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1 Productivity and International Competitiveness in Japan and the United States, 1960–1985

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1.1 Introduction

The political relationship between Japan and the United States has become increasingly preoccupied with "trade frictions." These disputes over trade issues have accompanied the massive expansion of Japanese exports to the United States. Explanations for the resulting trade imbalance must include variations in the yen-to-dollar exchange rate, changes in the relative prices of capital and labor in the two countries, and the relative growth of productivity in Japanese and U.S. industries. We analyze the role of each of these factors in explaining the rise in competitiveness of Japanese industries relative to their U.S. counterparts.

At the outset of our discussion it is essential to define a measure of international competitiveness. Our measure of international competitiveness is the price of an industry's output in Japan relative to the price in the United States. Japanese exports are generated by U.S. purchases from Japanese industries, while U.S. exports result from Japanese purchases from U.S. industries. The relative price of an industry's output enters the decisions of purchasers in both countries and the rest of the world. In order to explain changes in international competitiveness we must account for changes in the determinants of this relative price.

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The starting point for our analysis of the competitiveness of Japanese and U.S. industries is the yen-to-dollar *exchange rate*. This is simply the number of yen required to purchase one U.S. dollar in the market for foreign exchange. Variations in the yen-to-dollar exchange rate are easy to document and are often used to characterize movements in relative prices in the two countries. However, movements in relative prices of goods and services do not coincide with variations in the exchange rate. To account for changes in international competitiveness a measure of the relative prices of specific goods and services is required.

To assess the international competitiveness of Japanese and U.S. industries it is necessary to carry out price comparisons for industry outputs in the two countries. These comparisons are hampered by the fact that the makeup of a given industry may differ substantially between Japan and the U.S. For example, the steel industry produces an enormous range of different steel products. The relative importance of different types of steel differs between the two countries. The composition of the output of the steel industry in each country also changes over time. These differences must be taken into account in comparing the relative prices of steel between Japan and the United States.

Relative prices between Japanese and U.S. industries can be summarized by means of purchasing power parities. The purchasing power parity for a specific industry's output is the number of yen required in Japan to purchase an amount of the industry's output that would cost one dollar in the United States. The dimensions of purchasing power parities are the same as the yen-to-dollar exchange rate, namely, yen per dollar. However, the purchasing power parities reflect the relative prices of the goods and services that make up the industry's output in both countries.

The most familiar application of the notion of purchasing power parity is to the relative prices of such aggregates as the gross domestic product. This application has been the focus of the landmark studies of Kravis, Heston, and Summers (1978). As a consequence of their research, it is now possible to compare the relative prices of gross domestic product for a wide range of countries, including Japan and the United States. Kravis, Heston, and Summers have based their purchasing power parities for gross domestic product on relative prices for 153 commodity groups.

In this study we estimate purchasing power parities for 29 industries in Japan and the United States for the period 1960–85. These are relative prices of the outputs of each industry in the two countries in terms of yen per dollar. We divide the relative price of each industry's output by the yen-to-dollar exchange rate to translate purchasing power parities into relative prices in terms of dollars.[1] We find it convenient to employ relative prices in dollars as measures of international competitiveness. Variations in the exchange rate are reflected in the relative prices of outputs for all 29 industries.

To account for changes in international competitiveness between Japanese and U.S. industries, we have compiled purchasing power parities for the inputs into each industry. By analogy with outputs, the purchasing power parities for inputs are based on the relative prices of the goods and services that make up the inputs of each industry. We have disaggregated inputs among capital and labor services, which are primary factors of production, and energy and other intermediate goods, which are produced by one industry and consumed by other industries. We can translate purchasing power parities for inputs into relative prices in dollars by dividing by the yen-to-dollar exchange rate. We describe purchasing power parities for output and inputs in 29 industries of the United States and Japan in section 1.2 below.

Our final step in accounting for international competitiveness between Japanese and U.S. industries is to measure the relative levels of productivity for all 29 industries. For this purpose we employ a model of production for each industry. This model enables us to express the price of output in each country as a function of the prices of inputs and the level of productivity in that country. We can account for the relative prices of output between Japan and the United States by allowing input prices and levels of productivity to differ between countries. We have compiled data on relative productivity levels in Japan and the United States for the period 1960–85. For this purpose we have revised and extended the estimates for 1960–79 reported by Jorgenson, Kuroda, and Nishimizu (1987).

The methodology for our study was originated by Jorgenson and Nishimizu (1978). They provided a theoretical framework for productivity comparisons based on a bilateral production function at the aggregate level. They employed this framework in comparing aggregate output, input, and productivity for Japan and the United States.[2] This methodology was extended to the industry level by Jorgenson and Nishimizu (1981) and employed in international comparisons between Japanese and U.S. industries. The industry-level methodology introduced models of production for individual industries based on bilateral production functions for each industry. This methodology was used in Jorgenson, Kuroda, and Nishimizu (1987), which involved comparisons between Japan and the United States at the industry level for the period 1960–79.[3] We discuss the theoretical framework for international comparisons briefly in the appendix to this paper.

