raw Steel Production (%)

Period	U.S.	Japan	Germany	U.K.
1921-30	50.54	1.73	16.17	8.68
1931-38	38.96	5.18	17.99	11.21
1944-50	60.10	2.08	6.45	11.01
1951-60	44.97	5.10	12.32	9.22
1961-70	31.96	13.84	11.77	7.06
1971-76	24.32	20.82	10.11	4.68

Source: Eurostat, Iron and Steel Yearbook, 1976, 1978
AISI, Annual Statistical Report, various years

Trade Performances

In order to examine how the U.S. and Japanese steel producers have fared in the international market, we compared the average shares of exports as a percent of total production (or in some cases, net shipments) and also the average shares of imports as a percent of apparent domestic steel supply. The average shares of exports as a percent of production are shown in Table 3. (See also Table 34 and Table 35.) The U.S. and Japanese exports of steel as a percent of production are shown in Figure 2.

Table 3

Average Shares of Exports as a Percent of Production

Period	U.S.[a]	Japan
1921-30	N/A	9.76
1931-40	5.87	15.72
1941-50[b]	6.22	4.79
1951-60	4.60	17.23
1961-70	3.52	22.80
1971-76	3.67	35.05

[a] For the U.S., exports as a percent of net shipments, except for the period 1931-40

[b] For the U.S., the period is 1943-50.

Source: AISI, Annual Statistical Report, various years
JISF, Statistical Yearbook, various years

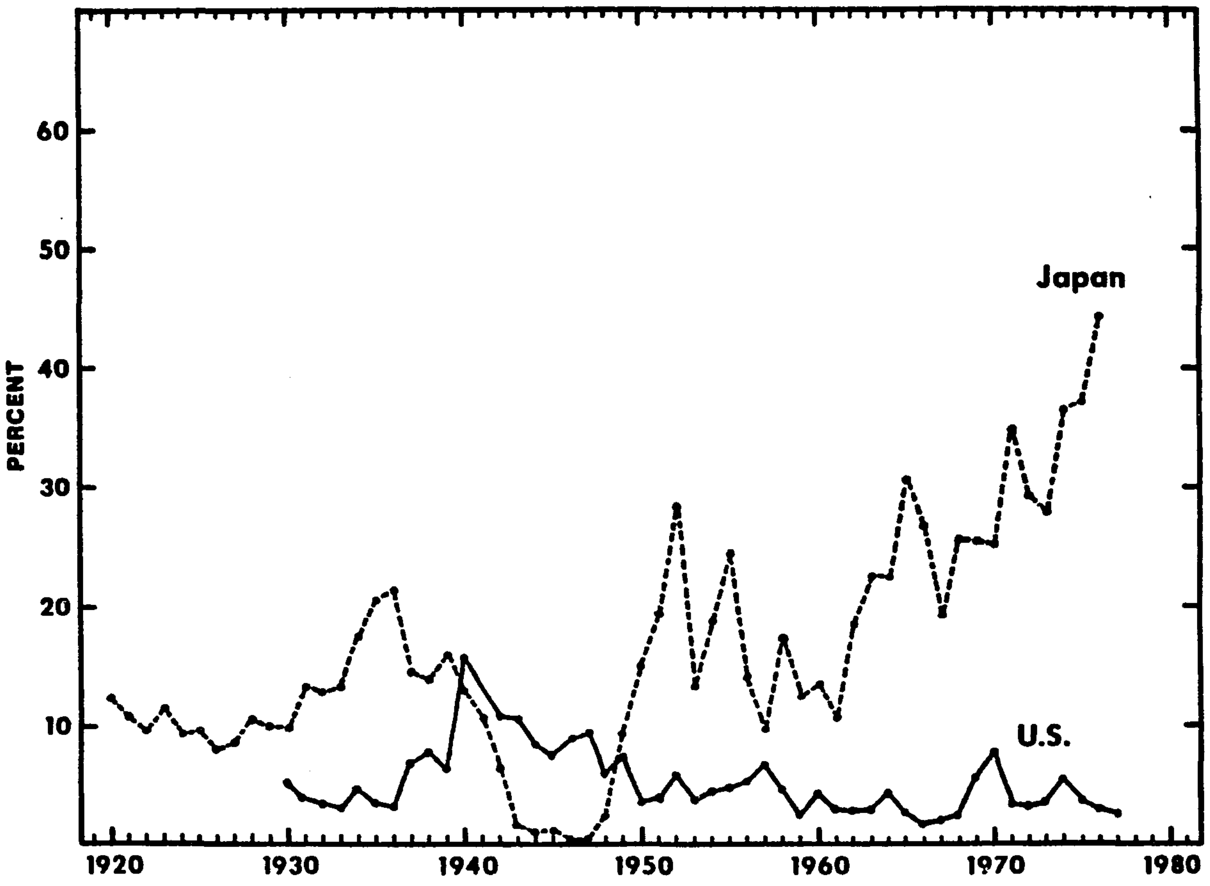

Figure 2

Exports of Steel as a Percentage of Production

The export performance of Japan has improved continuously over time, except for the period 1943-50, which is the period including World War II. (See also Table 34.) Over the whole period considered, U.S. average shares have been consistently lower than those of Japan except for the period 1943-50 again.

If we take a look at the statistics on imports and apparent domestic steel supply, there is a sharp contrast in the pattern of changes in import dependency between the U.S. and Japan. The average shares of imports as a percent of apparent domestic steel supply are shown in Table 4. (See also Table 34 and Table 35.) The U.S. and Japanese imports of steel as a percent of apparent consumption are shown in Figure 3.

Table 4

Imports as a Percent of Apparent Domestic Steel Supply

Period	U.S.	Japan
1921-30	N/A	45.17
1931-40	0.89	15.48
1941-50[a]	0.24	1.72
1951-60	2.64	2.70
1961-70	10.21	0.50
1971-76	14.65	0.24

[a] For the U.S., the period is 1943-50.

Source: AISI, Annual Statistical Report, various years
JISF, Statistical Yearbook, various years

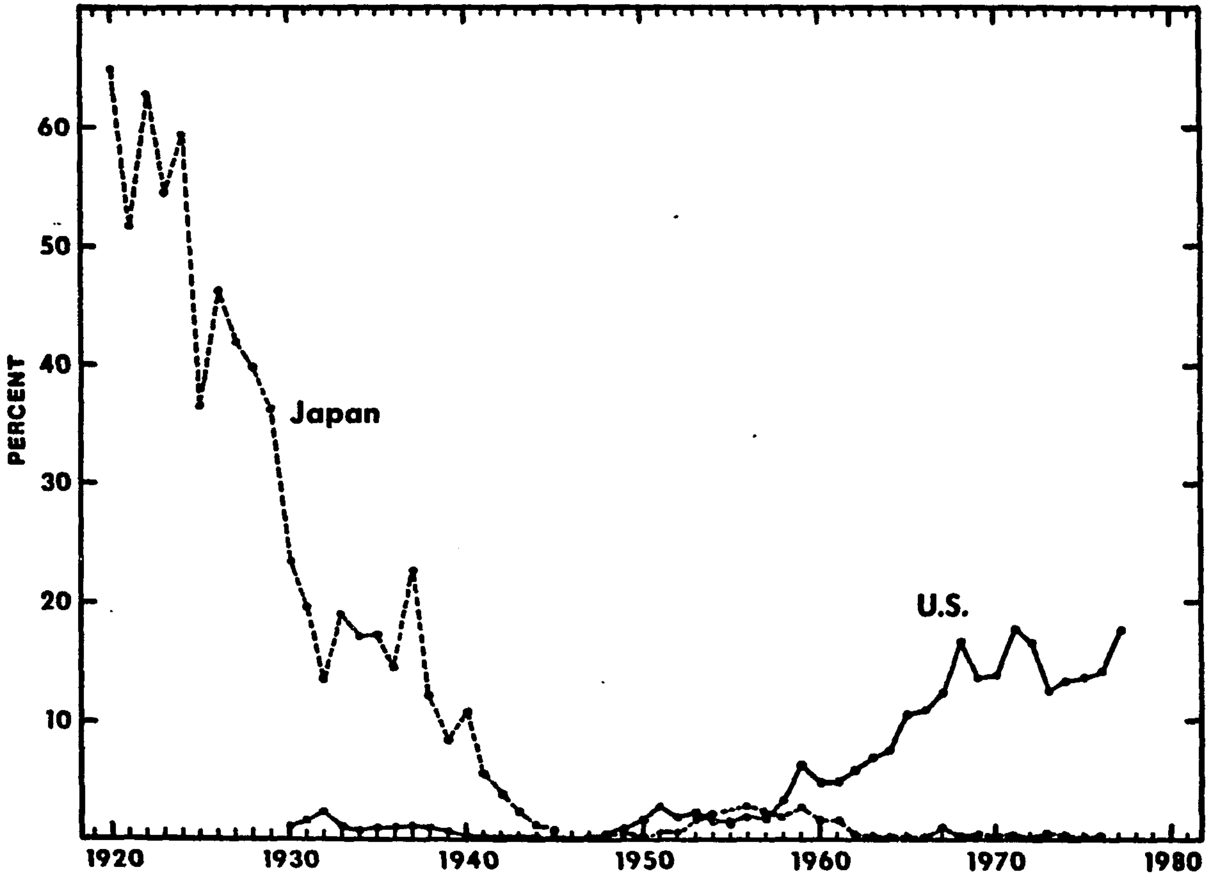

Figure 3

Imports of Steel as a Percentage of Apparent Consumption

Japan relied on imported steel during the early part of the 1920's (as much as 45% for its domestic consumption). Except for a slight disruption during the 1950's, Japan's import dependency was reduced dramatically, dropping to a negligible percentage in the 1960's and 1970's. On the other hand, the U.S. dependence on imported steel for domestic consumption showed a continuous increase, except for the period 1943-50, from 0.89% in the 1930's to almost 15% in the 1970's. (See also Table 35.)

Table 5

Average Amount of Net Exports (Crude Steel Equivalent)
(1,000 MT)

Period	U.S.	Japan
1930-39	+ 1,428	- 2
1941-50[a]	+ 5,447	+ 159
1951-60	+ 1,860	+ 1,493
1961-70	-19,019	+12,178
1971-76	-14,561	+36,717

[a] For the U.S., the period is 1943-50.

Source: AISI, Annual Statistical Report, various years
JISF, Statistical Yearbook, various years

In terms of net exports, measured in thousands of metric tons of crude steel equivalent, the U.S. experienced positive net exports until the 1950's, but began to have increasingly large amounts of negative net exports over time beginning with the 1960's. The average amounts of U.S. net exports increased only during the 1940's. (See Figure 4 for the fluctuations in net exports of the U.S. and Japan.)

On the other hand, the average amounts of Japanese net exports showed a continuous increase over time, although there are some fluctuations on a year to year basis. The average amounts of net exports, measured in thousands of metric tons of crude steel equivalent, are shown in Table 5.

General Trends in U.S. Comparative Advantage

Our observations on raw steel production and trade performance of the U.S. in comparison with other major steel producers in the world, especially Japan, point to the following facts:

U.S. comparative advantage in steel production experienced a decline starting as early as the 1920's. That trend was temporarily disrupted by World War II. During World War II, the steel production facilities of Japan were severely damaged. It lost about 1/4 of its pig iron capacity, 14% of ordinary steel capacity, and over 20% of special steel capacity. (See Table 6.)

It appears that the 1950's were the crucial period for the U.S. steel industry. The reasoning here is that

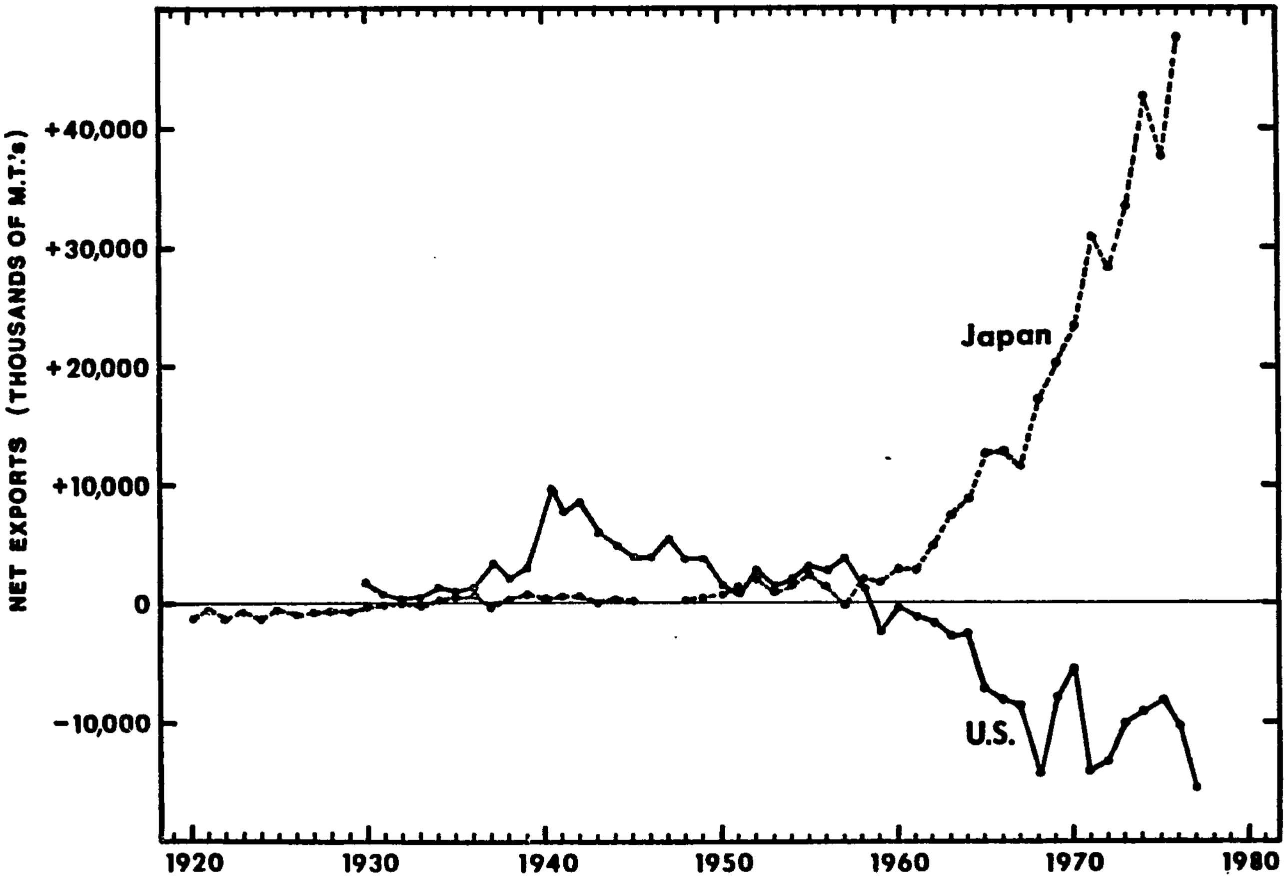

Figure 4

Net Exports (Thousands of Metric Tons)

since U.S. comparative advantage started declining even before World War II relative to other major competitors in the world, and such a declining trend was interrupted by World War II, the U.S. steel industry should have performed better during the recovery period, namely the 1950's, if it were to maintain a comparative advantage in steel production. But apparently the U.S. steel industry's performance for the given period was not sufficient to maintain its comparative advantage in steel production.

Table 6

Rates of War Damage on the Japanese Steel Industry
(1,000 MT)

	Production[a] Capacity	Damaged Capacity	Percent of Damaged Capacity
Pig Iron	3,461	849	24.5
Ordinary Steel	4,467	645	14.4
Special Steel	1,951	234	22.2

[a] End of 1944

Source: K. Kawahito [1972]

Why has U.S. comparative advantage in steel production declined relative to other major steel producers after World War II and what caused it? We will attempt to answer those questions in the subsequent chapters.

CHAPTER III

THE THEORETICAL MODEL

Brief Review of Literature

Our first goal is to examine the nature of technological changes that have occurred in the U.S. and Japanese steel industries and then to compare and contrast them. The literature on technological change is extensive. Solow [1957], Jorgenson and Griliches [1967], Christensen and Jorgenson [1969], [1970], Sato [1970], Caves, Christensen and Swanson [1978], Gollop and Jorgenson [1979], Gollop and Roberts [1979], and Wills [1979] are only some of the studies relevant to the present analysis.

The basic framework for measuring technical change for an aggregate, constant-returns-to-scale, production function was first developed by Solow [1957]. He decomposed the growth in per capita output into a change in per capita capital and a technological progress residual, in which the former represents a movement along the production function and the latter a shift of the production function. Many authors have since utilized Solow's framework and continued to distinguish between the two kinds of changes. Recently the use of translog function became very popular in the measurement of technological changes for its flexibility in dealing with specific forms of production functions. However, using a specific form of production function imposes à priori restrictions.

The main difference between the methodologies of previous studies and ours is that those analyses almost invariably used specific functional forms such as Cobb-Douglas, CES and translog functions. We do not need to specify the functional forms to estimate the rates of technical changes. Previous authors had to rely on specific functional forms because of the so-called, "Impossibility Theorem". The theorem states that under constant returns to scale one cannot estimate the factor-augmenting rates of technical changes without knowing the elasticity of substitution. Sato [1970] used a CEDD production function for his estimation of technical progress to avoid the impossibility theorem.[4] In our study, the same difficulty is overcome by using cost data which, by virtue of duality, contain 'indirect' information about the production function.

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[4] For a fuller discussion of the impossibility theorem, see Sato [1970].

The Basic Model

We begin by postulating a production function embodying factor-augmenting technological changes for the representative steel firm in both countries. With two factors, capital and labor, the production function takes the form[5]

(3.1) $X = F(A(t)K, B(t)L)$

where $A(t)$ and $B(t)$ are functions of time, t, representing capital and labor augmentation, respectively.[6] If r and w denote the rental rate on capital and the wage rate, respectively, the total cost of production is

(3.2) $C = rK + wL.$

Suppose that the representative steel firm tries to minimize the total cost of production subject to the technological constraint given by (3.1). From the first order conditions, the factor demand funtions for K and L are derived:

---

[5] Production functions are assumed to satisfy the following: They are homogeneous of degree one and twice continuously differntiable everywhere in the domain of definition. John S. Hekman [1978] estimated five-factor cost functions for the U.S. steel industry. His empirical findings suggested constant-returns-to-scale production functions.

[6] A and B are functions of time, t, and $A(0)=B(0)=1$, $A(t)>0$, $B(t)>0$ for all t. Technological change is capital-saving or capital-using according as $\dot{A}(t)/A(t)$ is positive or negative, where "." denotes time derivative.

(3.3) $K = K(r, w, A, B)X$

(3.4) $L = L(r, w, A, B)X$

where X is separable from K(r, w, A, B) and L(r, w, A, B) because of the linear homogeneity of F.