We present comparisons of productivity levels between the United States and Japan by industry in section 1.3. Jorgenson, Kuroda, and Nishimizu (1987) have presented a taxonomy of Japanese and U.S. industries, based on the development of relative productivity levels over the period 1960–79. They have used this taxonomy to project the likely development of relative productivity levels for each industry. We can now assess the validity of these projections on the basis of developments during the period 1960–85. We find that the taxonomy has been very useful in forming expectations about future developments in productivity. Finally, we employ changes in relative productivity levels and relative prices of inputs in accounting for changes in international competitiveness between Japanese and U.S. industries over the period 1960–85. Section 1.4 provides a summary and conclusion.

1.2 Purchasing Power Parities

We treat data on production patterns in Japan and the United States as separate sets of observations. We assume that these observations are generated by bilateral models of production for each industrial sector presented in detail in the appendix. We can describe the implications of the theory of production in terms of production functions for each industry. These production functions give industry outputs as functions of capital, labor, energy, and other intermediate inputs, a dummy variable equal to one for Japan and zero for the United States, and time as an index of technology.

In our bilateral models of production, the capital, labor, energy, and other intermediate input prices are aggregates that depend on the prices of individual capital inputs, labor inputs, energy inputs, and other intermediate inputs in Japan and the United States. The product of price and quantity indices must equal the value of all the components of each aggregate. We define price indices corresponding to each aggregate as ratios of the value of the components of the aggregate to the corresponding quantity index. In international comparisons, the price indices represent purchasing power parities between the yen and the dollar. For example, the price index for labor input represents the Japanese price in yen for labor input costing one in the United States.

Our methodology for estimating purchasing power parities is based on linking time-series data sets on prices in Japan and the United States. Suppose that we observe the price of the output of the ith industry in Japan and the United States, say $q_i(\text{JAPAN})$ and $q_i(\text{US})$, in the base period, where these prices are evaluated in terms of yen and dollars, respectively. We can define the *purchasing power parity* for the output of the ith industry, say PPP_i, as follows:

$$(1) \qquad \text{PPP}_i = \frac{q_i(\text{JAPAN})}{q_i(\text{US})}, \quad (i = 1, 2, \ldots, I).$$

The purchasing power parity gives the number of yen required in Japan to purchase an amount of the output of the ith industry costing one dollar in the United States in the base period.

To estimate purchasing power parities for outputs of all industries in Japan and the United States, we first construct a time series of prices for the output of each industry in both countries in domestic currency. To obtain price indices for industry outputs in the United States, we normalize the price index for each industry, say $q_i(\text{US}, T)$, at unity in the base period. We normalize the corresponding price index for Japan, say $q_i(\text{JAPAN}, T)$, at the purchasing power parity in the base period. We obtain estimates of purchasing power parities for all years, say $\text{PPP}_i(T)$, from these price indices and the purchasing power parity for the base period from the equation

$$(2) \qquad \text{PPP}_i(T) = \text{PPP}_i(0)\frac{q_i(\text{JAPAN}),T)}{q_i(\text{JAPAN},0)}\frac{q_i(\text{US},0)}{q_i(\text{US},T)}, \quad (i = 1, 2, \ldots, I).$$

where $\text{PPP}_i(0)$ is the purchasing power parity in the base period and $q_i(\text{JAPAN},0)$ and $q_i(\text{US},0)$ are the prices of outputs of the ith industry in Japan and the United States in the base period.

Finally, we define the *relative price* of the output of the ith industry in Japan and the United States in dollars, say $p_i(\text{JAPAN,US})$, as the ratio of the purchasing power parity for that industry to the yen-to-dollar exchange rate, say E:

$$(3) \qquad p_i(\text{JAPAN,US}) = \frac{\text{PPP}_i}{E}, \quad (i = 1, 2, \ldots, I).$$

The relative price of the output of the ith industry in Japan and the United States is the ratio of the number of dollars required in Japan to purchase an amount of the industry's output costing one dollar in the United States. This index is our measure of international competitiveness between the Japanese industry and its U.S. counterpart.

In order to construct purchasing power parities and the corresponding relative prices between Japanese and U.S. industries, we require an estimate of the purchasing power parity for each industry in the base period. For this purpose we have developed purchasing power parities for industry outputs based on the results of Kravis, Heston, and Summers (1978). They have provided purchasing power parities between the yen and the dollar for 153 commodity groups for the year 1970. These commodity groups are components of the gross domestic product of each country, corresponding to deliveries to final demand at purchasers' prices.

We construct purchasing power parities for industry outputs, energy inputs, and other intermediate inputs by mapping the 153 commodity groups employed by Kravis, Heston, and Summers (1978) into the industry classification system shown in table 1.1. Unfortunately, a complete correspondence between the two systems is impossible, since not all intermediate goods delivered by the different industrial sectors are included among the 153 commodity groups delivered to final demand. We have eliminated the gap between the two systems by utilizing the purchasing power parities of close substitutes for a given industry's deliveries to intermediate demand.