The unit cost U of production is

(3.5) $$U = C/X = (rK(r, w, A, B)X + wL(r, w, A, B)X)/X = U(r, w, A, B).$$

Note that (3.1) can be rewritten as

(3.6) $X = B(t)Lf(A(t)k/B(t))$

where $f(.) = F(.,1)$ and $k = K/L$.

Differentiating (3.5) with respect to t, we obtain

(3.7) $$\dot{U}/U = S_K\dot{r}/r + S_L\dot{w}/w - (Akf'/Bf)\dot{A}/A - (1 - Akf'/Bf)\dot{B}/B$$

where $S_K = rk/(rk + w)$ is the share of capital in the unit cost, $S_L = w/(rk + w)$ is the share of labor in the unit cost, and "." denotes the time derivative.

Making use of

(3.8) $w/r = (Bf - Akf')/Af'$

which follows from the first order conditions, we obtain

(3.9) $Akf'/Bf = S_K$

(3.10) $1 - Akf'/Bf = S_L$.

Substituting (3.9) and (3.10) into (3.7), we obtain

(3.11) $\dot{U}/U = S_K\dot{r}/r + S_L\dot{w}/w - S_K\dot{A}/A - S_L\dot{B}/B$.

Equation (3.11) expresses the rate of change in the unit cost in terms of the rate of change in the rental rate, and that in the wage rate weighted by the shares of capital and labor, and the rate of capital augmentation and that of labor augmentation similarly weighted by the shares of capital and labor. Furthermore, (3.11) clearly separates two distinct causes of change in the unit cost: change in the unit cost due to the changes in factor prices and change in the unit cost due to technical changes.

Equation (3.11) can be used as a basis for estimating the rates of technical changes if we note the fact that the variables $\dot{U}/U$, $\dot{r}/r$, $\dot{w}/w$, S_K and S_L are observable from cost data. Rewriting (3.11) as

(3.12) $\dot{U}/U - S_K\dot{r}/r - S_L\dot{w}/w = -(\dot{A}/A)S_K - (\dot{B}/B)S_L$,

we define $V = \dot{U}/U - S_K\dot{r}/r - S_L\dot{w}/w$

$\alpha_K = -\dot{A}/A$

$\alpha_L = -\dot{B}/B$.

Then we have

(3.13) $V = \alpha_K S_K + \alpha_L S_L$.

The term V may be called the 'factor-price-compensated' changes in the unit cost, because it represents the net change in the unit cost due strictly to technical changes. Thus, estimating $\dot{A}/A$ and $\dot{B}/B$ reduces to finding the coefficients when V is regressed on S_K and S_L.

Now we extend our model to a multifactor production process incorporating several major inputs involved in steel production. These are: capital (K), labor (L), raw material (M), and energy inputs (E).[7]

The production function, in this case, takes the form

$$X = F(A_K K,\ A_L L,\ A_M M,\ A_E E) \tag{3.14}$$

where A_K, A_L, A_M and A_E are functions of time, t, representing capital, labor, raw material, and energy augmentation, respectively.

Let P_K, P_L, P_M and P_E be the prices of capital, labor, raw material and energy inputs, respectively. Then the multifactor version of equation (3.11) is:

$$\begin{aligned} \dot{U}/U = {} & S_K(\dot{P}_K/P_K - \dot{A}_K/A_K) + S_L(\dot{P}_L/P_L - \dot{A}_L/A_L) \\ & + S_M(\dot{P}_M/P_M - \dot{A}_M/A_M) + S_E(\dot{P}_E/P_E - \dot{A}_E/A_E) \end{aligned} \tag{3.15}$$

where S_M and S_E are the shares of raw material and energy inputs in the unit cost, respectively.

Define $V = \dot{U}/U - S_K\dot{P}_K/P_K - S_L\dot{P}_L/P_L - S_M\dot{P}_M/P_M - S_E\dot{P}_E/P_E$

$$\alpha_K = -\dot{A}_K/A_K$$

$$\alpha_L = -\dot{A}_L/A_L$$

$$\alpha_M = -\dot{A}_M/A_M$$

$$\alpha_E = -\dot{A}_E/A_E.$$

---

[7] Iron ore and scrap are aggregated into a single input, raw material. Energy inputs include coking coal, fuel oil, electric power, noncoking coal for Japan; for the U.S., natural gas is added. See Appendix C for the construction of the Laspeyre price indexes of the aggregated inputs, M and E.

Then we have

$$(3.16) \qquad V = \alpha_K S_K + \alpha_L S_L + \alpha_M S_M + \alpha_E S_E.$$

Equation (3.16) is used as our basic regression equation. Because of the way we defined our regression equation, the rate of augmentation for factor i is minus one times the estimated value of α_i, i = K, L, M, E.

Variations of the Basic Model

The basic model developed in the previous section enables us to get independent estimates of the rates of factor augmentation. To the extent that these rates can differ from each other, we have possibilities of 'biases' in factor augmentation. It is interesting, therefore, to develop theoretical models which expressly deal with the question of biases in technological changes.

There are two major theories in the literature. Kennedy [1964] and Weizsäcker [1966] introduced a technological transformation function called the innovation possibilities curve. They argue that changes in relative factor prices are not essential for an induced bias in innovations. Rather, they claim that what determines the direction of technical change is the relative size of the shares of individual factors.

On the other hand, Fellner [1962], Hicks [1964] and Ahmad [1966] have argued that the relative factor prices are important in determining the direction of technical changes. The basic argument is that when entrepreneurs are faced with a relative increase in the price of a particular input, they will substitute cheaper inputs for more expensive ones and concentrate on innovations which will save more expensive inputs.

Let us first look at the Kennedy-Weizsäcker (K-W) model. In a two-factor production process embodying factor-augmenting technical changes, the rate of change in the unit cost is expressed as in equation (3.11). In the K-W model, $\dot{r}/r = \dot{w}/w = 0$. That is, factor prices are treated as having already been 'compensated' in the configuration of the change in the unit cost. So equation (3.11) reduces to

(3.17) $\dot{U}/U = - S_K\dot{A}/A - S_L\dot{B}/B.$

In this model, entrepreneurs are supposed to maximize the proportionate reduction in the unit cost subject to the innovation possibilities function. That is, maximize

(3.18) $V = - \dot{U}/U = S_K\dot{A}/A + S_L\dot{B}/B$

subject to

(3.19) $\dot{B}/B = \phi(\dot{A}/A), \phi' < 0, \phi'' < 0.$

Equations (3.18) and (3.19) yield

(3.20) $\phi'(\dot{A}/A) = - S_K/(1 - S_K).$

Total differentiation of (3.20) with respect to S_K gives us

(3.21) $d(\dot{A}/A)/dS_K = -1/(1-S_K)^2\phi''$.

Since $\phi'' < 0$, we have $d(\dot{A}/A)/dS_K > 0$. Similarly, we can show that $d(\dot{B}/B)/dS_K < 0$. So, if the share of capital is greater than the share of labor, the rate of capital augmentation will be, on balance, greater than the rate of labor augmentation. i.e., $S_K \gtrless S_L$ implies $(\dot{A}/A)^* \gtrless (\dot{B}/B)^*$, where * denotes the optimum rate.

We now extend the K-W model into a multifactor model. More specifically, we introduce four factors of production: K, L, M, and E. Suppose, as above, that entrepreneurs try to obtain a maximum level of the 'factor-price-compensated' reduction in the unit cost. That is, maximize

(3.22) $$\begin{aligned} V &= -(\dot{U}/U - S_K\dot{P}_K/P_K - S_L\dot{P}_L/P_L - S_M\dot{P}_M/P_M - S_E\dot{P}_E/P_E) \\ &= S_K\dot{A}_K/A_K + S_L\dot{A}_L/A_L + S_M\dot{A}_M/A_M + S_E\dot{A}_E/A_E \end{aligned}$$

subject to

(3.23) $\dot{A}_K/A_K = \Psi(\dot{A}_L/A_L, \dot{A}_M/A_M, \dot{A}_E/A_E)$.

In this case, the optimal choice of factor-augmenting technical progress is determined by the conditions:

(3.24) $\partial(\dot{A}_K/A_K)/\partial(\dot{A}_L/A_L) = -S_L/S_K$

(3.25) $\partial(\dot{A}_K/A_K)/\partial(\dot{A}_M/A_M) = -S_M/S_K$

(3.26) $\partial(\dot{A}_K/A_K)/\partial(\dot{A}_E/A_E) = -S_E/S_K$.

This means that the conclusion of the K-W theory still holds in the multifactor case with the modified assumption of the 'factor-price-compensated' reduction in the unit cost.

The K-W model postulates that the entrepreneurs respond to changes in factor shares in 'determining' the biases in factor augmentation. Alternatively, Fellner, Hicks and Ahmad postulate that the entrepreneurs respond to changes in relative factor prices. Their arguments can be summarized as follows:

It is assumed that the amount of a factor saved through innovation is a function of the amount of the other factor saved. Let K_s and L_s denote the amounts of capital and labor saved by innovations, respectively. Then the total cost saved is

(3.27) $C_s = rK_s + wL_s$

where the amount of labor saved is related to the amount of capital saved by

(3.28) $K_s = K_s(L_s), K_s' < 0, K_s'' < 0.$

Maximizing (3.27) subject to (3.28) yields

(3.29) $dK_s/dL_s = - w/r.$

Equation (3.28) corresponds to the innovation possibilities curve in the K-W theory. Equation (3.29) implies that the greater the relative price of capital over labor, the larger the amount of capital saved relative to the amount of labor saved will be.

The multifactor version of (3.29) is represented by

(3.30) $\partial K_s/\partial L_s = - P_L/P_K$

(3.31) $\partial K_s/\partial M_s = - P_M/P_K$

(3.32) $\partial K_s/\partial E_s = - P_E/P_K$

where M_s and E_s denote the amounts of M and E saved through innovations, respectively.

CHAPTER IV

EMPIRICAL RESULTS

In the first section, we estimate the rates of factor-augmenting technical changes for each of the factors K, L, M and E based on the regression equation developed in chapter III. In the second section, we construct the index of total factor productivity growth using the results of the first section. The third section discusses the effects of the difference in total factor productivity growth on the U.S.-Japan steel trade. In the fourth section, we will perform empirical tests of the Kennedy-Weizsäcker theory and the Fellner-Hicks-Ahmad theory of bias in induced innovations for the case of the U.S. and Japanese steel industries.

Estimation of the Rates of Factor-augmenting Technical Changes

We used equation (3.16) to estimate the coefficients representing the rates of factor-augmenting technical changes. Our data consists of yearly statistics for the time period 1956-1976. We found that the iron and steel industry is very sensitive to business cycles and other outside shocks. For this reason, two dummy variables were added: D_1, representing an unusual decrease in the unit cost, and D_2, representing an unusual increase in the unit cost. Here an unusual change refers to a substantial deviation from either the long-term average or from previous period.

For the U.S., 1958, 1960, 1970, 1974, and 1975 were the recession years.[8] Although 1967 was not a recession year for the economy as a whole, the steel industry experienced an unusual reduction in output due to slackened demand, and hence an increase in the unit cost. On the other hand, for the U.S., 1959 saw a 116-day labor strike,[9] and 1973 and 1976 were the years of unusual output growth, and hence a reduction in the unit cost relative to normal situation.

Actually, recessions and labor strikes produced opposite effects on changes in the unit cost. In a period of recession such as 1958, labor costs were reduced due to increased layoffs, but output also declined so that the unit labor costs actually rose and the unit total cost generally increased. On the other hand, in a period of labor strike such as 1959, there was an actual reduction

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[8] OECD Main Economic Indicators

[9] See Weiss [1971], pp. 302-303.

in the unit labor cost, and after the settlement of the labor dispute, production picked up. As a result, there was a reduction in the unit cost between 1958 and 1959. (See Table 36.)

For Japan, 1957, 1961, 1970, 1971 and 1974 were the recession years.[10] On the other hand, 1958 and 1959 saw an unusual cost reduction due to material and energy cost reductions. During 1964, 1966, 1973 and 1976, the Japanese steel industry experienced an unusual growth in output mainly due to increased demand, and hence a reduction in the unit cost relative to normal situations. (See Table 37.)

The regression analysis covers the period 1956-1976. The resulting estimated equations are summarized in Table 7. All the coefficients are significant at the 5% significance level, except for $\hat{\alpha}_L$ for the U.S., which is significant at the 10% significance level. By way of construction, the rates of factor-augmenting technical changes are minus one times the estimated coefficients. The estimated rates of technical changes are presented in Table 8.

The results of our regression analysis indicate that there is some difference in the pattern of technical changes between the U.S. and Japan. It shows that the U.S

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[10] OECD Main Economic Indicators

Table 7

Estimated Coefficients of Factor-augmenting Technical Changes

Dependent Variable: V

Independent Variables: S_K, S_L, S_M, S_E

	U.S.	Japan
$\hat{\alpha}_K$	-.646 (-2.79)[a]	.812 (2.32)
$\hat{\alpha}_L$	.098 (1.38)	-.992 (-2.68)
$\hat{\alpha}_M$	-.404 (-3.74)	-.246 (-3.31)
$\hat{\alpha}_E$	.556 (9.73)	.508 (3.35)
$\hat{\mu}_1$[b]	-.072 (-7.47)	-.038 (-2.23)
$\hat{\mu}_2$	.057 (7.52)	.064 (3.64)
D.W.	2.08	2.01
R^2	.96	.82

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[a] The figures in parentheses are the t-ratios.

[b] $\hat{\mu}_1$ and $\hat{\mu}_2$ are, respectively, the estimated coefficients of D_1 and D_2.

has adopted capital-saving and labor-using technologies, while Japan has adopted labor-saving and capital-using technologies. With respect to raw material and energy, the two countries experienced the same pattern of technical changes, namely, material-saving and energy-using technical changes. We attempt to investigate the causes of such changes in subsequent chapters.

Table 8

Estimated Rates of Factor Augmentation

	Capital	Labor	Materials	Energy
U.S.	.646	-.098	.404	-.556
Japan	-.812	.992	.246	-.508

It is interesting to observe that the rates of factor-augmentation have the same signs for capital and raw material for the U.S. and labor and raw material for Japan. This suggests that the state of technology in steel production is not the same between the U.S. and Japan. It also suggests that technical complementarity relationships may differ between some factors for different countries. We will attempt to explain such a phenomenon in the final section of this chapter.

Comparison of Total Factor Productivity Growth between the U.S. and Japan

In the first section of this chapter, we indicated that there are some differences in the pattern of technological changes between the steel industries of the U.S. and Japan. To get a more intuitively appealing quantitative measure, we calculate the index of total factor productivity growth. The index is defined as a weighted average of the augmentation rates of individual inputs, weights being the shares of individual inputs in the unit cost. We define the index as

$$W = S_K\dot{A}_K/A_K + S_L\dot{A}_L/A_L + S_M\dot{A}_M/A_M + S_E\dot{A}_E/A_E. \tag{4.1}$$

With dummy variables, which serve as adjustment items, the index is defined as

$$W_1 = S_K\dot{A}_K/A_K + S_L\dot{A}_L/A_L + S_M\dot{A}_M/A_M + S_E\dot{A}_E/A_E - \mu_1 D_1 - \mu_2 D_2. \tag{4.2}$$

Computing W_1 and averaging over the sample period, we obtained the following:

U.S. : .003047

Japan : .034461

The estimated value of W_1 serves as an adjusted index of total factor productivity growth. Statistical tests show that the estimated values of W_1 are significantly different between the U.S. and Japan.[11] As we expected, the Japanese steel industry experienced much more rapid technological progress than its U.S. counterpart over the time period under consideration.

The Effects of Factor Productivity Change on the U.S.-Japan Steel Trade

We now turn to the following question:

> Have the difference in the pattern of technical changes and the difference in the growth of total factor productivity between the U.S. and Japan significantly affected the flow of steel trade between the two countries?

To answer that question, we will consider two measures: static measure and dynamic measure. The static measure is designed to examine the relative unit cost of the U.S. over Japan and import penetration in the U.S. steel market. Equation (4.3) is one such relationship.

$$(4.3) \qquad M_{JA}/DCON_A = \alpha_1 + \alpha_2 U_A/U_J$$

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[11] As the test statistic, we used the following: $\overline{W}_j = \hat{\alpha}_{Kj}\overline{S}_{Kj} + \hat{\alpha}_{Lj}\overline{S}_{Lj} + \hat{\alpha}_{Mj}\overline{S}_{Mj} + \hat{\alpha}_{Ej}\overline{S}_{Ej}$, $\hat{\alpha}_{ij} \sim N(\alpha_{ij}, \sigma_{ij}^2)$, $i = K, L, M, E$; $j = 1,2$. Since $\overline{W}_j$ is also normally distributed, the relevant statistic is

$$Z = (\overline{W}_1 - \overline{W}_2)/(s_1^2/n_1 + s_2^2/n_2)^{1/2}$$

where n_j and s_j^2 are the sample size and estimated variance, $j = 1,2$, respectively, and "$-$" denotes sample mean.

where M_{JA} is U.S. imports of steel from Japan,
$DCON_A$ is U.S. domestic consumption of steel,
U_A is the unit total cost of the U.S., and
U_J is the unit total cost of Japan.

We expect a positive sign for $\hat{\alpha}_2$.

As a dynamic measure, we define H as the difference between the proportionate reduction in the unit total cost of Japan and that of the U.S.

(4.4) $$H = - \dot{U}_J/U_J - (- \dot{U}_A/U_A) = \dot{U}_A/U_A - \dot{U}_J/U_J$$

We can decompose H into two components by making use of (3.15) and (4.4).

(4.5) $$H = (W_J - W_A) + (\hat{P}_{FA} - \hat{P}_{FJ})$$

where W_A and W_J are the indices of total factor productivity growth for the U.S. and Japan, and $\hat{P}_{FA}$ and $\hat{P}_{FJ}$ are the rates of change in total factor prices, respectively, defined as a weighted average of the rates of change in individual factor prices, weights being the shares of individual inputs in the unit cost.

Two other regression equations examining the role of the dynamic measure are:

(4.6) $$\dot{M}_{JA}/M_{JA} = \beta_1 + \beta_2 H$$

(4.7) $$\dot{M}_{JA}/M_{JA} = \gamma_1 + \gamma_2 (W_J - W_A)$$

If we agree to call H "dynamic competitive edge" of Japan over the U.S., then we can say that the dynamic competitive edge of Japan over the U.S. will be greater, the larger the difference in total factor productivity growth in Japan over that in the U.S., and the greater the difference in the rate of change in total factor prices of the U.S. over that of Japan. In both (4.6) and (4.7), we expect positive signs of the coefficients, $\hat{\beta}_2$ and $\hat{\gamma}_2$.

We added one dummy variable to each of the equations (4.3), (4.6), and (4.7) to account for the effects of the Voluntary Restraint Agreements (1969-1974). The results of our regression analysis are presented in Table 9.

Table 9

Effects of Factor Productivity Change on Trade: Equations (4.3), (4.6) and (4.7)

$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$[a]	R^2	F
-.092 (-5.02)	.095 (6.76)	.008 (1.18)	.79	33.17
$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$[a]	R^2	F
.198 (.57)	11.71 (3.92)	.21 (.34)	.51	8.82
$\hat{\gamma}_1$	$\hat{\gamma}_2$	$\hat{\gamma}_3$[a]	R^2	F
.26 (.58)	14.89 (2.22)	-.51 (-.73)	.28	3.24

[a] $\hat{\alpha}_3$, $\hat{\beta}_3$, and $\hat{\gamma}_3$ are the estimated coefficients of the dummy variable in the respective equation.

Our results indicate that import penetration is positively related to the relative unit total cost of the

U.S. over Japan, the percentage change in U.S. imports from Japan is positively related to the dynamic competitive edge of Japan over the U.S., and finally the percentage change in U.S. imports from Japan is positively related to the difference in total factor productivity growth between Japan and the U.S. In each of the above cases, however, VRAs do not seem to have any significant effects on the steel trade between the U.S. and Japan.

Contrary to the findings of previous authors such as the PHB study [1978], our results show that what really contributed to the increased U.S. imports of steel is its lagging productivity growth.

Test of Bias in Technological Progress

In this section, we attempt to test how well the two competing theories of bias in technological progress developed in chapter III explain the observed pattern of technical changes in the U.S. and Japanese steel industries, and derive some implications from the test results.

In order to test the validity of the K-W theory, we compared the average shares of individual factors and the estimated values of factor-augmentation rates. The test results are presented in Table 10.

Table 10

Test of the K-W Theory

Shares[a]	Rates of Augmentation	K-W Conclusion
	U.S.	
$S_K < S_L$	$\dot{A}_K/A_K > \dot{A}_L/A_L$	No
$S_K < S_M$	$\dot{A}_K/A_K > \dot{A}_M/A_M$	No
$S_K < S_E$	$\dot{A}_K/A_K > \dot{A}_E/A_E$	No
$S_L > S_M$	$\dot{A}_L/A_L < \dot{A}_M/A_M$	No
$S_L > S_E$	$\dot{A}_L/A_L > \dot{A}_E/A_E$	Yes
$S_M > S_E$	$\dot{A}_M/A_M > \dot{A}_E/A_E$	Yes
	Japan	
$S_K < S_L$	$\dot{A}_K/A_K < \dot{A}_L/A_L$	Yes
$S_K < S_M$	$\dot{A}_K/A_K < \dot{A}_M/A_M$	Yes
$S_K < S_E$	$\dot{A}_K/A_K < \dot{A}_E/A_E$	Yes
$S_L < S_M$	$\dot{A}_L/A_L > \dot{A}_M/A_M$	No
$S_L > S_E$	$\dot{A}_L/A_L > \dot{A}_E/A_E$	Yes
$S_M > S_E$	$\dot{A}_M/A_M > \dot{A}_E/A_E$	Yes

[a] The average shares of inputs in the unit cost were:

	U.S.	Japan
Capital	10.5 (%)	19.8 (%)
Labor	50.4	23.4
Material	21.7	34.7
Energy	17.3	22.1

For the case of the U.S., only two cases out of six are consistent with the modified K-W theory; for Japan, five cases out of six are consistent with the modified K-W theory.

However, our actual estimation of factor-augmenting rates suggests that there may exist 'technical complementarity' relationships between some factors. For the U.S., $\dot{A}_K/A_K$ and $\dot{A}_M/A_M$ had the same sign (positive), while $\dot{A}_L/A_L$ and $\dot{A}_E/A_E$ had the same sign (negative). For Japan, $\dot{A}_K/A_K$ and $\dot{A}_E/A_E$ had the same sign (negative), while $\dot{A}_L/A_L$ and $\dot{A}_M/A_M$ had the same sign (positive), as can be seen in Table 8.

Therefore, we suspect that there exists a technical complementarity between K and M, and between L and E for the U.S., while a similar relation exists between K and E, and between L and M for Japan.

It appears that the difference in adoption rates of various steel production processes between the two countries is reponsible for such complementarity relationships. For example, the continuous casting process can save not only labor but also raw materials compared to traditional methods. The importance of continuous casting in the Japanese steel industry relative to the U.S. steel industry may help to explain the apparent complementarity between L and M in Japanese production, but the U.S. case is not so obvious.

Now we attempt to explain the effects of technical complementarity relationships on the direction of technical change. Suppose that technical complementarity exists between K and M, and also between L and E in the sense that

(4.8) $\dot{A}_K/A_K = g(\dot{A}_M/A_M)$, $g' > 0$

(4.9) $\dot{A}_L/A_L = h(\dot{A}_E/A_E)$, $h' > 0$.

Treating these as additional constraints faced by the entrepreneurs, the problem is now to maximize

(3.22) $V = S_K\dot{A}_K/A_K + S_L\dot{A}_L/A_L + S_M\dot{A}_M/A_M + S_E\dot{A}_E/A_E$

subject to (3.23), (4.8) and (4.9).

(3.23) $\dot{A}_K/A_K = \Psi(\dot{A}_L/A_L, \dot{A}_M/A_M, \dot{A}_E/A_E)$

In this case, the optimality requires

(4.10) $\partial(\dot{A}_K/A_K)/\partial(\dot{A}_L/A_L) = - S_L/S_K$

(4.11) $\partial(\dot{A}_K/A_K)/\partial(\dot{A}_M/A_M) = - (S_M/S_K + g')$

(4.12) $\partial(\dot{A}_K/A_K)/\partial(\dot{A}_E/A_E) = - (S_E/S_K + h'S_L/S_K)$.

To clarify the implications of these new optimality conditions, let us assume that $S_K > S_M$. Then the K-W theory suggests that $(\dot{A}_K/A_K)^* > (\dot{A}_M/A_M)^*$. However, if there exists a technical complementarity between K and M, and if the complementarity is strong enough, then entrepreneurs may be forced to choose different combination of $\dot{A}_K/A_K$ and $\dot{A}_M/A_M$. (This is illustrated in Figure 5.)

In Figure 5, I-I' represents the innovation possibilities curve, and $\dot{A}_K/A_K = g(\dot{A}_M/A_M)$ represents the technical complementarity relationship. Without the existence of technical complementarity, the point P will be chosen as

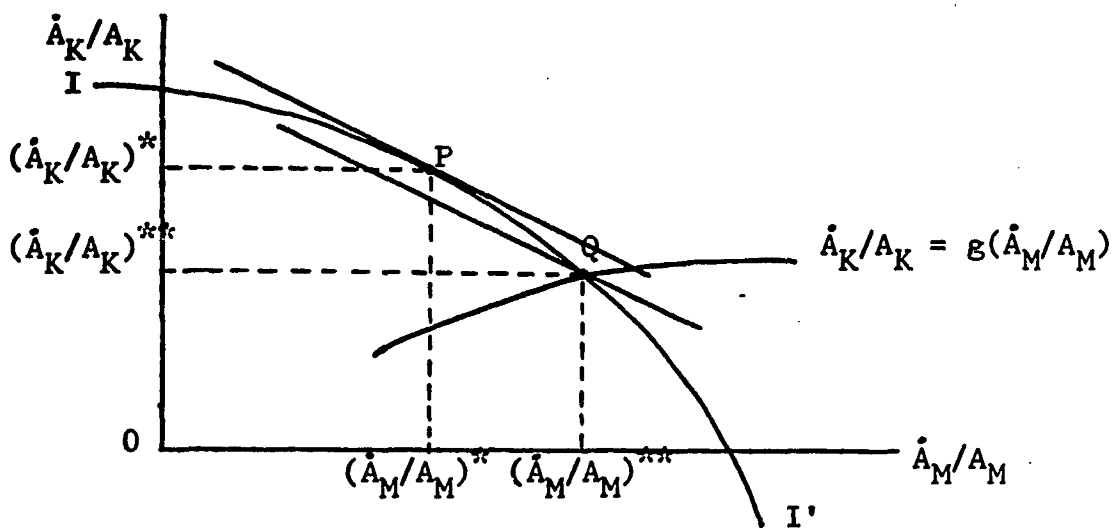

Figure 5
Illustration of Reversibility of Bias in Technical Change

the conditions (3.24), (3.25) and (3.26) dictate. Hence, $S_K > S_M$ implies $(\dot{A}_K/A_K)^* > (\dot{A}_M/A_M)^*$. However, with the existence of technical complementarity which is strong enough, the point Q will be chosen instead of P. Thus, even if $S_K > S_M$, it is possible that $(\dot{A}_K/A_K)^{**} < (\dot{A}_M/A_M)^{**}$. We will call this the "reversibility" of bias in technological change. This is very similar to the case of the second best theory.

If we take into account such a reversibility of bias in technological change, then all six cases are consistent with the modified version of the K-W theory for Japan; but for the U.S., three cases are still inconsistent.

Now we turn to the test of the theory by Fellner, Hicks and Ahmad (F-H-A theory). To see if the movements in relative factor prices are capable of explaining the pattern of technical changes, we compared the relative changes in input prices for both the U.S. and Japan over the same period as in the case of the K-W model. The test results are presented in Table 11.

For the U.S., only two cases out of six are consistent with the F-H-A theory; for Japan, five cases out of six are consistent with the F-H-A theory. So far as the U.S. and Japanese steel industries are concerned, the modified version of the K-W theory seems to perform a little better than the F-H-A theory. Our tests suggest the following:

Either the Japanese steel producers behaved more rationally in reducing costs through technological progress in response to changing factor prices, or alternatively, the U.S. steel producers were constrained from responding optimally to changing factor prices. With the wage rate increasing at a faster rate than both the rental rate on capital and the price of raw materials, the U.S. steel producers should have achieved labor-saving technical changes according to our theory. But, apparently they failed to do that. In contrast, Japanese steel producers moved in the right direction in the sense that they achieved

Table 11

Test of the F-H-A Theory

Price Change[a,b]	Rates of Augmentation	F-H-A Conclusion
	U.S.	
$\dot{P}_K/P_K < \dot{P}_L/P_L$	$\dot{A}_K/A_K > \dot{A}_L/A_L$	No
$\dot{P}_K/P_K < \dot{P}_M/P_M$	$\dot{A}_K/A_K > \dot{A}_M/A_M$	No
$\dot{P}_K/P_K < \dot{P}_E/P_E$	$\dot{A}_K/A_K > \dot{A}_E/A_E$	No
$\dot{P}_L/P_L > \dot{P}_M/P_M$	$\dot{A}_L/A_L < \dot{A}_M/A_M$	No
$\dot{P}_L/P_L > \dot{P}_E/P_E$	$\dot{A}_L/A_L > \dot{A}_E/A_E$	Yes
$\dot{P}_M/P_M > \dot{P}_E/P_E$	$\dot{A}_M/A_M > \dot{A}_E/A_E$	Yes
	Japan	
$\dot{P}_K/P_K < \dot{P}_L/P_L$	$\dot{A}_K/A_K < \dot{A}_L/A_L$	Yes
$\dot{P}_K/P_K < \dot{P}_M/P_M$	$\dot{A}_K/A_K < \dot{A}_M/A_M$	Yes
$\dot{P}_K/P_K < \dot{P}_E/P_E$	$\dot{A}_K/A_K < \dot{A}_E/A_E$	Yes
$\dot{P}_L/P_L > \dot{P}_M/P_M$	$\dot{A}_L/A_L > \dot{A}_M/A_M$	Yes
$\dot{P}_L/P_L > \dot{P}_E/P_E$	$\dot{A}_L/A_L > \dot{A}_E/A_E$	Yes
$\dot{P}_M/P_M < \dot{P}_E/P_E$	$\dot{A}_M/A_M > \dot{A}_E/A_E$	No

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[a] The average percentage changes in input prices were:

	U.S.	Japan
Capital	+ 2.7 (%)	+ 0.5 (%)
Labor	+ 6.7	+13.6
Material	+ 4.7	+ 2.1
Energy	+ 4.4	+ 7.1

[b] Note that $\dot{P}_i/P_i > \dot{P}_j/P_j$ is equivalent to the condition $d(P_i/P_j)/dt > 0$.

labor-saving technological changes with the wage rate rising at a faster rate than any other input price, and thereby were able to reduce the cost of production significantly.

As of 1976, output using obsolete technologies such as open hearth method and others equaled 21.3 million MT for the U.S. and 0.54 million MT for Japan. Output of obsolete technologies as a percent of total crude steel production was 18.3% for the U.S. and 0.5% for Japan. Total investments for the period 1957-1976 were $27 billion for each country. These facts can be seen as part of empirical evidence on investment decisions by the steel industries of the U.S. and Japan. A more detailed comparison of technologies between the U.S. and Japan will be presented in chapter V.

CHAPTER V

EXPLAINING THE EMPIRICAL RESULTS

In chapter II, we left an important question unanswered: Why has the U.S. comparative advantage in steel production declined relative to other steel producers in the world after World War II and what caused it? Our empirical findings in chapter IV indicate that lagging factor productivity growth in the U.S. steel industry relative to its major international competitors contributed to a decline in the U.S. comparative advantage in steel production.

It would be helpful to examine for this what happened to the U.S. and Japanese steel industries after World War II. What role, if any, did governments of the two countries play with respect to the steel industry? And, what additional factors have affected the relative positions of the two steel industries in the world market?

Government Involvement in the Steel Industry

This section analyzes the involvement of government in the steel industry including preferential treatment, subsidy, support in funding, price controls, war-related activities, regulations, and others.

Japan

Right after World War II, Japan was under the control of the Supreme Command of the Allied Powers (SCAP) until April, 1952. Severe restrictions were imposed on the reconstruction of Japanese iron and steel industry by SCAP. According to the Pauley Report,[12] as part of the reparations arrangements it was recommended that steel production capacity in Japan should be restricted as follows:

Blast Furnace: Limited to 500,000 MT per year
Steel Ingots: Limited to 2.25 million MT per year
Electric Furnace: Capacity exceeding 1 MT to be removed
Open Hearth and Bessemer Furnace: Capacity exceeding 2.25 million MT to be removed
Steel Rolling: Capacity exceeding 1.5 million MT to be removed

The United States, however, began to change its attitude toward Japan for two reasons: First, the increasing tension in China and Vietnam convinced the U.S. that it would be beneficial to have Japan as an ally in Asia. Second, the U.S. felt that making Japan

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[12] Edwin W. Pauley, U.S. ambassador to Japan, Report on Japanese Reparations to the President of the United States, Washington, D.C., April, 1946, pp. 13-15

self-sufficient would impose less economic burden on U.S. taxpayers. As a result, the severe restictions imposed immediately after World War II were relaxed.

Three types of government involvement in the steel industry are noteworthy:

First, the steel industry was given priority treatment in resource allocation by the government. Second, the steel industry received subsidies from the government, although the subsidy programs lasted for only a short period of time. Third, the steel industry was aided in its modernization programs by government funding support.

The Economic Stabilization Board, established in 1946, initiated a program called Preferential Resource Allocation Policy (Keisha Seisan Hoshiki). Under this program, the coal, iron and steel, shipbuilding, electric power and fertilizer industries were given preferential treatment. The coal and steel industries were given the highest priority.[13] There were two kinds of direct government subsidy programs: raw material subsidies and price subsidies.

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[13] See Kawahito [1972], pp. 8-9.

Raw Material Subsidies

The steel industry was supplied with home-produced coal at prices lower than official prices, the difference being subsidized by the government. In the case of imported raw materials, the difference between the landed prices and the official prices was subsidized by the government.

Price Subsidies

Government set the producer's CIF price, which is the producer's price minus raw material subsidy, and subsidized the difference between CIF price and the user's price.

Table 12

Estimated Subsidies as of July, 1948 (Yen/MT)

	A	B	C	D	E	B/A	(B+E)/A
Pig Iron	28780	13700	15080	3600	11480	48%	88%
Steel Bars	42305	21005	21300	10120	11180	50%	76%

A: Producer's Price
B: Raw Material Subsidy
C: Producer's CIF Price
D: User's Price
E: Price Subsidy

Source: Michio Kenmochi [1964]

The raw material subsidy for the purchase of coal was discontinued in August, 1948, and the subsidy on pig iron was discontinued in July, 1951. The price subsidy for steel products was terminated in June, 1950.

The Japanese steel industry carried out its modernization and rationalization throughout the 1950's. Government adopted a program to help rationalize the steel and coalmining industries by accepting the proposals of the Industrial Rationalization Council in August, 1950.

Over the period 1951-55, called the First Modernization period, the proportion of government-related financing was almost 40% of the total funds. The breakdown of the sources of funds is shown in Table 13.

Table 13

Sources of Funds for the First Modernization

Industrial Bank	17.8 (%)
Long-term Credit Bank	6.4
Development Bank	8.2
Foreign Exchange Loans	7.4
Commercial Banks	11.2
Corporate Bonds	15.4
Stocks	9.3
Internal Funds	24.3

Source: K. Kawahito [1972], p. 27

The Japanese steel industry undertook its Second Modernization program during the period 1956-1960. Due to limited capacity of domestic steel production, the Japanese government had to restrict steel exports in order to fill the domestic demand in October, 1955. Thus, in its Second Modernization period, the Japanese steel industry emphasized capacity expansion in ironmaking and steelmaking processes. Approximately 27% of financing was government-related. This is much lower than that of the First Modernization program, but we can see that the Japanese steel industry relied heavily on government sources for financing its modernization programs. The breakdown of the sources of funds is shown in Table 14.

Table 14

Sources of Funds for Second Modernization

Development Bank	5.5 (%)
Industrial Bank	5.5
Long-term Credit Bank	4.0
Commercial Banks	1.1
Trust Companies	6.7
Insurance Companies	5.9
World Bank	8.6
Export-Import Bank	2.4
Foreign Sources	1.3

Source: K. Kawahito [1972], p. 41

It is also notable that the Second Modernization program included planned construction of large-scale ore and coal carries. Construction of such carriers made a significant contribution in reducing the cost of transportation and thereby overcoming the handicap of shipping resources over longer distance than other countries.[14] As a result of the two modernization programs, the Japanese steel industry experienced a remarkable expansion in iron and steelmaking capacities. Also, as we will see later, this is in strong contrast with the U.S. steel industry performance for the same period.[15] The results of the modernization programs are shown in Table 15.

Table 15

Effect of Modernization (1951-60)

	Capacity (1,000 MT/Year)			% Increase	
	End of 1951	End of 1955	End of 1960	51-55	55-60
Ironmaking	2,938	6,344	12,535	116%	98%
Steelmaking	8,309	10,110	28,194	22	179
Rolling	14,763	23,864	34,125	62	43

Source: Ministry of International Trade and Industry, Japan

In addition, there were other forms of government help which included the following:

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[14] The average mileage of transportation was: U.S. 2,374, France 1,332, U.K. 1,277, Japan 3,196, W. Germany 1,671. See Kawahito [1972], p. 37.