To obtain purchasing power parities for industry outputs from the producer's point of view, we adjust the price indices for commodity groups in Japan and the United States by "peeling off" the indirect taxes paid and trade and transportation margins for each industry. We estimate these margins from the interindustry transactions table for 1970 for each country. To obtain the purchasing power parities for industry outputs, we aggregate the results for commodity groups, using as weights the relative shares of each commodity in the value of industry output from the 1970 interindustry transactions tables. Similarly, to obtain purchasing power parities for components of intermediate input in each industry, we aggregate purchasing power parities for goods and services delivered by that industry to other industries. We employ relative

Table 1.1 List of Industries

Number	Industries	Abbreviation
1.	Agriculture, forestry, & fisheries	Agric.
2.	Mining	Mining
3.	Construction	Construct.
4.	Food & kindred products	Foods
5.	Textile mill products	Textiles
6.	Apparel & other fabricated textile	Apparel
7.	Lumber and wood products, except furniture	Lumber
8.	Furniture & fixtures	Furniture
9.	Paper & allied products	Paper
10.	Printing, publishing, & allied products	Printing
11.	Chemical & allied products	Chemical
12.	Petroleum refinery & coal products	Petroleum
13.	Rubber & miscellaneous plastic products	Rubber
14.	Leather & leather products	Leather
15.	Stone, clay, & glass products	Stone
16.	Primary metal products	Prim. Metal
17.	Fabricated metal products	Fab. Metal
18.	Machinery	Machinery
19.	Electric machinery	Elec. Mach.
20.	Motor vehicles & equipment	Mot. Veh.
21.	Transportation equipment, except motors	Trsp. Eqpt.
22.	Precision instruments	Prec. Inst.
23.	Miscellaneous manufacturing	Mfg. Misc.
24.	Transportation & communication	Trsp. Comm.
25.	Electric utility & gas supply	Utilities
26.	Wholesale & retail trade	Trade
27.	Finance, insurance, & real estate	Finance
28.	Other service	Service
29.	Government services	Gov. Serv.

shares in the value of deliveries of intermediate input from other industries from the 1970 interindustry transactions tables as weights.

For both Japan and the United States, capital stocks are divided among seven types of depreciable assets and two types of nondepreciable assets for each industry. These assets are further subdivided among legal forms of organization. We employ the equality between the price of an asset and the discounted flow of future capital services to derive service prices for capital input. Although we estimate the decline in efficiency of capital goods for each component of capital input separately for Japan and the United States, we assume that the relative efficiency of new capital goods in a given industry is the same in both countries. The appropriate purchasing power parity for new capital goods is the purchasing power parity for the corresponding component of investment goods output. To obtain the purchasing power parity for capital input, we multiply the purchasing power parity for investment goods by the

Table 1.2 The Japanese Price Index Transformed by the Purchasing Power Parity Index at 1970 (United States Price = 1.000)

Industry	Output Price	Capital Price	Labor Price	Energy Price	Material Price
Agric.	1.04556	.90835	.21352	1.48236	.91204
Mining	.72125	.88095	.21263	1.44013	.70573
Construct.	1.03487	.92127	.18607	1.42641	.72203
Foods	1.03569	.9219	.21894	1.26554	.88483
Textiles	.77898	.90871	.24099	1.18329	.76975
Apparel	.76952	.86037	.18975	1.24298	.74821
Lumber	.79154	.84363	.22805	1.2268	.90165
Furniture	.67945	.84214	.22952	1.22178	.74429
Paper	.58858	.89567	.2217	1.18606	.65664
Printing	.78107	.86742	.21251	1.12482	.65975
Chemical	.6621	.91711	.25039	1.3363	.712
Petroleum	1.59952	.89588	.21846	1.31298	.88291
Rubber	1.06186	.86013	.24042	1.22499	.76731
Leather	.71273	.82076	.23569	1.31561	.81086
Stone	.69603	.89998	.23083	1.31627	.72567
Prim. Metal	.81706	.91205	.252	1.37079	.80318
Fab. Metal	.81514	.90205	.21072	1.32346	.77507
Machinery	.61327	.9202	.22564	1.28346	.71093
Elec. Mach.	.68127	.92036	.22308	1.24327	.71054
Mot. Veh.	.78627	.91647	.18581	1.1729	.76428
Trsp. Eqpt.	.94794	.87722	.21944	1.24063	.76549
Prec. Inst.	.71912	.86402	.2315	1.22607	.71774
Mfg. Misc.	.69473	.88034	.22549	1.27395	.71238
Trsp. Comm.	.47247	.91027	.22713	1.43624	.68624
Utilities	1.02936	.90389	.26605	1.4949	.78528
Trade	.66155	.93094	.26889	1.35118	.73683
Finance	.86176	.833	.30796	1.1449	.77297
Service	.56751	.91719	.25592	1.22718	.73724
Gov. Serv.	.30797	0	.19482	1.35489	.68436

Note: See table 1.1 for key to industry abbreviations.

ratio of the price of capital goods for Japan relative to the United States. The resulting price index represents the purchasing power parity for capital input.

For both Japan and the United States, labor inputs are cross-classified by employment status, sex, age, education, and occupation. Given the detailed classification of labor input for each industry in our data base, we construct purchasing power parities for labor input on the basis of relative wage levels for each component of labor input in each industry. Purchasing power parities for industry output, capital, labor, energy, and other intermediate inputs in 1970 are shown in table 1.2.

According to our purchasing power parities for industry output in 1970, prices in Japan were higher than those in the United States in only six sectors—agriculture-forestry-fisheries, construction, food and kindred products, petroleum refinery and coal products, rubber products, and electricity and gas. The purchasing power parities for labor input in 1970 represent substantially lower costs of labor input in Japan relative to the United States. In that year, hourly wages in Japan were 30% or less of U.S. hourly wages. By contrast, the cost of capital in Japan averaged about 80% of that in the United States in 1970. The purchasing power parities for intermediate inputs are calculated as a weighted average of the purchasing power parities of industry outputs. The cost of intermediate inputs in Japan, other than energy, is 60%–90% of the cost in the United States in 1970. On the other hand, the purchasing power parities for energy inputs in 1970 are greater than unity, implying that the cost of energy in Japan was higher than that in the United States.

We have estimated purchasing power parities between the yen and the dollar in 1970 for the 29 industries listed in table 1.1 above. We have also compiled price indices for industry outputs and inputs in both countries for the period of 1960–85. We obtain indices of prices of outputs and inputs for each industry in Japan relative to those in the United States for each year from equation (2) above. Table 1.3 presents time series for price indices of value added and capital and labor inputs for the period 1960–85 in Japan and the United States. Column 1 of the table represents the yen-dollar exchange rate. The second and third columns represent price indices for Japan. The second column gives the domestic price index with base equal to the purchasing power parity in 1970. The third column gives this price index, divided by an index of the yen-dollar exchange rate, equal to one in 1970. The fourth column gives the corresponding price index in the United States with base equal to one in 1970.

According to the results presented in table 1.3, the price deflator for aggregate value added in Japan was 0.49401 in 1960, while that in the United States was 0.78454 in that year. This implies that the Japanese aggregate price index in 1960 was only 63% of that in the United States. Under the fixed yen-dollar exchange rate of 360 yen to the dollar that prevailed until 1970, the ratio of the Japanese price index to the U.S. price index rose to 76% in 1970. With the collapse of the fixed-exchange-rate regime in 1970 and the beginning of the energy crisis in 1973, the price index in Japan, denominated in dollars, exceeded the corresponding U.S. price index. This was a consequence of more rapid inflation in Japan and a substantial appreciation of the yen through 1973. The competitiveness of U.S. industries relative to their Japanese counterparts reached a temporary peak in that year.

After 1973 the U.S. inflation rate continued at a high level, while Japan underwent a severe deflation, accompanied by depreciation of the yen. This had the short-run effect of restoring the competitiveness of Japanese industries. Inflation resumed in Japan after 1974, and the yen was allowed to appreciate again, reaching an exchange rate of 210 yen to the dollar in 1978. Once again, Japanese prices, denominated in terms of dollars, exceeded U.S. prices. This situation continued until 1980 as inflation in the United States

Table 1.3 **Comparison of Trend of Value-added Price Index between Japan and the United States**

Year	(1) Exchange Rate	(2) Value-added Japan (1)	(3) Value-added Japan (2)	(4) Value-added United States
1960	360	.49401	.49401	.78454
1961	360	.53183	.53183	.79409
1962	360	.55298	.55298	.80279
1963	360	.57685	.57685	.80636
1964	360	.59492	.59492	.81536
1965	360	.61978	.61978	.83047
1966	360	.64779	.64779	.86174
1967	360	.67604	.67604	.88078
1968	360	.69657	.69657	.91007
1969	360	.72318	.72318	.95491
1970	360	.75878	.75878	1
1971	348	.77834	.80517	1.0476
1972	303.1	.80947	.96143	1.09325
1973	271.7	.92428	1.22466	1.16623
1974	292.1	.8719	1.0746	1.29731
1975	296.8	.99093	1.20194	1.42734
1976	296.5	1.05665	1.28294	1.49954
1977	268.3	1.10367	1.48088	1.60448
1978	210.1	1.18892	2.03717	1.73642
1979	219.5	1.21565	1.99378	1.89859
1980	203	1.27198	2.25573	2.09651
1981	219.9	1.30588	1.13787	2.29653
1982	235	1.34193	1.05572	2.43595
1983	232.2	1.36365	2.11418	2.51156
1984	251.1	1.37795	1.97556	2.59771
1985	224.05	1.38862	2.23121	2.66754

Note: Col. 1 is the observed exchange rate (yen/dollar); col 2 is the Japanese price index transformed by the purchasing power parity (PPP) index; col 3 is the Japanese PPP-based price index denominated by exchange rate; col. 4 is the U.S. corresponding price index.

continued at high rates. In the 1980s U.S. prices in dollars rose to well above the level of Japanese prices due to the rapid appreciation of the U.S. dollar relative to the Japanese yen. By 1985 the Japanese price level in dollars was only 83% of the U.S. price, which implies that Japanese industries had a substantial competitive advantage relative to their U.S. counterparts.

According to the international comparison of capital input prices shown in table 1.4, the cost of capital in Japan in 1960 was almost 78% of that in the United States and gradually rose to within 89% of the U.S. level by 1970. After the energy crisis in 1973 the cost of capital in Japan increased relative to the United States, exceeding the U.S. level by almost 11% in 1978. The appreciation of the U.S. dollar reversed this trend. By 1985 the relative cost of capital in Japan had fallen to only 75% of the U.S. level, which is below

Table 1.4 **Comparison of Trend of Capital Input Prices between Japan and the United States**