[15] See Table 18 for the U.S. steel industry performance for the same period.

a. Exemption of duty on imports of the machinery and equipment used for modernization (About 60% of the machinery and equipment was imported.)

b. Special tax treatment on new machinery and equipment by allowing depreciation at a rate 50% higher than the normal rate for three years after acquisition (1951-1961)

c. Special depreciation of 50% of the acquisition cost in the first year (1952-1961)[16]

These additional types of government aid, which lasted throughout most of the 1950's, appears to be consistent with our empirical observation of capital-using technical change in the Japanese steel industry. (A comparison of depreciation laws between the U.S. and Japan will be made at the end of this section.)

However, the sum of all forms of government aid translated into the unit cost figures would amount to less than one dollar per metric ton of steel produced.[17, 18]

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[16] See Kawahito [1972], pp. 27-28.

[17] See the FTC study [1977], p. 331.

[18] Although the effect of government aid is small in terms of the reduction in the unit cost, the effect at the margin may not be small. The exact scope of such marginal effects needs further research.

By the end of the 1950's, the Japanese steel industry became very competitive in the world market. One of the most remarkable achievements of the Japanese steel industry in the 1950's is that it solved the problem of scarcity of raw materials, especially iron ore and coking coal. Imports of raw materials became available at low prices on a long-term basis. That was the result of the opening of new mines in Goa, Malaysia, the Philippines and India,[19] the conclusion of long-term purchase contracts, the extensive use of large-scale carriers and modernization of port facilities. Between 1951 and 1960, the Japanese steel industry was able to lower raw material cost by about 20% per metric ton of steel produced, while labor productivity increased by more than 100% during the same period. Labor costs for the same period increased at a slightly slower rate than the labor productivity increased.[20]

The Effect of the Korean War on the Japanese Steel Industry

It is also believed that the Korean War benefited the Japanese steel industry considerably. The United States

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[19] Australia became one of the major sources of iron ore and coal supplies beginning in the early 1960's.

[20] According to Saburo Tanabe, a specialist in Japanese steel industry economics, the Japanese steel industry was able to reduce major raw material costs per metric ton of pig iron by $11.00 between 1956 and 1960.

and the United Nations made special procurements of war-relared materials and equipment from Japan, which was the nearest source of supply. The Japanese steel industry experienced a sharp increase in demand both through a large volume of direct special procurements and through an increase in demand from other sectors of the domestic economy which stepped up production in response to special procurements and a rise in the general level of income.

Although the Korean War boom lasted only for a short period of time, it provided momentum for the post-World War II Japanese steel industry development. It helped the Japanese steel industry by generating a basis for a continuous increase in demand for steel and by providing the industry with funds needed for modernization programs.

Table 16

Special Procurements of Steel (1950-51)
(1,000 MT)

July, 1950	0.06
Aug.	16.4
Sept.	44.9
Oct.	36.5
Nov.	21.5
Dec.	22.3
Jan., 1951	41.9
Feb.	11.4
Mar.	15.1

Source: Michio Kenmochi [1964], p. 39

Tables 16 and 17 describe special procurements of steel by the U.S. and U.N., and production of pig iron and crude steel for the Korean War period.

Table 17

Production of Pig Iron and Crude Steel, 1950-51
(1,000 MT)

	Pig Iron	Crude Steel
April, 1950	179	368
May	200	414
June	197	395
July	196	403
August	187	399
September	190	400
October	211	453
November	208	473
December	215	497
January, 1951	212	487
February	198	444
March	239	547

Source: JISF, Sengo Tekko Shi, 1968, p. 87

U.S.

The U.S. steel industry has not been given any direct subsidies or other forms of help by the government, except for minor loans given to some small companies. The FTC study [1977] indicated that government actions might have affected the U.S. steel industry to some extent. Those actions included the following:

a. The Army Corps of Engineers did some work on waterway and harbor projects that benefited some steelworks.

b. Tying clauses in the U.S. foreign aid programs may have helped U.S. steel exports.

c. Voluntary Restraint Agreements negotiated by the U.S. State Department with the governments of Japan and the European Community may have benefited the U.S. steel industry.

d. The imposition of price controls between 1971 and 1974 may have affected the U.S. steel industry.[21]

It is very difficult to quantify possible effects of the first three items. However, for the price controls of 1971-74, the FTC study shows some negative relationship between the profits of the U.S. steel industry and price controls.[22]

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[21] See the FTC study [1977], pp. 319-20.

[22] The FTC study [1977] regression results were as follows:

$$\begin{aligned} DNP = {} & -166.993 + \underset{(3.70)}{0.011}\ PROD + \underset{(4.66)}{0.004}\ DUO - \underset{(-1.21)}{0.00001}\ M \\ & + \underset{(0.59)}{2.75}\ JB - \underset{(-3.50)}{105.783}\ PC, \qquad R^2 = 0.587 \end{aligned}$$

where DNP is net profits after taxes deflated by the BLS wholesale price index for all commodities,
PROD is production of raw steel in net tons,
DUO is unfilled orders for steel products in dollars deflated by the ratio of steel shipments in dollars to steel shipments in tons,
M is imports of steel in net tons, lagged one quarter,
JB is a dummy variable for jawboning, and
PC is a dummy variable for the price controls.

The argument is mainly based on the cyclical characteristic of the steel industry. If government price controls reduce the industry's profits during its boom periods, it is possible that industry's long-run position could be damaged. In order to make up for its low profits for the recession periods, it may have to earn higher than average profits during boom periods, and thereby earn sufficient long-run profits to attract funds for expansion and modernization.

Using two estimates on the cost of building steel capacity by AISI and by Peter Marcus,[23] the FTC study concludes that the reduction in after-tax steel profits amounts to between \$1.1 billion and \$1.7 billion. If this were invested in a new steel plant, it could have bought from 1.1 million to 2.2 million annual tons of shipped steel capacity based on 1975-76 costs. If this is translated into the unit cost, it would amount to about 20 cents per metric ton of steel. In other words, had there been no price controls, the unit cost of steel production would have been about 20 cents lower per metric ton of steel.

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[23] See AISI, Steel Industry Economics and Federal Income Tax Policy, June, 1975, and Peter Marcus, World Steel Supply Dynamics, 1976.

In order to compare the U.S. steel industry's performance for the same period as that during which the Japanese modernization programs were in effect, we look at the U.S. steel production and blast furnace capacities.

Table 18

U.S. Steel Production (Ingots and Steel for Casting) and Blast Furnace Capacities (1,000 MT)

				% Increase	
	1951	1955	1960	51-55	55-60
Steel Production	94,557	114,151	134,783	20.7	18.1
Blast Furnace	72,472	83,971	96,521	15.9	14.9

Source: AISI, Annual Statistical Report, various years

These figures are in sharp contrast with the Japanese steel industry performance figures for the same period.

One other aspect of government involvement in the steel industry is in the area of environmental regulations. We will attempt to compare the environmental control standards and expenditures of the U.S. and Japan. It is very difficult to make an international comparison of environmental control standards, because in addition to national standards, each locality where a plant is located may impose additional requirements and sometimes there are negotiations between a particular plant and the environmental agency in charge. But, in general, the environmental control standards in Japan are even stricter than they are in the U.S. (See Table 20.)

For both countries, 1972-78 is the period of peak investment in pollution control. Between 1970 and 1976, the U.S. steel industry invested about 12.6% of total expenditures in pollution control, and this amounted to about 3.2 cents per metric ton of steel. For Japan, about 16.2% of total investment was in pollution control, which amounted to about 5.7 cents per metric ton of steel. Environmental control investment expenditures of the U.S. and Japanese steel industries are shown in Table 19.

Table 19

Environmental Control Expenditures (1,000 U.S. dollars)

	U.S.		Japan	
Year	A	B	A	B
1970	182.6	10.5 (%)	N/A	N/A
1971	161.6	11.3	219.2	8.9 (%)
1972	201.8	17.2	284.4	13.4
1973	100.1	7.2	367.9	17.3
1974	267.2	12.6	555.6	18.6
1975	453.1	14.3	685.2	18.4
1976	489.2	15.0	920.1	20.6

A: Pollution Control Investment
B: Pollution Control Investment as a percent of Total Investment

Source: H. Mueller and K. Kawahito [1978]

Table 20

Comparison of Ambient Air Quality Standards

Pollutant	Averaging Time	U.S.	Japan
SO_2	Annual	0.03 PPM[a]	(0.017 PPM)[b]
	24 Hour	0.14 PPM	0.04 PPM
	1 Hour	- - -	0.1 PPM
NO_2	Annual	0.05 PPM	(0.02-0.03 PPM)[b]
	24 Hour	- - -	0.04-0.06 PPM
Photochemical Oxidants	1 Hour	0.12 PPM	0.06 PPM
Hydrocarbons (non-methane)	3 Hour	0.24 PPM	- - -
CO	24 Hour	- - -	10 PPM
	8 Hour	9 PPM	20 PPM
	1 Hour	35 PPM	- - -
Particulate Matter	Annual	75 $\mu g/M^3$ [c]	- - -
	24 Hour	260 $\mu g/M^3$	100 $\mu g/M^3$
	1 Hour	- - -	200 $\mu g/M^3$

[a] PPM = Part Per Million

[b] Not stipulated but calculated from other averaging time values

[c] μg = microgram (one millionth of one gram)

Source: JISF, Japan Steel Bulletin, June, 1980

The Japanese steel industry seems to spend a little larger proportion of investment expenditures for pollution control purposes and to incur a little more cost per metric ton of steel produced than the U.S. producers. However, for both countries pollution control costs are an insignificant proportion of the total costs of steel production.

There is another aspect of government involvement which may have affected the competitiveness of the U.S. steel industry. This is the area of depreciation laws. Some industry analysts (including the U.S. steel industry representatives) have claimed that American products found it increasingly difficult to compete in the world market because depreciation laws in foreign countries were much more liberal than they were in the U.S.[24] This applies to the steel industry, too. The arguments can be summarized as follows:

Before World War II, depreciation reserves were quite adequate for the replacement of plants and equipment. Between 1945 and 1962, the U.S. steel industry had spent huge amounts of money on replacement and expansion. But despite this investment, there was a considerable amount of obsolescence in the steel production facilities. The

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[24] See W. T. Hogan [1967].

basic reason for such obsolescence was that the industry did not have sufficient funds to modernize its older facilities. It was contended that the deficiency of funds largely resulted from the fact that the depreciation charges permitted under the tax laws could not keep up with the replacement costs. Depreciation reserves permitted the firms to recapture the original cost, not the replacement cost. Thus, as inflation accelerates, the cost of replacement was substantially higher than the original cost.

In 1962, measures were taken by the U.S. Congress to shorten the useful lives of depreciable assets and a 7% investment tax credit was implemented. A comparison of depreciation deductions between the U.S. and Japan is presented in Table 21. (For a more detailed comparison of depreciation laws between the U.S. and Japan, see Table 50.)

It appears that there was a considerable difference in the rates of capital recovery between the U.S. and Japan before 1962. But after 1962, the rates of capital recovery under the U.S. system improved significantly.

On the other hand, when we look at the rates of inflation, Japan experienced a severe inflation after World War II until 1951. In Japan, the price level measured by the wholesale price index for all commodities in Tokyo, increased almost 100 times between 1945 and 1951, while the U.S. price level for the same period was quite stable.

The wholesale price indexes for all commodities in Tokyo are shown in Table 22. (For a more detailed comparison of WPI's, the reader is referred to Table 51.)

Table 21

Depreciation Deductions, Initial and Investment Allowances (Percent of Cost of Assets)

	1st Year	1st 2 Years	1st 5 Years
Japan	43.4	51.0	68.2
U.S.			
Prior to July 11, 1962	13.3	24.9	51.1
With New Depreciation Guidelines	16.7	30.6	59.8
With New Depreciation Guidelines and 7% Investment Credit	29.5	42.5	69.6

Source: W. T. Hogan [1967]

Table 22

Tokyo Wholesale Price Index[a] (1934-36=100)

Year	WPI	Year	WPI
1935	99.4	1948	12,792.6
1940	164.1	1949	20,876.4
1945	350.3	1950	24,680.7
1946	1,627.1	1951	34,253.1
1947	4,815.2	1956	35,796.7

[a] WPI for all commodities

Source: Bank of Japan, Statistics Bureau

Thus, for the period 1945-1951, any favorable effects of the Japanese depreciation laws relative to their U.S. counterparts might well have been offset by inflation. However, for the period 1952-1962, the difference in depreciation laws between the U.S. and Japan should have had some effect, since the price levels were relatively stable in both countries for that period.

Considering the fact that the 1950's were an important period for the U.S. steel industry, as we pointed out at the end of chapter II, the claims by the U.S. steel industry representatives and some industry analysts may have some validity during this particular period.

Adoption of Technologies

In this section, we will discuss the adoption of various types of steelmaking technologies. We will also examine whether or not the adoption of technologies has affected the competitiveness of the U.S. and Japanese steel industries.

Conventional steelmaking involves several different stages. For our purposes, the whole process is divided into four stages:

First, coking coal is converted into coke and iron ore is sintered and pelletized; coke, iron ore, and limestone are used in blast furnaces to make pig iron. This will be called an ironmaking stage.

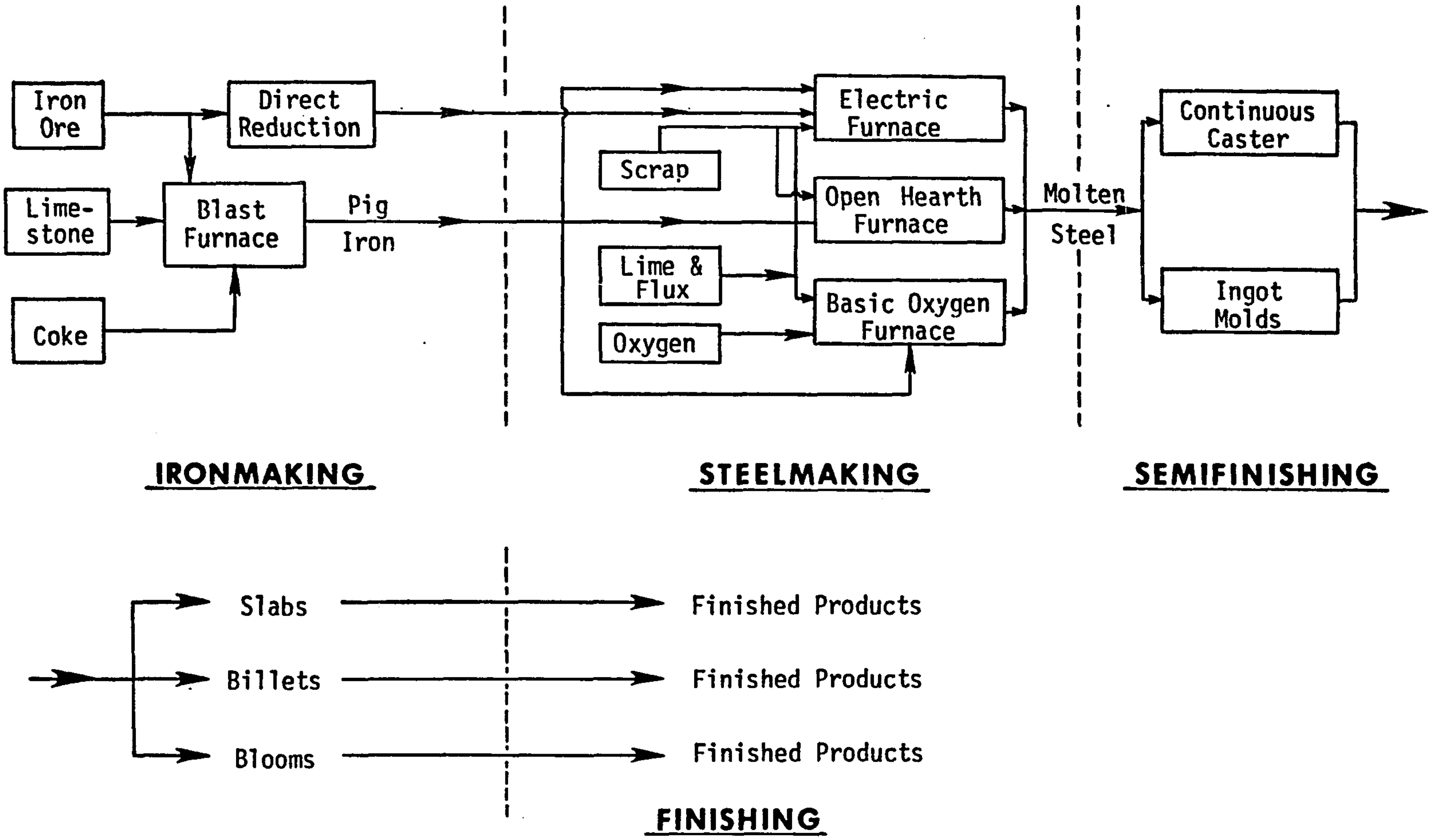

Figure 6

Illustration of Steelmaking Stages

Second, the liquid iron is made into steel in a furnace by adding scrap and other alloy materials. Either one of open hearth, basic oxygen, or electric furnace can be used. This will be called a steelmaking stage.

Third, molten steel is poured into molds, and is cooled and reheated to produce semifinished products such as blooms, billets and slabs. This will be called a semifinishing stage.

Fourth, blooms, billets, and slabs can be further processed to produce finished products. This will be called a finishing stage.

Three types of furnaces used in the steelmaking stage have different characteristics. An open hearth furnace can use 20 to 80% scrap in the total charge; an electric furnace may use from 30 to 100% scrap in charge; the basic oxygen furnace can use up to 30% scrap in the charge.

The advantage of the basic oxygen converter is that it can produce top-grade steel more quickly and efficiently than older methods such as open hearth and others and moreover it entails lower investment costs. Table 23 shows the comparative costs of steelmaking between open hearth and basic oxygen furnace methods.

A closer look at Table 23 indicates that there is a significant difference in the steelmaking costs between the OH and BOF processes. Measured in 1955 dollars, adoption of the BOF process would reduce the unit cost of steel production relative to the OH process by approximately $24-$26 and about $20 of that reduction would come from the reduction in the unit cost of capital. Thus, a higher rate of adoption of the BOF process relative to older OH process would result in a substantial decrease in capital costs.

A study by the United Nations Economic Commission for Latin America and Europe confirms the report by Rueckel and Irwin.

Table 23

Comparative Costs of BOF and OH Steelmaking

	0.5 Million Ton Annual Capacity		1 Million Ton Annual Capacity	
	BOF	OH	BOF	OH
Capital Cost Per Annual Ton	$20.22	$39.61	$12.67	$33.71
Cost of Metallics Per Annual Ton	37.41	36.67	37.41	36.67
Operating Cost Per Ton	9.37	14.63	8.38	14.25

Source: Rueckel and Irwin [1955], p. 62

The BOF process is both capital and labor-saving (actually close to neutral technical change) compared to the open hearth technique. The BOF process is both capital and labor-saving, but more capital-saving relative to the electric furnace process. The relative capital and labor-saving characteristic of major steel production techniques is indicated in Table 24.