Year	(1) Exchange Rate	(2) Capital Japan (1)	(3) Capital Japan (2)	(4) Capital United States
1960	360	.62499	.62499	.79723
1961	360	.7001	.7001	.80034
1962	360	.64268	.64268	.87577
1963	360	.62544	.62544	.9131
1964	360	.68795	.68795	.96814
1965	360	.68865	.68865	1.05671
1966	360	.71741	.71741	1.08764
1967	360	.7829	.7829	1.06235
1968	360	.86281	.86281	1.07711
1969	360	.88634	.88634	1.09371
1970	360	.89842	.89842	1
1971	348	.81956	.8478206	1.07581
1972	303.1	.83773	.9949943	1.16855
1973	271.7	.9224	1.2221715	1.22005
1974	292.1	.99464	1.2258486	1.12504
1975	296.8	.9234	1.1200269	1.29908
1976	296.5	.94393	1.1460870	1.42287
1977	268.3	.96151	1.2901364	1.63368
1978	210.1	1.15219	1.9742427	1.78198
1979	219.5	1.21611	1.9945312	1.82541
1980	203	1.00809	1.7877458	1.85044
1981	219.9	.98245	1.6083765	2.00438
1982	235	1.04394	1.5992272	1.96229
1983	232.2	1.06156	1.6458294	2.13968
1984	251.1	1.10386	1.5825949	2.43909
1985	224.05	1.1502	1.8481231	2.46379

Note: Col. 1 is the observed exchange rate (yen/dollar); col 2 is the Japanese price index transformed by the purchasing power parity (PPP) index; col 3 is the Japanese PPP-based price index denominated by exchange rate; col. 4 is the U.S. corresponding price index.

the level that prevailed almost a quarter century earlier, in 1960. The rise in the cost of capital in Japan relative to that in the United States after the energy crisis was a consequence of the appreciation of the yen. The fall of this relative price in the 1980s resulted from the appreciation of the dollar.

Finally, a comparison of labor input prices in table 1.5 shows that the Japanese wage rate in 1960 was only 11% the U.S. wage rate. By 1970 the Japanese wage rate had reached 23% of the U.S. level. Rapid wage increases in Japan during the 1970s and the sharp appreciation of the yen raised wage rates in Japan to 60% of the U.S. level in 1980. The subsequent appreciation of the dollar and rapid wage increases in the United States resulted in a decline in Japanese wage rates relative to the United States. The relative price of labor input in Japan was only 50% of the U.S. level in 1985.

Table 1.5 **Comparison of Trend of Labor Input Prices between Japan and the United States**

Year	(1) Exchange Rate	(2) Labor Japan (1)	(3) Labor Japan (2)	(4) Labor United States
1960	360	.06759	.06759	.60926
1961	360	.07795	.07795	.64391
1962	360	.08871	.08871	.65408
1963	360	.10203	.10203	.66726
1964	360	.10864	.10864	.68739
1965	360	.12425	.12425	.70308
1966	360	.13732	.13732	.74533
1967	360	.15215	.15215	.79066
1968	360	.17714	.17714	.8549
1969	360	.20104	.20104	.90917
1970	360	.23211	.23211	1
1971	348	.26643	.2756172	1.07431
1972	303.1	.30113	.3576601	1.14898
1973	271.7	.38076	.5045034	1.24142
1974	292.1	.46834	.5772078	1.36978
1975	296.8	.55019	.6673463	1.49983
1976	296.5	.59518	.7226468	1.62713
1977	268.3	.6492	.8710846	1.73529
1978	210.1	.67337	1.1537991	1.84918
1979	219.5	.70365	1.1540501	2.00071
1980	203	.75423	1.3375507	2.21758
1981	219.9	.79732	1.3052987	2.39774
1982	235	.8339	1.2774638	2.54319
1983	232.2	.83456	1.2938914	2.64133
1984	251.1	.85129	1.2204874	2.73005
1985	224.05	.89202	1.4332836	2.864

Note: Col. 1 is the observed exchange rate (yen/dollar); col 2 is the Japanese price index transformed by the purchasing power parity (PPP) index; col 3 is the Japanese PPP-based price index denominated by exchange rate; col. 4 is the U.S. corresponding price index.

Our international comparisons of relative prices of aggregate output and inputs show, first, that the Japanese economy has been more competitive than the U.S. economy throughout the period 1960–85, except for 1973 and 1978–79. Second, lower wage rates have contributed to Japan's international competitiveness throughout the period, especially before the energy crisis in 1973. Lower costs of capital have also contributed to Japan's international competitiveness for most of the same period with important exceptions in 1973 and 1978–80.

We turn next to international competitiveness of Japanese and U.S. industries. Exchange rates play the same role in relative price comparisons at the industry level as at the aggregate level. However, industry inputs include energy and other intermediate goods as well as the primary factors of production—capital and labor inputs. The price of energy inputs in each industrial sector is an aggregate of inputs of petroleum and coal products and electricity and gas products. The relative prices of the outputs of these two industries in Japan and the United States are given in table 1.6

The energy crisis of 1973 had an enormous impact on the prices of energy in both Japan and the United States. Prices of petroleum and coal products in Japan were almost double those in the United States, while prices of electricity and gas were about 1.3 times those in the United States in 1985. By comparison petroleum and coal products in Japan were only 1.6 times as expensive as those in the United States in 1970, while electricity and gas were only slightly more expensive in Japan than in the United States in that year.