Table 24

Relative Capital and Labor-saving Characteristics of Major Steel Production Techniques

	Plant	Capital Input		Labor Input	
	Annual Capacity	BOF/OH	BOF/EF	BOF/OH	BOF/EF
ECLA[a]	1 Million MT	0.671	0.704	0.672	0.916
Mexico 1962	1 Million MT	0.667	1.202	0.600	0.750
ECE[b]	Unspecified	0.500	0.667	0.563	0.703

[a] Economic Commission for Latin America, United Nations

[b] Economic Commission for Europe, United Nations

Source: Maddala and Knight [1966]

Clearly, the U.S. steel industry fell behind the Japanese steel producers in adopting the BOF process both in terms of the percentage of BOF production relative to total steel production and in the absolute tonnage of steel production by the BOF process. (See Table 42 and Table 43.)

There is another steelmaking process, called the continuous casting process, which bypasses the ingot molding stage and directly produces semifinished products without cooling and reheating the molten steel. Major advantages of continuous casting are:

a. Energy Savings

By eliminating energy-intensive steps, the continuous casting process reduces the consumption of fuels such as natural gas, oil, and in-plant byproduct gases. It is estimated that about 1.1 million BTU of energy is saved per metric ton of steel cast. In Japan, about half of total steel is continuous cast, while in the U.S. only 18% of steel is continuous cast as of 1980.

b. Higher Yield

By reducing end losses and oxidation losses, there is an estimated increase in yield of at least 10 to 12%.

Minor advantages include:

a. Simplicity and improved control

b. Higher labor productivity

c. Better quality of steel

d. Reduced pollution

e. Lower capital costs

Economic costs and benefits of adopting continuous casting are listed in Table 44. The U.S. steel industry also fell behind other major steel producers in adopting the continuous casting process. (See Figure 7 for the diffusion of continuous casting for the U.S., Japan, W. Germany and United Kingdom.)

Over the period 1956-1976, the average adoption rate of the open hearth process for the U.S. was almost

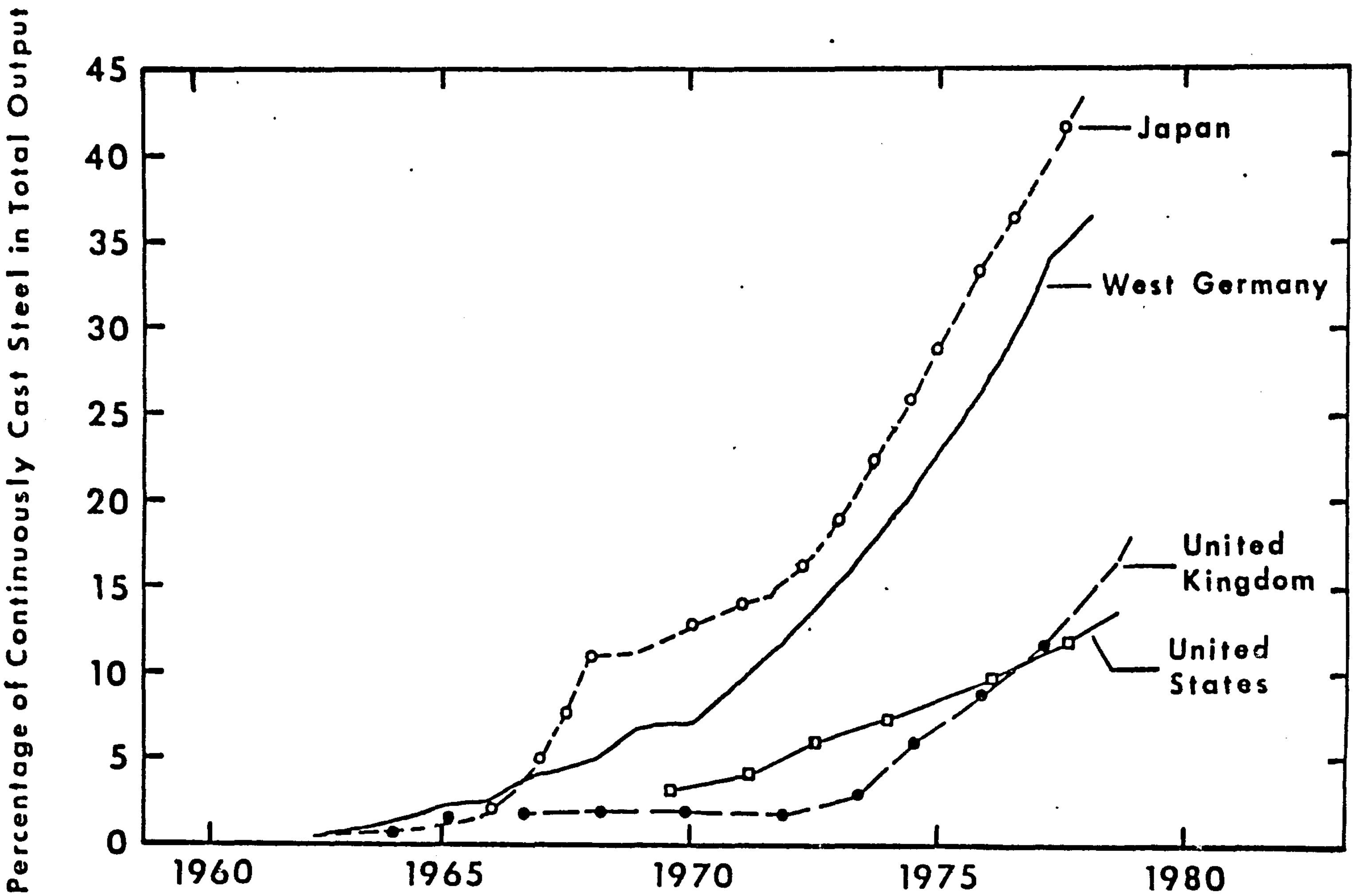

Figure 7

The Diffusion of Continuous Casting

Source: Organization for Economic Cooperation and Development twice as high as it was for Japan. On the other hand, the average adoption rate of the basic oxygen process in the U.S. was about half that for Japan. The average adoption rate of the electric furnace process for the U.S. is a little lower than that for Japan. Also there is a significant difference in the adoption rate of the continuous casting process between the U.S. and Japan. Table 25 shows the tonnage and shares of continuous casting.

Table 25

Output and Share of Continuous Casting
(1,000 MT and Percent)

Year	W.Germany	(%)	EC(9)	(%)	U.S.	(%)	Japan	(%)
1971	4,110	(10.3)	6,097	(4.8)	5,272	(4.8)	9,958	(11.2)
1972	6,088	(13.9)	9,955	(7.2)	6,973	(5.8)	16,462	(17.0)
1973	8,057	(16.3)	14,090	(9.4)	9,270	(6.8)	24,716	(20.7)
1974	10,337	(19.4)	19,595	(12.6)	10,722	(8.1)	29,411	(25.1)
1975	9,813	(24.3)	20,717	(16.5)	9,653	(9.1)	31,814	(31.1)
1976	12,014	(28.3)	26,967	(20.1)	12,246	(10.5)	37,629	(35.0)
1977	13,272	(34.0)	32,029	(25.4)	13,350	(11.8)	41,807	(40.8)

Source: IISI, A Handbook of World Steel Production

Why is there such a difference in the adoption rates of the BOF and continuous casting processes between the U.S. and Japan?

The U.S. is relatively scrap rich when compared to Japan. And, if we look at the relative price of iron ore

Table 26

Average Adoption Rates of Various Technologies[a]

Process	U.S.	Japan
OH	58.9 (%)	30.7 (%)
BOF	27.9	54.2
EF	12.6	18.6
CC	8.1	25.8

[a] The time period is 1956-1976 for the OH, BOF, and EF processes, and 1971-1977 for the CC process.

Source: JISF, Statistical Yearbook, various years
IISI, A Handbook of World Steel Production

over scrap, except for the period 1956-58, it has been consistently higher in the U.S. than in Japan. (See Table 45.) This fact probably is responsible for the slow adoption of the BOF process by the U.S. steel industry.

The BOF process can use only up to 30% scrap in the total charge so that it has to rely more heavily on iron ore. Note that the OH method can use 20 to 80% scrap in the charge, but the BOF process allows only up to 30% scrap in the charge so that more than 70% of the charge must consist of pig iron which is made from iron ore. Thus, there is not much incentive for the U.S. steel producers to adopt the BOF process very rapidly. When we examine the ratio of the unit cost of iron ore over the unit cost of scrap, we come to the same conclusion, because the ratio is consistently higher in the U.S. than in Japan for the whole period under consideration. (See Table 46.)

The fact that the average adoption rate of the electric furnace process for the U.S. is lower than that for Japan can be explained by the higher price of electric power in the U.S. than in Japan. (See Table 47 and Table 48.) Had the price of scrap been lower in Japan, Japanese steel producers would have utilized the electric furnace process more.

What about the adoption of the continuous casting process? Why was the U.S. steel industry a slow adopter of the continuous casting process? In spite of a drastic increase in energy costs after the oil crisis (1973-74), and energy-saving characteristic of the continuous casting process, the U.S. adoption of the continuous casting process did not increase significantly. The U.S. steel industry representatives cite inability to finance new investments. However, McLouth, an integrated steel producer has already replaced all its ingot casting with continuous casting and another company, National Steel, is trying to do the same.[25]

It appears that the U.S. steel industry underestimated the long-term benefits of the continuous casting process.

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[25] See the OTA study [1980], p. 289.

The Wall Street Journal reports that the U.S. steel industry representatives hesitated for a long time in making a decision to install continuous casters.[26]

Table 49 summarizes a cross-sectional comparison of technologies between the U.S. and Japan.

Other Factors Involved

There are many other factors which might have contributed to the present relative positions of the U.S. and Japanese steel industries.

1. Modernity of Plant and Equipment

According to Mueller and Kawahito [1978], almost 100% of the present steel production facilities in Japan has been built since 1956. But in the U.S., only about 30% of the present capacity has been built since 1956. The Japanese steel industry has added about 70% of the present facilities since 1967, while the U.S. steel industry has added only about 5% since 1967. Moreover, such an expansion has been in the form of constructing integrated greenfield plants for Japan, while in the U.S. it has been mostly in the form of rounding-out of existing facilities.

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[26] The Wall Street Journal, April 2, 1981 quoted a U.S. steel industry representative as saying, "In retrospect, you might say it was a mistake to hesitate so long in putting in continuous casters".

2. Labor-Management Relations

The Japanese labor-management relationship is based on a life-time employment system. Under this system, employers recruit the employees from schools and retain them until the time of their retirement. This makes labor turnover rates very low. Another advantage of such a system is that employers can undertake long-term manpower training programs. In the U.S. steel industry, the labor-management relationship does not seem to be very smooth. The Wall Street Journal reports that poor labor relations at U.S. steelmakers might have affected their ability to compete with foreign steel producers.[27]

Also Japanese steel mills benefit from the voluntary activities of small groups of workers, called "Jishu-Kanri" (J-K). These are a group of workers consisting of a foreman and six or seven workers in the same workshop. The objective of J-K groups is to eliminate errors, improve machinery and equipment designs, reduce the wastes of raw materials and improve product quality. As of September, 1977, 31,148 J-K groups at 170 plants of 43 steel companies were known to be in existence.[28]

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[27] See The Wall Street Journal, April 7, 1981.

[28] See Kawahito [1979], p. 18.

3. Use of Computers

According to Kawahito [1979], the application of computer technology in the Japanese steel industry is more thorough than in the U.S. steel industry. This is also related to the modernity of the plant and equipment. Conventional plant layouts limit the scope for the application of computer technologies, because it is difficult to install computers in obsolete facilities. Computer control systems can be used for various purposes:

Analysis of customer order specifications
Inspection of operational details
Setting up of optimal production schedules
Specification of cutting the final products
Stocking and shipping

Summary of Chapter V

1. Government involvement in the steel industries of the U.S. and Japan does not seem to have affected the competitiveness significantly based on our observations on the changes in the unit cost of steel production. However, the effects at the margin require a more careful examination. The difference in depreciation laws between the U.S. and Japan may have had some effect for the period 1952-1962.

2. In the adoption of technologies such as the basic oxygen furnace and continuous casting processes, the U.S. steel producers fell behind their international competitors, which resulted in a decline in technical efficiency relative to the competitors.

3. Although difficult to quantify, it is possible that differences in the modernity of plant and equipment, in the use of computers, and in labor-management relationships might have affected the competitiveness of the U.S. in the steel industry.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

The U.S. comparative advantage in steel production has been declining relative to the other major steel producers in the world starting as early as the 1920's. Such a trend was temporarily disrupted by World War II, but the prewar trend continued after the 1950's.

According to our regression analysis, over the time period 1956-1976, the U.S. steel industry experienced capital-saving and raw material-saving, and labor-using and energy-using technical changes, while its Japanese counterpart experienced labor-saving and raw material-saving, and capital-using and energy-using technical changes.

Our analysis also suggests that there may exist technical complementarity relationships between some factors of production and that the overall state of technology is not the same for the U.S. and Japanese steel industries.

As for the growth of total factor productivity, the Japanese steel industry experienced much more rapid technological changes than its U.S. competitors over the same period 1956-1976. This result is in sharp contrast with claims by U.S. steel industry representatives. Now it appears that U.S. steel industry representatives are beginning to acknowledge that the U.S. is lagging behind the Japanese steel industry in terms of technology.[29]

Moreover, our findings indicate that the difference in total factor productivity growth between the steel industries of the two countries has had a significant effect on the U.S.-Japan steel trade. Contrary to the findings of previous studies, our results suggest that the lower growth rate of total factor productivity of the U.S. steel industry relative to its international competitors, especially Japan, is the major factor which resulted in a decline in the U.S. comparative advantage in steel production, and thereby the rapid growth of steel imports into the United States.

We find that government involvement such as subsidies, preferential treatment, price controls, environmental regulations, and trade interventions had some but not significant effects on the competitiveness of the steel industries, except for the difference in depreciation laws between the two countries for the period 1952-1962.

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[29] See the statement by David M. Roderick, chaiman of the United States Steel Corporation in The Wall Street Journal, May 15, 1980.

Although, at present, the wage level is lower in Japan than in the U.S., the average rate of increase in Japanese employment costs is much higher than that for the U.S. So the gap in employment costs is likely to decrease in the future.

With respect to the direction of technological changes, the U.S. steel industry failed to respond correctly to given changes in factor prices. Among other things, the U.S. steel industry was not able to sustain labor-saving technological progress, while Japanese steel producers did in response to a rapid rise in labor costs.

Policy Implications

In the recent past, the U.S. steel industry's position has been to try to get some kind of protection from the government. The industry has been claiming that foreign producers are trying to erode the U.S. steel market by dumping their products at prices below production costs and raise prices after they have succeeded in taking up a considerable share of the U.S. steel market. Such an argument seems dubious at best. Instead, U.S. steel producers have to realize that they are lagging behind Japanese producers in productivity growth and begin to do something about it.

The U.S. steel industry has to make a greater effort toward improving factor productivity if it is to prosper in face of international competition. More specifically, the U.S. will have to improve labor productivity and achieve energy-saving technological progress[30] in the steel industry.

On specific technology aspects of the problem, we recommend faster adoption of the continuous casting process and the scrapping of obsolete steel production facilities. Government intervention in any form would not be very helpful at this point. The only case in which government intervention might be necessary would be for national security reasons. In that case, government can first determine the minimum level of steel production capacity necessary to maintain national defense. Government should let the industry take care of the problem on its own unless production falls below some critical level. If output falls below the minimum acceptable level, government involvement might be needed (in the form of a subsidy, for example).

In view of Japanese experience after World War II, a subsidy toward modernization might be a good idea. But even in this case, the subsidy should be short-term in order to prevent any possible adverse effects on efforts

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[30] See Table 52 for an increase in the share of energy inputs in recent years, especially after the oil crisis (1973-74).

at continued technological improvement on the part of U.S. steel industry.

Any concern about an increasing unemployment in the steel producing sector must be considered in the same context. Concessions from the steelworkers in the form of lower increase in wages in future contracts would be a very unpopular measure. However, in light of the very high level of wages for the U.S. steelworkers which exceeds the average of all manufacturing industries in the U.S.,[31] let alone the Japanese steelworkers' wage level, such a measure is a conceivable alternative.

Limitations of the Present Study and Suggestions for Future Research

There are two major limitations in the present study in particular, and in the literature on technological change in general. There is no model in the literature which incorporates the demand side explicitly. The present study used dummy variables to resolve this problem. Second, there is no model which deals with the case of imperfect competition. If a new model could be developed which remedies those two limitations, it would be a substantial contribution to the analysis of the world

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[31] See Table 54 for a comparison of hourly wages for the steelworkers and all manufacturing average.

steel market.

Another limitation which is unique to the present study is the small sample size which limited our ability to conduct empirical work that assured a high degree of reliability. For example, in estimating the rates of technical changes, an analysis for two different time periods, pre-World War II and post-World War II, to test for structural changes in parameters, would have been desirable.

Despite the limitations discussed above, the present study points the way toward the use of a new and simple methodology for analyzing the international competitiveness of specific industries based on productivity changes. Other areas of possible research would include:

Tests for biases in technological changes in other industries in order to determine the robustness of the K-W theory and the F-H-A theory; Developing a more general theory of technical complementarity and reversibility of bias in technological progress.