Table 1.7 gives average annual growth rates of input prices in Japan and the United States in the 1960s, 1970s, and 1980s at the industry level. Differences in the growth rates of the cost of capital between Japan and the United States

Table 1.6 Relative Prices of Outputs in Two Energy Industries

	Petroleum & Coal		Electricity & Gas	
Year	Japan	United States	Japan	United States
1960	1.71118	.97477	.83247	.94299
1965	1.51919	.94523	1.00311	.96430
1970	1.59952	1.00000	1.02936	1.00000
1975	5.34666	2.51780	2.26813	1.78555
1980	14.75987	6.46713	5.99713	3.45804
1985	13.28313	5.98764	6.25211	5.04334

Table 1.7 Annual Growth Rate of Prices

		Price Increase (%)	
Period	Source	Japan	United States
1960–70	Capital service	2.8435	2.2153
	Labor service	12.2062	4.5325
	Energy input	.5881	.4513
	Material input	2.1515	2.0432
1970–80	Capital service	−.5899	6.3782
	Labor service	11.6868	8.0232
	Energy input	13.8936	15.1777
	Material input	7.7005	8.1342
1980–85	Capital service	.0777	5.9044
	Labor service	3.8273	5.2741
	Energy input	1.2662	4.3062
	Material input	.5704	3.2437

Note: Annual growth rates of each price are estimated in terms of a simple average of an annual growth rate by industry in each item.

were negligible in the 1960s. Since 1970, average rates of growth in the United States have been considerably higher. The rates of growth of wage rates in Japan were substantially higher than U.S. rates throughout in the 1960s and 1970s. During the 1980s, however, annual rates of growth of wages in the United States exceeded those in Japan by about 1.5% per year.

The movements of energy input prices were similar in the two countries in the 1960s. We have already described these movements during the energy crisis of the 1970s. Rates of growth of energy prices in the United States during the 1980s were about 3% per year higher than those in Japan. This implies that differences between energy prices in the two countries have been decreasing since 1980, in spite of the relatively high level of energy prices in Japan. The growth rates of other intermediate input prices in the United States were also higher than that in Japan after 1980. The higher growth rates of input prices in the United States since 1980—including capital, labor, energy, and other intermediate inputs—have resulted in a substantial deterioration of international competitiveness of U.S. industries relative to their Japanese counterparts.

1.3 Relative Productivity Levels

In this section we estimate relative levels of productivity in Japan and the United States for each of the 29 industries included in our study. Jorgenson, Kuroda, and Nishimizu (1987) have reported relative productivity levels for the two countries for the period 1960–79. All Japanese industries had lower levels of productivity than their U.S. counterparts in 1960. However, there were nine industries in which productivity gaps between the two countries had closed during the period 1960–79. In 19 industries, differences in productivity levels between Japan and the United States remained in 1979.

Jorgenson, Kuroda, and Nishimizu (1987) have divided Japanese and U.S. industries into seven categories. Type 1 included four industries in which productivity gaps between Japan and the United States were expected to increase in the future—agriculture-forestry-fisheries, textiles, printing and publishing, and trade. Type 2 includes industries in which the productivity gaps were decreasing before 1973, but increasing after 1973. These industries were food and kindred products, apparel, furniture, rubber, stone and clay, other transportation equipment, utilities, and other services. Type 3 includes industries in which the United States had an advantage in productivity in 1979, but productivity gaps between Japan and the United States were expected to close in the near future. This category contains investment-goods industries such as nonelectrical machinery, electrical machinery, and motor vehicles.

Paper and allied products constitute type 4; in this industry U.S. productivity levels increased relative to those in Japan before 1973, but the productivity gap was decreasing afterward due to deterioration of productivity in the U.S. industry. Petroleum and coal products with a constant productivity gap, favoring the United States, and construction with negative growth rates of productivity in both countries are classified as type 5 and type 6, respectively. Finally, type 7 includes the nine industries in which Japan had a productivity advantage in 1979. The Japanese advantage was expected to increase in the future. These include mining, lumber, chemicals, primary metals, fabricated metals, precision instruments, miscellaneous manufacturing, transportation and communication, and finance and insurance.

In order to assess the validity of this taxonomy in projecting future patterns of relative productivity growth in Japan and the U.S. we consider additional observations for the period 1979–1985. However, we must take note of the following revisions in the data base. First, we have revised U.S. intermediate input measures by constructing a time series of interindustry transactions tables for the period 1947–85. The methodology is consistent with the approach used for constructing a time series of Japanese interindustry transactions tables for the period 1960–85.[4] Second, we were able to obtain more detailed information on wage differentials between full-time employees and other employees in Japan. We used this information to improve our estimates of labor compensation for temporary employees, day laborers, and unpaid family workers in Japan.

The earlier estimates of purchasing power parities for labor input were based on relative wage levels for full-time workers in Japan and the United States. In the agricultural sector in Japan, however, there is a substantial number of irregular and part-time workers, especially unpaid family workers. Taking the labor compensation of these workers into account, we find that we overestimated the purchasing power parity of labor input in the agricultural sector in our earlier work. We have revised the purchasing power parity index of labor input in the agriculture-forestry-fisheries industry in 1970 from 0.60588 to 0.21352, as shown table 1.2. This is much closer to results for other industries, where we only take account of ordinary full-time employees in estimating the purchasing power parity index for labor input.

The three revisions in the data base have resulted in two substantial changes in the taxonomy of industries presented for the period 1960–79 in Jorgenson, Kuroda, and Nishimizu (1987). The fabricated metal products industry was moved to type 1 from the type 7 classification of Jorgenson, Kuroda, and Nishimizu (1987). Second, the trade sector was classified in type 1 and is now classified in type 7 in the revised version. The remaining 26 industries were classified in the same way as in the industrial taxonomy of the earlier paper.