APPENDIX A

STATISTICAL TABLES

Table 27

Free World Raw Steel Production (Million MT)

Year	Free World	Japan (%)	EC(9) (%)	U.S. (%)
1950	153.0	4.8 (2.6)	48.4 (25.8)	87.8 (46.7)
1951	168.5	6.5 (3.1)	53.8 (25.5)	95.4 (45.3)
1952	165.1	7.0 (3.3)	59.5 (28.0)	84.6 (39.8)
1953	182.0	7.6 (4.2)	57.6 (24.5)	101.2 (43.1)
1954	166.8	7.7 (3.4)	62.8 (28.0)	80.1 (35.8)
1955	207.5	9.4 (3.5)	72.9 (27.0)	106.1 (39.3)
1956	215.6	12.0 (4.2)	77.9 (27.5)	104.5 (36.8)
1957	219.5	12.5 (4.3)	82.0 (28.1)	102.2 (35.0)
1958	190.6	12.1 (4.4)	78.0 (28.8)	77.4 (28.5)
1959	212.7	16.6 (5.4)	84.0 (27.5)	84.7 (27.7)
1960	241.0	22.1 (6.4)	97.9 (28.3)	90.1 (26.0)
1961	247.7	28.2 (8.0)	96.1 (27.1)	88.9 (25.1)
1962	248.2	27.6 (7.7)	94.0 (26.3)	89.2 (24.9)
1963	268.6	31.5 (8.2)	96.5 (25.2)	99.2 (25.9)
1964	311.4	39.8 (9.2)	110.0 (25.3)	115.3 (26.5)
1965	324.0	41.2 (9.0)	113.9 (24.9)	119.3 (26.1)
1966	331.7	47.8 (10.2)	110.2 (23.4)	121.7 (25.8)
1967	346.6	62.1 (12.5)	114.6 (23.1)	115.4 (23.2)
1968	371.0	66.9 (12.7)	125.4 (23.7)	119.3 (22.6)
1969	408.2	82.1 (14.3)	134.7 (23.5)	128.2 (22.4)
1970	418.4	93.4 (15.7)	137.6 (23.2)	119.3 (20.1)
1971	393.8	88.5 (15.3)	128.2 (22.1)	109.2 (18.8)
1972	434.3	96.9 (15.4)	139.2 (22.1)	120.8 (19.2)
1973	491.1	119.3 (17.1)	150.1 (21.5)	136.8 (19.6)
1974	494.9	117.1 (16.5)	155.6 (21.9)	132.2 (18.6)
1975	423.9	102.3 (15.8)	125.3 (19.4)	105.8 (16.4)
1976	453.1	107.4 (15.7)	134.4 (19.7)	116.1 (17.0)
1977		102.4 (15.2)	131.6 (19.5)	113.7 (16.9)

Source: AISI, Annual Statistical Report, various years

Table 28

U.S. Trade in Steel Mill Products (1,000 MT)

Year	Net Shipments(NS)	Imports (I)	Exports (E)	Apparent Consumption	I/AC[a] (%)	E/NS (%)
1950	65,528	920	2,394	64,056	1.4	3.7
1951	71,604	1,975	2,846	70,812	2.8	3.9
1952	61,693	1,090	3,633	59,214	1.8	5.8
1953	72,713	1,545	2,713	71,595	2.1	3.6
1954	57,292	699	2,533	55,595	1.3	4.2
1955	76,855	883	3,684	74,053	1.2	4.8
1956	75,525	1,217	3,944	72,797	1.7	5.2
1957	72,480	1,048	4,852	68,676	1.5	6.7
1958	54,354	1,549	2,561	53,341	2.9	4.7
1959	62,938	3,988	1,521	65,405	6.1	2.4
1960	64,546	3,047	2,701	64,892	4.7	4.2
1961	59,989	2,869	1,805	61,053	4.7	3.0
1962	64,004	3,719	1,826	65,898	5.6	2.9
1963	68,543	4,941	2,018	71,513	6.9	2.9
1964	77,062	5,842	3,123	79,781	7.3	4.1
1965	84,066	9,419	2,264	91,221	10.3	2.7
1966	81,643	9,755	1,564	89,834	10.9	1.9
1967	76,111	10,392	1,529	84,974	12.2	2.0
1968	83,331	16,293	1,969	97,656	16.7	2.4
1969	85,165	12,732	4,744	93,152	13.7	5.6
1970	82,371	12,124	6,407	88,089	13.8	7.8
1971	78,960	16,622	2,565	93,001	17.9	3.2
1972	83,285	16,040	2,606	96,719	16.6	3.1
1973	101,089	13,744	3,676	111,157	12.4	3.6
1974	99,312	14,488	5,292	108,509	13.4	5.3
1975	72,537	10,897	2,679	80,755	13.5	3.7
1976	81,146	12,959	2,408	91,697	14.1	3.0
1977	82,688	17,515	2,180	98,386	17.8	2.6

[a] AC = Apparent Consumption

Source: AISI, Annual Statistical Report, various years

Table 29

U.S. Imports of Steel Mill Products by Country of Origin
(1,000 MT)

Year	Japan (%)	EC(9) (%)	Rest of World (%)
1960	541 (17.74)	1,887 (61.92)	595 (19.52)
1961	542 (18.87)	1,921 (66.93)	409 (14.25)
1962	973 (26.15)	2,120 (57.00)	628 (16.88)
1963	1,640 (33.16)	2,355 (47.62)	951 (19.22)
1964	2,219 (37.98)	2,604 (44.57)	1,019 (17.44)
1965	4,008 (42.55)	4,455 (47.30)	956 (10.15)
1966	4,401 (45.11)	4,163 (42.68)	899 (9.22)
1967	4,053 (39.00)	5,135 (49.41)	567 (5.46)
1968	6,617 (40.61)	7,620 (46.77)	2,056 (12.62)
1969	5,673 (44.56)	5,528 (43.42)	1,532 (12.04)
1970	5,384 (44.41)	4,896 (40.38)	1,843 (15.21)
1971	6,267 (37.74)	7,723 (46.50)	2,615 (15.75)
1972	5,842 (36.42)	7,057 (44.00)	2,475 (15.43)
1973	5,114 (37.21)	5,906 (42.97)	2,724 (19.82)
1974	5,587 (38.57)	5,828 (40.22)	3,073 (21.21)
1975	5,302 (48.65)	3,740 (34.32)	1,856 (17.03)
1976	7,243 (55.89)	2,892 (22.31)	2,824 (21.79)

Source: AISI Annual Statistical Report, various years

Table 30

Japanese Exports of Steel Products by Destination
(1,000 MT)

Year[a]	S.E. Asia	Middle East	U.S. (%)	EC(9) (%)
1956			101 (7.4)	
1957			76 (7.2)	
1958			388 (21.2)	
1959			656 (36.4)	
1960			583 (23.3)	
1961			615 (24.5)	
1962			1,163 (28.1)	
1963			1,796 (31.9)	
1964			2,687 (38.9)	
1965			4,349 (43.9)	
1966			4,695 (47.4)	
1967	2,986	215	4,349 (47.6)	209 (2.3)
1968	3,661	419	6,916 (52.6)	266 (2.0)
1969	4,763	649	5,651 (35.3)	1,055 (6.6)
1970	5,353	576	5,922 (32.9)	1,058 (5.9)
1971	7,281	1,171	6,268 (26.0)	2,002 (8.3)
1972	7,101	1,259	6,258 (28.5)	1,516 (6.9)
1973	9,790	1,671	5,287 (20.6)	1,278 (5.0)
1974	10,995	3,217	6,510 (19.7)	1,090 (3.3)
1975	8,919	4,592	5,724 (19.1)	1,640 (5.5)
1976	10,865	5,232	7,444 (20.1)	1,616 (4.4)
1977	12,895	3,937	7,596 (21.7)	1,286 (3.7)

[a] Fiscal year, not the calendar year

Source: JISF, Statistical Yearbook, various years

Table 31

Japanese Trade in Steel Products (1,000 MT)

Year	Production (P)	Imports (I)	Exports (E)	E/P (%)
1956	8,615	295	1,623	18.8
1957	9,891	1,590	1,261	12.7
1958	9,478	204	2,216	23.4
1959	12,600	405	2,207	17.4
1960	16,844	308	3,144	18.7
1961	21,412	412	3,192	14.9
1962	21,753	249	5,269	24.2
1963	24,959	69	7,195	28.8
1964	31,137	49	8,940	28.7
1965	32,446	32	12,705	39.2
1966	37,828	36	12,155	32.1
1967	48,892	461	11,315	23.1
1968	53,772	139	16,322	30.4
1969	64,854	168	19,875	30.6
1970	74,072	126	22,323	30.1
1971	70,545	58	28,302	40.1
1972	80,401	116	26,008	32.3
1973	100,280	244	30,247	30.2
1974	99,154	254	38,409	38.7
1975	84,469	120	34,353	40.7
1976	90,469	176	42,355	46.8
1977	88,600	249	39,449	44.5

Source: JISF Statistical Yearbook, various years

Table 32

World Crude Steel Production by Major Steel Producers and Their Shares(Million MT and %)

Year	Germany	U.K.	U.S.S.R.	U.S.	Japan
1920	9.3(12.5)	10.0(13.4)	0.2(0.3)	44.7(59.8)	0.8(1.1)
1921	11.0(23.8)	4.1(8.8)	0.2(0.5)	20.8(45.3)	0.9(1.9)
1922	13.0(18.4)	6.3(8.9)	0.2(0.5)	37.4(52.9)	0.9(1.3)
1923	7.3(9.1)	9.1(11.3)	0.6(0.8)	47.0(58.4)	1.0(1.2)
1924	11.3(14.1)	8.8(10.9)	1.0(1.2)	39.5(49.1)	1.1(1.4)
1925	13.8(15.0)	7.5(8.1)	1.9(2.0)	47.1(52.1)	1.3(1.5)
1926	14.1(14.8)	3.7(3.8)	2.9(3.1)	50.0(52.6)	1.5(1.6)
1927	18.2(17.8)	9.2(9.1)	3.6(3.5)	45.7(44.8)	1.7(1.7)
1928	16.5(15.1)	8.7(7.9)	4.3(3.9)	52.4(47.7)	2.0(1.8)
1929	18.4(15.2)	9.8(8.1)	4.9(4.0)	57.3(47.4)	2.3(1.9)
1930	13.4(14.1)	7.4(7.8)	5.8(6.1)	41.4(43.5)	2.3(2.4)
1931	9.8(14.1)	5.3(7.6)	5.6(8.1)	26.4(37.8)	1.9(2.7)
1932	7.2(14.5)	5.3(10.7)	5.9(11.9)	13.9(27.9)	2.4(4.8)
1933	9.3(13.6)	7.1(10.5)	6.9(10.1)	23.7(34.8)	3.2(4.7)
1934	13.8(16.8)	9.0(10.9)	9.7(11.8)	27.1(32.8)	3.9(4.7)
1935	16.4(16.5)	10.0(10.0)	12.6(12.6)	35.1(35.2)	4.8(4.8)
1936	19.2(15.5)	12.0(9.6)	16.4(13.2)	49.6(40.0)	5.3(4.3)
1937	19.8(14.6)	13.2(9.7)	17.7(13.1)	52.8(39.0)	5.8(4.3)
1938	22.7(20.6)	10.6(9.6)	18.1(16.5)	29.2(26.6)	6.5(6.0)
1944	20.1(13.1)	12.3(8.0)	12.0(7.8)	81.3(52.8)	6.7(4.4)
1945	1.7(1.4)	12.0(10.4)	12.5(10.9)	72.3(62.7)	2.0(1.7)
1946	3.0(2.7)	13.0(11.6)	13.6(12.2)	60.4(54.1)	0.6(0.5)
1947	4.0(3.0)	12.9(9.5)	14.7(10.8)	77.0(56.6)	1.0(0.7)
1948	7.1(4.6)	15.1(9.7)	18.9(12.1)	80.4(51.7)	1.7(1.1)
1949	11.5(7.2)	15.8(9.9)	23.3(14.6)	72.5(45.4)	3.1(1.9)
1950	15.0(8.0)	16.6(8.8)	27.3(14.5)	90.4(47.9)	4.8(2.6)
1951	17.4(8.3)	15.9(7.6)	31.4(14.9)	99.1(47.2)	6.5(3.1)
1952	20.1(9.4)	16.7(7.8)	34.5(16.1)	87.8(41.1)	7.0(3.3)
1953	20.2(8.6)	17.9(7.6)	38.1(16.2)	104.1(44.1)	7.7(3.2)
1954	22.7(10.1)	18.8(8.4)	41.4(18.5)	82.1(36.7)	7.8(3.5)
1955	27.0(10.0)	20.1(7.4)	45.3(16.8)	108.6(40.2)	9.4(3.5)
1956	29.3(10.4)	21.0(7.4)	48.7(17.2)	107.6(38.1)	11.1(3.9)
1957	30.9(10.6)	22.0(7.6)	51.0(17.6)	105.1(36.2)	12.6(4.3)
1958	29.6(11.2)	19.9(7.5)	54.9(20.7)	79.1(29.8)	12.1(4.6)
1959	32.6(11.1)	20.5(7.0)	60.0(20.3)	87.1(29.5)	16.6(5.6)
1960	37.4(11.3)	24.7(7.5)	65.3(19.8)	91.9(27.8)	22.1(6.7)

Table 32 (Continued)

Year	Germany	U.K.	U.S.S.R.	U.S.	Japan
1961	37.4(10.9)	22.4(6.5)	70.8(20.6)	90.5(26.3)	28.3(8.2)
1962	36.7(10.4)	20.8(5.9)	76.3(21.6)	91.2(25.9)	27.5(7.8)
1963	35.7(9.4)	22.9(6.1)	80.2(21.2)	101.5(26.8)	31.5(8.3)
1964	41.7(9.8)	26.7(6.2)	85.0(19.9)	118.0(27.7)	39.8(9.3)
1965	40.7(9.1)	27.4(6.2)	91.0(20.4)	122.0(27.4)	41.2(9.2)
1966	39.9(8.6)	24.7(5.3)	96.9(21.0)	124.7(27.0)	47.8(10.3)
1967	41.5(8.6)	24.3(5.0)	102.2(21.1)	118.0(24.4)	62.2(12.8)
1968	45.9(8.9)	26.3(5.1)	106.5(20.7)	121.9(23.6)	66.9(13.0)
1969	50.5(9.0)	26.8(4.8)	110.4(19.7)	131.2(23.4)	82.2(14.7)
1970	50.1(8.7)	28.3(4.9)	115.9(20.0)	122.1(21.1)	93.3(16.1)
1971	46.1(8.2)	24.1(4.3)	120.6(21.5)	111.8(19.9)	88.6(15.8)
1972	49.5(8.1)	25.3(4.2)	125.6(20.7)	123.8(20.4)	96.9(16.0)
1973	55.4(8.2)	26.6(4.0)	131.5(19.6)	139.9(20.9)	119.3(17.8)
1974	59.4(8.7)	22.3(3.3)	136.2(20.0)	135.3(19.8)	117.1(17.1)
1975	46.9(7.6)	20.1(3.2)	141.5(22.8)	109.1(17.6)	102.2(16.5)
1976	49.0(7.2)	22.4(3.3)	147.0(21.5)	116.1(17.0)	107.4(15.7)

Source: Eurostat, Iron and Steel Yearbook, 1976, 1978
AISI Annual Statistical Report, various years

Table 33

Free World Crude Steel Production and Shares of Individual Countries (1,000 MT and Percent)

Year	Germany	U.K.	U.S.	Japan	Free World
1920	12.5%	13.4%	60.0%	1.1%	74,506 MT
1921	23.9	8.8	45.5	1.9	45,780
1922	18.5	8.9	53.1	1.3	70,382
1923	9.2	11.4	58.9	1.2	79,785
1924	14.3	11.0	49.7	1.4	79,407
1925	15.3	8.3	52.2	1.5	90,232
1926	15.3	4.0	54.3	1.7	92,089
1927	18.5	9.4	46.4	1.8	98,408
1928	15.7	8.2	49.6	1.9	105,649
1929	15.9	8.5	49.4	2.0	116,046
1930	15.1	8.3	46.3	2.6	89,339
1931	15.3	8.2	41.1	2.9	64,080
1932	16.4	12.2	31.7	5.5	43,873
1933	15.1	11.6	38.7	5.2	61,211
1934	19.0	12.4	37.2	5.4	72,807
1935	18.8	11.5	40.3	5.5	87,112
1936	17.8	11.1	46.0	4.9	107,700
1937	16.8	11.2	44.9	4.9	117,670
1938	24.7	11.5	31.8	7.1	91,743
1944	14.2	8.7	57.2	4.7	142,100
1945	1.6	11.7	70.4	1.9	102,732
1946	3.1	13.2	61.7	0.6	97,987
1947	3.3	10.6	63.4	0.8	121,482
1948	5.2	11.1	58.9	1.3	136,622
1949	8.4	11.6	53.2	2.3	136,409
1950	9.3	10.3	56.0	3.0	161,371
1951	9.8	8.9	55.4	3.6	178,750
1952	11.3	9.3	49.0	3.9	179,258
1953	10.2	9.0	52.8	3.9	197,872
1954	12.4	10.3	45.0	4.3	182,566
1955	12.0	9.0	48.4	4.2	224,729
1956	12.5	9.0	46.0	4.8	233,802
1957	12.9	9.2	43.9	5.3	239,607
1958	14.1	9.5	37.6	5.8	210,280
1959	13.9	8.7	37.0	7.1	235,100
1960	14.1	9.3	34.7	8.4	265,208

Table 33 (Continued)

Year	Germany	U.K.	U.S.	Japan	Free World
1961	13.7%	8.2%	33.2%	10.4%	272,749 MT
1962	13.3	7.5	33.0	10.0	276,194
1963	12.0	7.7	34.1	10.6	297,774
1964	12.2	7.8	34.5	11.7	341,666
1965	11.5	7.7	34.4	11.6	355,000
1966	10.9	6.8	34.1	13.1	365,509
1967	10.9	6.4	30.9	16.3	381,800
1968	11.2	6.4	29.8	16.3	409,268
1969	11.3	6.0	29.3	18.4	447,800
1970	10.8	6.1	26.4	20.2	462,727
1971	10.4	5.5	25.3	20.0	442,463
1972	10.2	5.2	25.6	20.1	483,011
1973	10.3	4.9	25.9	22.1	540,341
1974	10.8	4.1	24.7	21.4	547,494
1975	9.8	4.2	22.8	21.4	478,500
1976	9.1	4.2	21.7	20.0	536,160

Source: Eurostat, Iron and Steel Yearbook, 1976, 1978
AISI Annual Statistical Report, various years

Table 34

Japanese Trade of Steel Products
(1,000 MT of Crude Steel Equivalent)

Year	Production (A)	Imports (B)	Exports (C)	Apparent Cons. (D)	C/A(%)	B/D(%)
1920	811	1,316	100	2,026	12.4	64.9
1921	832	797	89	1,547	10.7	51.7
1922	909	1,388	87	2,210	9.6	62.8
1923	959	1,013	108	1,864	11.3	54.4
1924	1,100	1,446	103	2,443	9.3	59.2
1925	1,300	674	126	1,848	9.7	36.4
1926	1,506	1,188	120	2,574	8.0	46.1
1927	1,685	1,110	145	2,650	8.6	41.9
1928	1,906	1,127	200	2,833	10.5	39.8
1929	2,294	1,167	229	3,232	10.0	36.1
1930	2,289	626	226	2,689	9.9	23.3
1931	1,883	396	250	2,029	13.3	19.5
1932	2,398	327	311	2,414	13.0	13.5
1933	3,198	648	426	3,420	13.3	19.0
1934	3,844	653	680	3,816	17.7	17.1
1935	4,704	768	984	4,489	20.9	17.1
1936	5,223	710	1,120	4,813	21.4	14.7
1937	5,801	1,459	848	6,412	14.6	22.8
1938	6,472	758	908	6,322	14.0	12.0
1939	6,696	506	1,069	6,134	16.0	8.3
1940	6,856	724	889	6,690	13.0	10.8
1941	6,844	360	735	6,469	10.7	5.6
1942	7,044	263	461	6,846	6.5	3.8
1943	7,650	159	125	7,684	1.6	2.1
1944	6,729	70	71	6,728	1.0	1.0
1945	1,963	15	21	1,957	1.1	0.8
1946	557	--	0.5	557	0.1	--
1947	952	--	0.8	951	0.1	--
1948	1,715	2	42	1,674	2.5	0.1
1949	3,111	7	288	2,831	9.3	0.3
1950	4,839	3	727	4,114	15.0	0.06
1951	6,502	33	1,269	5,266	19.5	0.6
1952	6,988	31	1,988	5,031	28.5	0.6
1953	7,662	124	1,035	6,751	13.5	1.8
1954	7,750	106	1,465	6,391	18.9	1.7
1955	9,408	83	2,305	7,185	24.5	1.1