A new industrial taxonomy, based on our revised data base for the period 1960–1985, is given in table 1.8. Industries in which the United States has a substantial advantage in productivity in 1980 and productivity gaps between Japan and the United States are expected to persist into the future include agriculture-forestry-fisheries, textile products, and printing and publishing industries. These industries coincide with type 1 in Jorgenson, Kuroda, and Nishimizu (1987). Productivity growth since 1980 has added three industries to this category—petroleum and coal products, construction, and food and kindred products. These industries were classified in types 2, 5, and 6 in the earlier paper.

Type 2 includes those industries in which the United States had a productivity advantage in 1980 after productivity gaps had been closing during the 1960s and 1970s, but the U.S. productivity advantage was expected to grow in the future. The industries in this category in the 1987 paper included furniture and fixtures, rubber products, stone, clay and glass and other transportation equipment. Motor vehicles was added to this category in the 1980s. In the previous paper this industry was classified as type 3, where the technology gaps were expected to close in the near future.

According to new evidence on the productivity gap in the motor vehicle industry during the period 1980–85, the gap between Japan and the United States had closed by 1982, as we expected from our earlier observations. After 1983, however, the gap increased again due to rapid productivity growth in the U.S. industry. The index of productivity in motor vehicles in Japan and the U.S. during the period 1979–1985 is given in table 1.9.

Type 3 includes industries in which productivity gaps are expected to close in the near future, even though the United States had an productivity advantage in 1980. Three industries included in this category in Jorgenson, Kuroda, and Nishimizu (1987)—leather, nonelectrical machinery, and electrical machinery—had already attained U.S. levels of productivity by 1980, as we expected. In table 1.8 we have reclassified these industries in type 7. Industries added to type 3 in the 1980s were apparel, miscellaneous manufacturing, and finance, insurance, and real estate, previously classified as type 2 and type 7. These are three industries in which we were unable to project relative trends in productivity during the 1980s. Finally, type 7 includes industries in which Japan had a productivity advantage that we expected to increase in the future. Three industries previously classified in type 3 were added to this category in the 1980s, so that 12 industries of the 29 are included in type 7.

In evaluating the usefulness of the industrial taxonomy presented in Jorgenson, Kuroda, and Nishimizu (1987), we find only four industries in which the trend of technology gaps was not projected. The U.S. productivity advantage was expected to increase in apparel and miscellaneous manufacturing. The Japanese advantage was expected to increase in motor vehicles and finance. We conclude that the predictive power of the Jorgenson-Kuroda-Nishimizu taxonomy is substantial. We can also draw attention to the findings from new observations during the period 1980–85. According to table 1.9, industries with a clear advantage in productivity in Japan or the United States fall into two groups. Type 1 includes seven industries with a U.S. advantage, while Type 7 includes 12 industries with a Japanese advantage.

To analyze the trend of productivity differences between Japan and the United States, we have estimated the mean and variance of relative productivity by industry during the period 1960–85. The results are shown in figures

Table 1.8 **An Industrial Taxonomy in Terms of Technology Gaps**

Type of Technology	Industry	Technology Gaps, 1980	Average Annual Growth Rate of Productivity						Technology Gaps, 1985
			1960–70		1970–80		1980–85		
			Japan	United States	Japan	United States	Japan	United States	
Type 1	(1) Agric.	U > J	.452	1.178	−1.641	.673	−.274	4.431	U > J
	(3) Construct.	U > J	.854	.228	.717	−1.07	−1.707	.516	U > J
	(4) Foods	U > J	−.155	.556	.37	.208	−.917	.8	U > J
	(5) Textiles	U > J	.526	1.437	−1.22	.187	.188	.309	U > J
	(10) Printing	U > J	.858	.647	−1.469	.218	.02	.979	U > J
	(12) Petroleum	U > J	−1.358	1.616	−3.889	−4.56	−1.29	3.422	U > J
	(17) Fab. Metal	U > J	2.668	.293	.837	.618	.009	.376	U > J
Type 2	(8) Furniture	U > J	1.405	.03	1.364	.792	1.02	1.475	U > J
	(13) Rubber	U > J	1.499	.868	.55	.981	2.623	3.502	U > J
	(15) Stone	U > J	2.794	.339	−1.248	.555	.414	2.443	U > J
	(20) Mot. Veh.	J > U	.086	.155	.512	.282	−1.286	2.553	U > J
	(21) Trsp. Eqpt.	U > J	6.649	1.395	.706	−4.26	2.107	3.456	U > J

Type 3	(6) Apparel	U > J	2.294	.625	1.414	1.16	.42	.203	U > J
	(28) Service	U > J	1.378	.7	−3.033	.018	.502	−1.179	U > J
	(27) Finance	U > J	1.81	.535	.15	.181	3.311	−1.179	U > J
Type 5	(25) Utilities	U > J	3.222	2.111	−2.991	−1.497	.603	−1.668	U > J
Type 7	(2) Mining	J > U	1.662	1.084	1.722	−5.584	.301	.045	J > U
	(7) Lumber	J > U	2.781	.965	2.032	.738	3.522	1.211	J > U
	(9) Paper	J > U	1.616	.338	.505	.233	1.982	1.207	J > U
	(11) Chemical	J > U	3.343	1.501	.731	−1.517	2.671	1.63	J > U
	(14) Leather	U > J	.926	.452	.713	1.066	.552	−4.352	J > U
	(16) Prim. Metal	J > U	.915	.088	.781	.534	.624	−2.294	J > U
	(18) Machinery	J > U	2.212	.809	.377	.693	−1.073	.785	J = U
	(19) Elec. Mach.	J > U	3.304	.093	3.663	.693	3.222	.5	J > U
	(22) Prec. Inst.	J > U	1.943	.729	3.626	.13	1.513	3.105	J > U
	(23) Mfg. Misc.	J > U	1.741	.647	1.257	.795	.252	.23	J > U
	(24) Trsp. Comm.	J > U	3.056	1.085	.49	.995	1.186	.251	J > U
	(26) Trade	J > U	2.507	.077	.838	.316	.607	2.6	J = U