Table 34 (Continued)

Year	Production (A)	Imports (B)	Exports (C)	Apparent Cons.(D)	C/A(%)	B/D(%)
1956	11,106	283	1,570	9,819	14.1	2.9
1957	12,570	1,584	1,219	12,934	9.7	12.2
1958	12,118	188	2,122	10,184	17.5	1.8
1959	16,629	397	2,091	14,934	12.6	2.7
1960	22,138	305	2,996	19,448	13.5	1.6
1961	28,268	412	3,015	25,666	10.7	1.6
1962	27,546	236	5,077	22,706	18.4	1.0
1963	31,501	69	7,195	24,375	22.8	0.3
1964	39,799	49	8,940	30,908	22.5	0.2
1965	41,161	32	12,705	28,488	30.9	0.1
1966	47,784	38	12,789	35,032	26.8	0.1
1967	62,154	463	11,918	50,699	19.2	0.9
1968	66,893	139	17,227	49,905	25.8	0.3
1969	82,166	170	21,029	61,307	25.6	0.28
1970	93,322	132	23,621	69,833	25.3	0.19
1971	88,557	61	31,015	57,603	35.0	0.11
1972	96,900	121	28,306	68,715	29.2	0.18
1973	119,322	256	33,430	86,148	28.0	0.3
1974	117,131	268	43,028	74,371	36.7	0.36
1975	102,313	124	37,927	64,510	37.1	0.19
1976	107,399	181	47,605	59,975	44.3	0.3

Source: JISF Statistical Yearbook, various years

Table 35

U.S. Trade in Steel Mill Products
(1,000 MT)

Year	(A) Total Net Shipments	(B) Imports	(C) Exports	(D) Apparent Consumpt.	C/A(%)	B/D(%)
1930[a]	41,353	400	2,099	39,653	5.1	1.0
1931	26,362	383	1,056	25,689	4.0	1.5
1932	13,901	287	470	13,718	3.4	2.1
1933	23,605	183	735	23,054	3.1	0.8
1934	26,474	153	1,268	25,359	4.8	0.6
1935	34,640	292	1,239	33,693	3.6	0.9
1936	48,535	368	1,572	47,331	3.2	0.8
1937	51,381	392	3,519	48,254	6.8	0.8
1938	28,805	224	2,217	26,812	7.7	0.8
1939	47,899	230	3,020	45,108	6.3	0.5
1940	60,767	24	9,583	51,208	15.8	0.05
1941[a]	75,151	23	7,756	67,418	10.3	0.03
1942[a]	78,048	22	8,503	69,566	10.9	0.03
1943	56,437	15	6,007	50,445	10.6	0.03
1944	58,236	42	4,943	53,334	8.5	0.08
1945	51,930	49	3,950	48,029	7.6	0.1
1946	44,249	21	3,969	40,301	9.0	0.05
1947	57,205	29	5,370	51,864	9.4	0.06
1948	59,850	134	3,583	56,401	6.0	0.2
1949	52,712	264	3,941	49,035	7.5	0.5
1950	65,528	920	2,394	64,054	3.7	1.4
1951	71,604	1,975	2,846	70,733	4.0	2.8
1952	61,693	1,090	3,633	59,149	5.9	1.8
1953	72,713	1,545	2,713	71,545	3.7	2.2
1954	57,292	699	2,533	55,459	4.4	1.3
1955	76,855	883	3,684	74,053	4.8	1.2
1956	75,525	1,217	3,944	72,797	5.2	1.7
1957	72,480	1,048	4,852	68,676	6.7	1.5
1958	54,354	1,549	2,561	53,341	4.7	3.1
1959	62,938	3,988	1,521	65,405	2.4	6.1
1960	64,546	3,047	2,701	64,892	4.2	4.7

Table 35 (Continued)

Year	(A) Total Net Shipments	(B) Imports	(C) Exports	(D) Apparent Consumpt.	C/A(%)	B/D(%)
1961	59,989	2,869	1,805	61,053	3.0	4.7
1962	64,004	3,719	1,826	65,898	2.9	5.6
1963	68,543	4,941	2,018	71,513	2.9	6.9
1964	77,062	5,842	3,123	79,781	4.1	7.3
1965	84,066	9,419	2,264	91,221	2.7	10.3
1966	81,643	9,755	1,564	89,834	1.9	10.9
1967	76,111	10,392	1,529	84,974	2.0	12.2
1968	83,331	16,293	1,969	97,656	2.4	16.7
1969	85,165	12,732	4,744	93,152	5.6	13.7
1970	82,371	12,124	6,407	88,089	7.8	13.8
1971	78,960	16,622	2,565	93,001	3.3	17.9
1972	83,285	16,040	2,606	96,719	3.1	16.6
1973	101,089	13,744	3,676	111,157	3.6	12.4
1974	99,312	14,488	5,292	108,509	5.3	13.4
1975	72,537	10,897	2,679	80,755	3.7	13.5
1976	81,146	12,959	2,408	91,697	3.0	14.1
1977	82,688	17,515	2,180	98,386	2.6	17.8

[a] 1930-42: Production figures rather than net shipments

Source: AISI Annual Statistical Report, various years

Table 36

U.S. Steel Industry Basic Data

Year	Raw Steel Output (Million MT)	Unit Labor Cost ($)	Unit Total[a] Cost ($)	Total Hours Worked(1000 Hrs)
1957	102.2	60.24	120.30	1,222,695
1958	77.4	70.09	135.58	981,710
1959	84.7	66.67	126.09	1,003,259
1960	90.1	71.83	133.10	1,086,875
1966	121.7	65.93	128.98	1,152,502
1967	115.4	69.88	135.28	1,083,717
1968	119.3	70.35	134.34	1,095,117
1969	128.2	75.18	141.18	1,098,975
1970	119.3	80.81	154.77	1,029,738
1971	109.2	85.03	165.83	931,501
1972	120.8	89.52	175.01	940,302
1973	136.8	87.31	178.21	1,022,955
1974	132.2	100.91	233.54	1,013,127
1975	105.8	132.87	294.37	854,905
1976	116.1	143.55	320.75	876,786

[a] Unit total cost refers to total cost for major inputs per metric ton of steel produced. Major inputs include capital, labor, iron ore, scrap, coking coal, noncoking coal, electric power, fuel oil, and natural gas.

Source: AISI, Annual Statistical Report, various years
FTC Staff Report [1977]

Table 37

Japanese Steel Industry Basic Data

Year	Raw Steel Output (Million MT)	Unit Labor Cost($)	Unit Total Cost($)	Total Hours Worked(1000 Hrs)
1956	11.1	26.66	135.77	35,305
1957	12.5	26.79	149.81	37,655
1958	11.8	30.12	119.85	40,860
1959	16.6	25.02	110.55	
1960	22.1	23.01	105.72	
1961	28.3	21.94	112.08	
1962	27.6	24.10	104.62	
1963	31.5	23.76	101.06	57,233
1964	39.8	20.97	96.76	62,685
1965	41.2	22.11	96.92	59,478
1966	47.8	20.68	90.38	
1967	62.1	19.93	86.45	
1968	66.9	20.83	85.02	
1969	82.1	21.20	87.76	
1970	93.4	23.22	97.57	62,813
1971	88.5	27.98	106.43	60,696
1972	96.9	31.97	112.04	57,426
1973	119.3	35.32	129.90	58,367
1974	117.1	42.60	178.85	57,201
1975	102.3	49.93	200.04	53,137
1976	107.4	49.64	204.28	53,074

Source: JISF Statistical Yearbook, various years
FTC Staff Report [1977]

Table 38

Japanese Input Costs Per Metric Ton of Steel (U.S. dollars)

Year	Unit Total Cost[a]	Capital[b]	Labor	Iron Ore	Scrap	Energy
1956	135.77	15.94	26.66	25.78	35.15	32.24
1957	149.81	16.60	26.79	31.55	37.98	36.89
1958	119.85	21.20	30.12	21.20	19.37	27.96
1959	110.55	20.51	25.02	18.08	24.59	22.35
1960	105.72	20.64	23.01	17.91	23.16	21.00
1961	112.08	20.49	21.94	18.54	30.09	21.02
1962	104.62	23.06	24.10	18.97	17.43	21.06
1963	101.06	22.03	23.76	17.80	18.12	19.35
1964	96.76	21.56	20.97	16.73	19.27	18.23
1965	96.92	20.54	22.11	18.63	16.75	18.89
1966	90.38	18.52	20.68	18.14	14.88	18.16
1967	86.45	16.92	19.93	16.68	15.73	17.19
1968	85.02	17.24	20.83	16.99	12.16	17.80
1969	87.76	17.83	21.20	16.66	14.00	18.07
1970	97.57	19.52	23.22	17.47	16.05	21.31
1971	106.43	25.15	27.98	19.43	9.06	24.81
1972	112.04	28.48	31.97	16.97	12.04	22.58
1973	129.90	28.93	35.32	17.62	23.38	24.65
1974	178.85	31.55	42.60	21.65	33.65	49.40
1975	200.04	40.78	49.93	27.85	17.23	64.25
1976	204.28	42.35	49.64	26.87	22.72	62.70

[a] Unit total cost of major inputs: capital, labor, iron ore, scrap, and energy inputs.

[b] Includes equity cost of capital

Source: FTC Staff Report [1977] and Tekko Nenkan

Table 39

Japanese Input Prices

Year	Capital[a] (%)	Labor ($/Man-Hr)	Iron Ore ($/MT)	Scrap ($/MT)
1956	14.72	0.43	18.40	72.75
1957	14.14	0.47	21.70	83.80
1958	14.31	0.48	16.20	47.57
1959	15.64	0.50	14.00	51.54
1960	15.93	0.53	14.20	50.22
1961	16.09	0.58	14.20	55.08
1962	15.70	0.62	14.30	41.36
1963	16.52	0.66	13.58	42.75
1964	16.66	0.75	13.46	45.37
1965	15.88	0.82	13.42	46.07
1966	15.55	0.91	13.13	44.30
1967	15.72	1.04	12.66	45.99
1968	15.32	1.17	12.23	39.05
1969	15.89	1.40	11.64	44.99
1970	16.38	1.69	11.84	55.40
1971	15.67	1.98	11.58	39.07
1972	15.03	2.48	11.43	44.18
1973	13.86	3.42	12.26	85.19
1974	14.01	4.24	14.62	133.70
1975	16.11	4.94	16.70	88.74
1976	15.74	5.25	17.43	90.19

[a] Lending rate of Long-term Credit Bank of Japan + Rate of depreciation

Source: FTC Staff Report [1977]

IISI, Financing Steel Investment, 1961-1971

Bank of Japan, Economic Statistics Annual, various years

Table 40

U.S. Input Costs Per Metric Ton of Steel (U.S. dollars)

Year	Unit Total Cost[a]	Capital[b]	Labor	Iron Ore	Scrap	Energy
1956	120.61	9.77	54.67	17.51	17.78	20.88
1957	120.30	10.30	60.24	18.17	10.95	20.64
1958	135.58	13.40	70.09	19.75	9.94	22.40
1959	126.09	12.11	66.67	17.25	10.87	19.19
1960	133.10	12.92	71.83	19.47	8.24	20.64
1961	136.94	14.44	72.36	20.58	9.45	20.11
1962	135.77	17.03	71.36	19.93	6.83	20.62
1963	132.89	16.88	69.62	19.60	7.39	19.40
1964	130.48	15.51	67.00	20.41	8.25	19.31
1965	127.77	14.78	65.06	19.92	8.56	19.45
1966	128.98	15.77	65.93	19.95	7.72	19.61
1967	135.28	17.58	69.88	20.10	6.73	20.99
1968	134.34	14.94	70.35	20.65	6.71	21.69
1969	141.18	15.93	75.18	20.34	8.60	21.13
1970	154.77	17.54	80.81	21.54	10.05	24.83
1971	165.83	19.85	85.03	22.85	8.53	29.57
1972	175.01	19.90	89.52	23.84	11.26	30.49
1973	173.21	17.00	87.31	24.42	17.08	32.40
1974	233.54	17.99	100.91	29.66	34.10	50.88
1975	294.37	24.10	132.87	37.58	18.98	80.84
1976	320.75	26.10	143.55	44.51	21.82	84.77

[a] Unit total cost of major inputs

[b] Includes the cost of equity.

Source: FTC Staff Report [1977]

AISI Annual Statistical Report, various years

Table 41

U.S. Input Prices

Year	Capital[a] (%)	Labor ($/Man-Hr)	Iron Ore ($/MT)	Scrap ($/MT)
1956	8.29	3.35	10.61	52.95
1957	8.73	3.60	11.49	46.00
1958	9.14	3.87	11.70	37.48
1959	9.03	4.14	11.91	40.26
1960	9.30	4.19	12.29	31.70
1961	9.76	4.36	12.99	35.70
1962	11.16	4.51	12.79	27.78
1963	11.56	4.60	12.86	26.68
1964	11.85	4.63	13.09	33.13
1965	11.77	4.72	13.01	33.80
1966	12.55	4.93	12.94	30.38
1967	12.89	5.11	13.13	27.18
1968	11.85	5.37	13.57	25.44
1969	13.03	5.80	13.69	30.38
1970	13.71	6.10	14.39	40.40
1971	13.07	6.67	15.56	33.55
1972	13.03	7.46	16.58	36.30
1973	13.04	8.02	17.06	57.02
1974	13.97	9.35	21.63	106.78
1975	14.00	11.03	26.44	70.58
1976	13.81	12.14	30.45	76.55

[a] Moody's industrial bond rate + Rate of depreciation

Source: FTC Staff Report [1977]
IISI, Financing Steel Investment, 1961-1971
Moody's Industrial Manual

Table 42

U.S. Production of Steel by Process (1,000 MT)

Year	OH	(%)	BOF	(%)	EF	(%)	Total
1956	93,297	(89.3)	459	(0.4)	7,839	(7.5)	104,523
1957	92,224	(90.2)	555	(0.5)	7,231	(7.1)	102,255
1958	68,838	(89.0)	1,201	(1.6)	6,038	(7.8)	77,343
1959	74,089	(87.4)	1,691	(2.0)	7,741	(9.1)	84,774
1960	78,353	(87.0)	3,055	(3.4)	7,601	(8.4)	90,068
1961	76,660	(86.3)	3,599	(4.0)	7,860	(8.3)	88,918
1962	75,258	(84.4)	5,038	(5.6)	8,176	(9.2)	89,202
1963	80,588	(81.3)	7,752	(7.8)	9,905	(10.2)	99,120
1964	89,045	(77.3)	14,008	(12.1)	11,320	(9.8)	115,150
1965	85,423	(71.8)	20,750	(17.4)	12,280	(10.3)	118,985
1966	77,133	(63.4)	30,780	(25.3)	13,466	(11.1)	121,630
1967	64,130	(55.6)	37,589	(32.6)	13,689	(11.9)	115,408
1968	59,725	(50.1)	44,282	(37.1)	15,254	(12.8)	119,262
1969	55,243	(43.1)	54,646	(42.6)	18,264	(14.3)	128,153
1970	43,566	(36.5)	57,453	(48.2)	18,291	(15.3)	119.310
1971	32,259	(29.5)	58,009	(53.1)	18,998	(17.4)	109,266
1972	31,694	(26.2)	67,663	(56.0)	21,520	(17.8)	120,876
1973	36,088	(26.4)	75,533	(55.2)	25,183	(18.5)	136,805
1974	32,205	(24.4)	73,984	(56.0)	26,009	(19.7)	132,197
1975	20,104	(19.0)	65,138	(61.6)	20,575	(19.4)	105,818
1976	21,292	(18.3)	72,502	(62.4)	22,328	(19.2)	116,122
1977	18,183	(16.0)	70,224	(61.8)	25,295	(22.2)	113,702

[a] Total includes production of steel by Bessemer process.

Source: Japan Iron and Steel Federation, Annual Statistical Yearbook, various years

Table 43

Japanese Production of Steel by Process (1,000 MT)

Year	OH	(%)	BOF	(%)	EF	(%)	Total
1956	8,967	(80.7)	---	(--)	1,691	(15.2)	11,106
1957	9,930	(79.0)	56	(0.4)	2,187	(17.4)	12,570
1958	9,211	(76.1)	790	(6.5)	2,081	(17.1)	12,118
1959	12,312	(74.0)	1,205	(7.3)	3,112	(18.7)	16,629
1960	15,045	(68.0)	2,629	(11.9)	4,464	(20.1)	22,138
1961	16,971	(60.0)	5,357	(19.0)	5,941	(21.0)	28,268
1962	13,284	(48.2)	8,441	(30.7)	5,821	(21.1)	27,546
1963	12,195	(38.7)	12,045	(38.2)	7,262	(23.1)	31,501
1964	13,853	(34.8)	17,581	(44.2)	8,365	(21.0)	39,799
1965	10,164	(24.7)	22,629	(55.0)	8,368	(20.3)	41,161
1966	8,635	(18.1)	29,912	(62.6)	9,237	(19.3)	47,784
1967	9,042	(14.5)	41,751	(67.2)	11,361	(18.3)	62,154
1968	5,424	(8.1)	49,281	(73.7)	12,188	(18.2)	66,893
1969	5,240	(6.4)	63,191	(76.9)	13,735	(16.7)	82,166
1970	3,855	(4.1)	73,847	(79.1)	15,620	(16.7)	93,322
1971	2,090	(2.4)	70,839	(80.0)	15,628	(17.6)	88,557
1972	1,905	(2.0)	76,984	(79.4)	18,011	(18.6)	96,900
1973	1,849	(1.5)	96,057	(80.5)	21,416	(17.9)	119,322
1974	1,553	(1.3)	94,687	(80.8)	20,891	(17.8)	117,131
1975	1,103	(1.1)	84,428	(82.5)	16,782	(16.4)	102,313
1976	487	(0.5)	86,891	(80.9)	20,022	(18.6)	107,399
1977	378	(0.4)	82,429	(80.5)	19,598	(19.1)	102,405

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[a] Total includes production of steel by Bessemer process.

Source: Japan Iron and Steel Federation, Annual Statistical Yearbook, various years

Table 44
Economic Costs and Benefits of Adopting Continuous Casting

Percent CC	Incr. in CC Tonnage (1000 MT)	Energy Saved (10^{12} Btu)	Incr. in Yield	Incr. in Steel Shipped (1000 MT)	New Industry Yield	CC Capital Cost ($/MT)[a]	Total Annual Benefits ($Million)[b]
25	13,424	44.1	0.10	1,342	0.73	44	185
						44	222
						66	185
						66	222
			0.12	1,611	0.73	44	192
						44	237
						66	192
						66	237
						66	281
						88	281
50	44,496	147.2	0.10	4,450	0.75	44	613
						44	736
						66	613
						66	736
			0.12	5,340	0.76	44	638
						44	785
						66	638
						66	785
						66	932
						88	932

[a] Three levels of capital cost for CC have been used. $44/MT is somewhat greater than recent expenditures by National Steel; $66/MT may be appropriate where ingot facilities have not been fully depreciated.

[b] Total annual benefit is calculated on the basis of an $11/MT combined savings for the additional CC tonnage and product of the increase in steel tonnage shipped and the hot metal to scrap savings.

Source: Office of Technology Assessment [1980]

Table 45

Relative Price of Iron Ore over Scrap

Year	U.S.	Japan
1956	0.200	0.253
1957	0.250	0.259
1958	0.312	0.341
1959	0.296	0.272
1960	0.388	0.283
1961	0.364	0.258
1962	0.460	0.346
1963	0.482	0.318
1964	0.395	0.297
1965	0.385	0.291
1966	0.426	0.296
1967	0.483	0.275
1968	0.533	0.313
1969	0.451	0.259
1970	0.356	0.214
1971	0.464	0.296
1972	0.457	0.259
1973	0.299	0.144
1974	0.203	0.109
1975	0.375	0.188
1976	0.398	0.193

Source: Federal Trade Commission [1977]

Table 46

Ratio of Unit Cost of Iron Ore over Unit Cost of Scrap

Year	U.S.	Japan
1956	0.985	0.733
1957	1.659	0.831
1958	1.987	1.094
1959	1.587	0.735
1960	2.363	0.773
1961	2.178	0.616
1962	2.918	1.088
1963	2.652	0.982
1964	2.474	0.868
1965	2.327	1.112
1966	2.584	1.219
1967	2.987	1.060
1968	3.077	1.397
1969	2.365	1.190
1970	2.143	1.088
1971	2.679	2.145
1972	2.117	1.409
1973	1.430	0.754
1974	0.870	0.643
1975	1.980	1.616
1976	2.040	1.183

Source: Federal Trade Commission [1977]

Table 47

U.S. Prices of Energy Inputs (U.S. dollars)

Year	Coking Coal (MT)	Fuel Oil (MT)	Electric Power (M Kwh)	Noncoking Coal (MT)
1956	10.86	20.41	12.58	8.78
1957	11.87	22.32	12.65	9.05
1958	11.55	18.59	13.43	8.92
1959	11.57	18.85	13.49	8.62
1960	11.64	19.25	13.69	8.42
1961	10.84	19.55	13.78	8.45
1962	10.69	19.59	13.96	8.26
1963	10.31	19.25	13.85	8.08
1964	10.86	18.59	13.72	7.91
1965	10.64	18.36	13.72	7.85
1966	10.82	18.29	13.76	7.91
1967	11.39	18.36	13.69	7.94
1968	11.67	18.85	13.78	7.97
1969	11.86	18,69	13.96	8.46
1970	13.53	23.18	14.34	10.23
1971	16.83	29.02	15.50	11.19
1972	19.49	28.73	16.36	11.57
1973	21.81	32.06	17.11	12.25
1974	37.72	74.96	21.21	20.46
1975	58.05	71.88	26.39	23.01
1976	61.77	68.88	28/36	24.55

Source: Federal Trade Commission [1977]

Table 48

Japanese Prices of Energy Inputs (U.S. dollars)

Year	Coking Coal (MT)	Fuel Oil (MT)	Electric Power (M Kwh)	Noncoking Coal (MT)
1956	24.40	19.95	9.07	20.78
1957	28.90	29.98	9.07	23.93
1958	21.29	19.20	9.07	17.40
1959	18.00	15.52	9.07	14.23
1960	17.23	17.77	9.35	13.30
1961	17.09	16.78	9.66	13.39
1962	16.92	14.47	10.05	12.87
1963	16.25	14.05	10.24	12.56
1964	15.91	13.21	10.24	12.30
1965	15,73	13.52	10.24	11.78
1966	15.88	13.15	10.24	11.65
1967	15.67	14.83	10.24	11.26
1968	15.87	14.41	10.24	11.47
1969	16.34	12.19	10.24	12.04
1970	20.16	13.60	10.24	15.33
1971	21.40	16.70	10.61	---
1972	21.90	16.87	12.07	---
1973	23.82	26.12	14.28	---
1974	44.88	76.36	24.37	---
1975	56.02	85.44	26.65	---
1976	59.08	71.08	30.63	---

Source: Federal Trade Commission [1977]

Table 49

Comparison of Technologies: U.S. and Japan (1976)

	U.S.	Japan
Capacity of 10 largest plants (Average)	53.6 Million MT	104.3 Million MT
No. of plants with a crude steel capacity greater than 6 million NT	5	11
No. of blast furnaces with a capacity of more than 2,000 cubic meters	6	37
Average output of the 3 largest blast furnaces	1.7 Million MT	3.9 Million MT
Output per rolling mill in operation	.21 Million MT	.47 Million MT
BOF output	72.5 Million MT	86.9 Million MT
BOF output as a percent of total crude steel output	62.4%	80.9%
Percent of total BOF capacity replaced or added, 1960-76	80.0%	89.0%
EF output	22.3 Million MT	20.0 Million MT
EF output as a percent of total crude steel output	19.2%	18.6%
Percent of EF capacity replaced or added, 1960-76	20.0%	11.0%
Output of obsolete technologies (OH etc.)	21.3 Million MT	.54 Million MT
Output of obsolete technologies as a percent of total crude steel output	18.3%	.5%
Continuous casting output	12.2 Million MT	37.7 Million MT
Continuous casting output as a percent of total crude steel output	10.5%	35.1%

Table 49 (Cotinued)

	U.S.	Japan
CC capacity as a percent of total melting capacity replaced or added, 1960-76	23.6%	39.2%
Total investments, 1957-76, excluding those in sales, distribution, mining and nonsteel operations	$27 billion	$27 billion
Capacity replaced, 1957-76	86.2 Million MT	9.98 Million MT
Capacity added, 1957-76	39.9 Million MT	137.0 Million MT
Man-hours per MT of products	12.75	10.26
Coke rate in blast furnaces	1,332 Lbs/MT	969 Lbs/MT
Fuel rate in blast furnaces (coke plus oil)	1,378 Lbs/MT	1,058 Lbs/MT
Environmental control outlays as a percent of total investment, 1971-76	16.73%	22.14%

Source: Mueller and Kawahito [1978]

Table 50

Comparison of Depreciation Laws: U.S. and Japan

Period of Capital Recovery: Machinery and Equipment

U.S.

All Industry Pre-1971 Assets: 13 Years
All Industry Post-1971 Assets: 10 and a Half Years
Steel Industry Pre-1971 Assets: 18 Years
Steel Industry Post-1971 Assets: 14 and a Half Years

Japan 11 Years[a]

Acceleration of Capital Recovery

U.S.

200% Declining-Balance Method
Sum of the Year's Digits Method

Japan

Multiply Double-Declining Balance Rate by a Factor of 1.28 for Multiple Shift Operations

25% Additional First Year Allowance on New Steel Producing Assets

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Additional Capital Allowances

U.S.

7% Investment Tax Credit

Japan

Special 25% Allowance in the First Year

Other Tax Incentives

U.S.

Tax Deferral Permitted

Japan

Special First Year Depreciation Allowance of 10-33% as Adjusted by the Ministry of Finance

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[a] Average of 16 Years until 1967

Source: AISI [1975] and Treasury Memorandum on Foreign Systems

Table 51

Wholesale Price Index for All Commodities (1967=100)

Japan				U.S.			
Year	WPI	Year	WPI	Year	WPI	Year	WPI
1945	0.9	1961	94.9	1945	54.6	1961	94.5
1946	4.3	1962	93.3	1946	62.3	1962	94.8
1947	12.8	1963	95.0	1947	76.5	1963	94.5
1948	34.1	1964	95.2	1948	82.8	1964	94.7
1949	55.7	1965	95.9	1949	78.7	1965	96.6
1950	65.9	1966	98.2	1950	81.8	1966	99.8
1951	91.4	1967	100.0	1951	91.1	1967	100.0
1952	93.2	1968	100.9	1952	88.6	1968	102.5
1953	93.8	1969	103.0	1953	87.4	1969	106.5
1954	93.2	1970	106.7	1954	87.6	1970	110.4
1955	91.5	1971	105.9	1955	87.8	1971	114.0
1956	95.5	1972	106.7	1956	90.7	1972	119.1
1957	98.4	1973	123.7	1957	93.3	1973	134.7
1958	92.0	1974	162.5	1958	94.6	1974	160.1
1959	93.0	1975	167.3	1959	94.8	1975	174.9
1960	94.0	1976	175.7	1960	94.9	1976	182.9

Source: Economic Report of the President, 1973, 1977
Bank of Japan, Economic Statistics Annual, various years

Table 52

U.S. Factor Shares in the Unit Cost

Year	Capital	Labor	Raw Materials	Energy
1956	0.0810	0.4533	0.2926	0.1731
1957	0.0856	0.5007	0.2421	0.1716
1958	0.0988	0.5170	0.2190	0.1652
1959	0.0960	0.5287	0.2230	0.1522
1960	0.0971	0.5397	0.2082	0.1551
1961	0.1054	0.5284	0.2193	0.1469
1962	0.1254	0.5256	0.1971	0.1519
1963	0.1270	0.5239	0.2031	0.1460
1964	0.1189	0.5135	0.2197	0.1480
1965	0.1157	0.5092	0.2229	0.1522
1966	0.1223	0.5112	0.2145	0.1520
1967	0.1300	0.5166	0.1983	0.1552
1968	0.1112	0.5237	0.2037	0.1615
1969	0.1128	0.5325	0.2050	0.1497
1970	0.1133	0.5221	0.2041	0.1604
1971	0.1197	0.5128	0.1892	0.1783
1972	0.1137	0.5115	0.2006	0.1742
1973	0.0954	0.4899	0.2329	0.1818
1974	0.0770	0.4321	0.2730	0.2179
1975	0.0819	0.4514	0.1921	0.2746
1976	0.0814	0.4475	0.2068	0.2643

Source: FTC Staff Report [1977]
AISI Annual Statistical Report, various years

Table 53

Japanese Factor Shares in the Unit Cost

Year	Capital	Labor	Raw Materials	Energy
1956	0.1174	0.1964	0.4488	0.2375
1957	0.1108	0.1788	0.4641	0.2462
1958	0.1769	0.2513	0.3385	0.2333
1959	0.1855	0.2263	0.3860	0.2022
1960	0.1952	0.2177	0.3885	0.1986
1961	0.1828	0.1958	0.4339	0.1875
1962	0.2204	0.2304	0.3479	0.2013
1963	0.2180	0.2351	0.3554	0.1915
1964	0.2228	0.2167	0.3721	0.1884
1965	0.2119	0.2281	0.3650	0.1949
1966	0.2049	0.2288	0.3653	0.2009
1967	0.1957	0.2305	0.3749	0.1988
1968	0.2028	0.2450	0.3429	0.2094
1969	0.2032	0.2416	0.3494	0.2059
1970	0.2001	0.2380	0.3435	0.2184
1971	0.2363	0.2629	0.2677	0.2331
1972	0.2542	0.2853	0.2589	0.2015
1973	0.2227	0.2719	0.3156	0.1898
1974	0.1764	0.2382	0.3092	0.2762
1975	0.2039	0.2496	0.2254	0.3212
1976	0.2073	0.2430	0.2428	0.3069

Source: FTC Staff Report [1977]
Tekko Nenkan, various years

Table 54

Average Hourly Earnings (U.S. dollars)

Year	Steel Industry	All Manufacturing	Difference
1958	2.91	2.11	0.80
1959	3.10	2.19	0.91
1960	3.08	2.26	0.82
1961	3.20	2.32	0.88
1962	3.29	2.39	0.90
1963	3.36	2.46	0.90
1964	3.41	2.53	0.88
1965	3.46	2.61	0.85
1966	3.58	2.72	0.86
1967	3.62	2.83	0.79
1968	3.82	3.01	0.81
1969	4.09	3.19	0.90
1970	4.22	3.36	0.86
1971	4.57	3.57	1.00
1972	5.15	3.81	1.34
1973	5.56	4.07	1.49
1974	6.38	4.40	1.98
1975	7.11	4.81	2.30
1976	7.86	5.19	2.67
1977	8.67	5.63	3.04

Source: Bureau of Labor Statistics

APPENDIX B

DESCRIPTION OF DATA

Sources of Data

Prices of labor, iron ore, scrap, coking coal, fuel oil, electric power, noncoking coal, and natural gas were taken from the Federal Trade Commission Staff Report [1977].

The unit costs of labor, iron ore, scrap, and energy inputs were also taken from the same source.

The measure r + d was used for the price of capital, where r is Moody's industrial bond rate for the U.S., and the long-term interest rate of the Long-term Credit Bank for Japan, and d is the rate of depreciation in iron and steel industry. These were taken, in order, from Moody's Industrial Manual [1979], Economic Statistics Annual, Bank of Japan, various years, and Financing Steel Investment, 1961-1971, International Iron and Steel Institute.

Data on the unit cost of capital, which includes depreciation and interest paid per metric ton of steel produced, were generated from Tekko Nenkan (Japanese Steel Newspaper Corporation publication) and American Iron and Steel Institute Annual Statistical Report, various years, in conjunction with the FTC data and some adjustments were made.

Adjustments of Data

U.S.

Wages and salaries, depreciation, and interest paid on borrowed capital as a percent of total revenue were calculated from various issues of AISI Annual Statistical Report.

The unit costs per metric ton of steel produced were taken from the FTC Staff Report [1977].

Let R denote the dollar value of total revenue, and let S_l, S_d, and S_i be the shares of labor cost, depreciation, and interest paid, in total cost, respectively. If U_K and U_L are the unit capital cost including equity cost and the unit labor cost, respectively, then

$$U_K = (S_d + S_i(1 + e))U_L/S_l$$

where e is the ratio of equity to liabilities, which can be obtained from AISI Annual Statistical Report.

Japan

Profit, wages and salaries, depreciation, and interest paid as a percent of value added are published in Tekko Nenkan. The unit labor costs were taken from the FTC Staff Report [1977].

The case for Japan is more complicated because published statistics do not cover contract workers. According to Mueller and Kawahito [1978], contract workers receive about 70% of wages and salaries of regular workers.

The ratio of the number of contract workers to regular workers is 0.35 for 1956-59, 0.36 for 1960-64, 0.40 for 1965-69, 0.44 for 1970-73, and 0.48 for 1974-76.

Let V be value added, and let S_1, S_d, and S_i be the shares of employment cost not including that of contract workers, depreciation, and interest paid on borrowed capital in value added, respectively. If S_1', S_d', and S_i' denote the corresponding shares adjusted for inclusion of contract workers, we must have

$$\begin{aligned} S_1' &= (S_1V + 0.7\lambda S_1V)/(V + 0.7\lambda S_1V) \\ &= ((1 + 0.7\lambda)S_1)/(1 + 0.7\lambda S_1) \\ S_d' &= S_dV/(V + 0.7\lambda S_1V) = S_d/(1 + 0.7\lambda S_1) \\ S_i' &= S_iV/(V + 0.7\lambda S_1V) = S_i/(1 + 0.7\lambda S_1) \end{aligned}$$

where λ is the ratio of contract workers to regular workers.

Thus, with the inclusion of equity cost of capital, we have

$$U_K = (S_d + S_i + S_ie)U_L/(1 + 0.7\lambda)S_1.$$

APPENDIX C

LASPEYRE PRICE INDEX FOR RAW MATERIAL AND ENERGY INPUTS

In chapter III, we aggregated iron ore and scrap into one input, M (= raw material). Also coking coal, fuel oil, electric power, noncoking coal, and natural gas were aggregated into one input, E (= energy inputs). Changes in prices of aggregated inputs M and E are captured by constructing the Laspeyre price indexes with 1967 as the base period. For example, the price index PM_i of raw material for the ith year is given by

$$PM_i = (PI_i * QI_{67} + PS_i * QS_{67})/(PI_{67} * QI_{67} + PS_{67} * QS_{67})$$

where PI_i = price of iron ore for the ith year

PS_i = price of scrap for the ith year

PI_{67} = price of iron ore for 1967

PS_{67} = price of scrap for 1967

QI_{67} = quantity of iron ore required to produce a metric ton of steel for 1967

QS_{67} = quantity of scrap required to produce a metric ton of steel for 1967.

The quantity data was obtained from the FTC Staff Report [1977]. Actual formulae for calculating the price indexes are:

<u>U.S.</u> $PM_i = (PI_i * 1.531 + PS_i * 0.248)/(13.13 * 1.531 + 27.18 * 0.248)$

<u>Japan</u> $PM_i = (PI_i * 1.317 + PS_i * 0.342)/(12.66 * 1.317 + 45.99 * 0.342)$

For the price index PE_i of the energy input, E, we have:

<u>U.S.</u> $PE_i = (PCC_i*0.95 + PFO_i*0.057 + PEP_i*387 + PNC_i*0.079 + PNG_i*6.77)/(11.39*0.95 + 18.36*0.057 + 13.69*387 + 7.94*0.079 + 0.47*6.77)$

<u>Japan</u> $PE_i = (PCC_i*0.655 + PFO_i*0.126 + PEP_i*480 + PNC_i*0.012)/(15.67*0.655 + 14.83*0.126 + 10.24*480 + 11.26*0.012)$

where PCC_i = price of coking coal for the ith year
PFO_i = price of fuel oil for the ith year
PEP_i = price of electric power for the ith year
PNC_i = price of noncoking coal for the ith year
PNG_i = price of natural gas for the ith year

The yearly price indexes are shown on the next page.

Table 55

Laspeyre Price Index

Year	U.S. PM	U.S. PE	Japan PM	Japan PE
1956	1.094	0.919	1.516	0.887
1957	1.080	0.924	1.767	0.888
1958	1.014	0.981	1.161	0.887
1959	1.051	0.985	1.113	0.886
1960	0.994	1.000	1.107	0.914
1961	1.071	1.006	1.159	0.944
1962	0.986	1.020	1.018	0.982
1963	0.980	1.011	1.003	1.000
1964	1.053	1.002	1.026	1.000
1965	1.054	1.002	1.032	1.000
1966	1.019	1.005	1.001	1.000
1967	1.000	1.000	1.000	1.000
1968	1.009	1.007	0.909	1.000
1969	1.062	1.020	0.948	1.000
1970	1.194	1.048	1.066	1.001
1971	1.197	1.133	0.883	1.037
1972	1.281	1.196	0.931	1.179
1973	1.500	1.251	1.398	1.395
1974	2.220	1.554	2.005	2.382
1975	2.160	1.935	1.615	2.606
1976	2.444	2.079	1.660	2.993

Source: FTC Staff Report [1977]

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