Note: For industry abbreviations, see table 1.1 above. U = United States; J = Japan. Type 1: the United States had still an advantage in the 1980 technology. The technology gaps are expected to continue to expand in the future. Type 2: the United States had an advantage in the 1980 technology. Before 1980, the technology gaps partly were closing. But they, however, were expanding in 1980's and are expected to expand in the future. Type 3: the United States had an advantage in the 1980 technology. The technology gaps are expected to close in the near future. Type 5: the United States had an advantage in the 1980 technology. The technology gaps were mostly constant during the period 1960–85. Type 7: Japan had an advantage in the 1980 technology. The technology gaps are expected to continue to expand in the future.

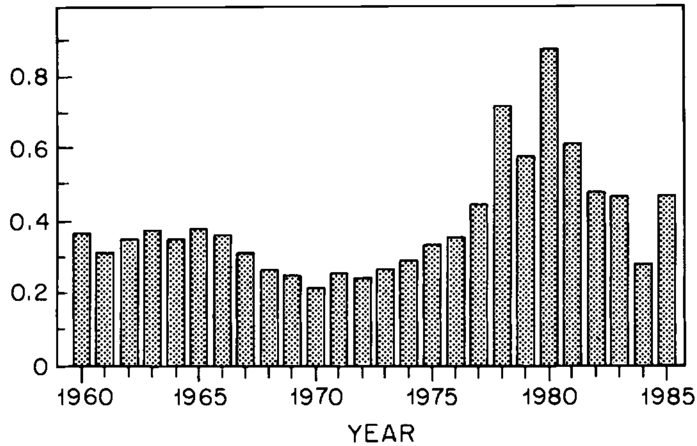

Fig. 1.1. Average of proportional gap of the technology between the United States and Japan

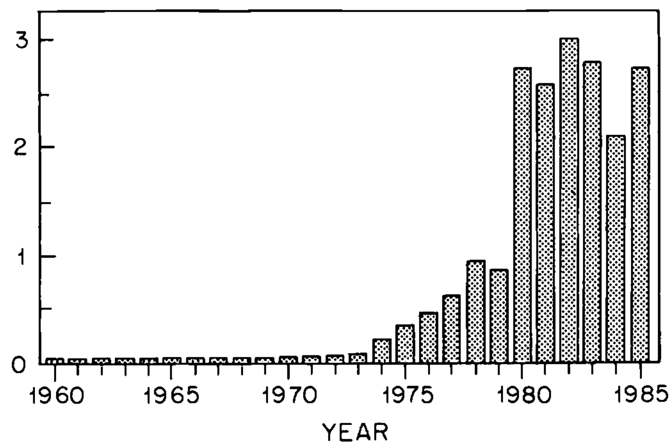

Fig. 1.2 Variance of proportional gap of the technology between the United States and Japan

1.1 and 1.2. The mean of relative productivity levels between the two countries remained fairly stable during until 1973 and then rose through the 1970s. This movement peaked in 1980. Since that time, the trend has reversed with gains in productivity levels for the United States during the 1980s. The variance of the relative productivity levels shown in figure 1.2 was stable until the oil crisis in 1973 and has expanded rapidly since.

We conclude that the energy crisis had a very substantial impact on patterns of productivity growth by industry. Both the mean and the variance of relative productivity levels between Japan and the United States expanded during the period 1974–80. In the 1980s the mean of the relative productivity levels has fallen, while the variance has increased rapidly. This implies that the relative productivity levels in the two countries have tended to differ substantially among industries, as shown in table 1.9.

Finally, we turn to international competitiveness between Japan and the United States. We can account for movements in the relative prices of industry outputs in the two countries by changes in relative input prices and changes in relative productivity levels. Figures 1.3a and 1.3b show the relative prices of industry outputs between Japan and the United States in terms of dollars. We have expressed these prices in logarithmic form so that a negative difference implies that the U.S. output price is below the Japanese price, while a positive difference implies the Japanese price is below the U.S. price.

Figure 1.3a includes plots of the relative prices of industries in which the United States has a higher level of productivity in 1985. In the 1960s the Japanese output prices were relatively low, due primarily to lower labor costs. Although lower relative wage rates in Japan helped to reduce relative prices of output, they were almost totally offset by the lower levels of productivity in Japan during the 1960s.

After the energy crisis of 1973, U.S. output prices in the industries plotted in figures 1.3a fell relative to Japanese prices until 1980 due to much greater increase in energy prices in Japan and appreciation of the yen relative to the dollar. During the 1980s the international competitiveness of Japanese industries has been increasing in spite of the productivity gains in the United States. This is because of the more rapid increase in U.S. wage rates and costs of capital and the appreciation of the dollar. It is especially interesting that output prices in textile products, motor vehicles, and fabricated metals industries have been almost the same in Japan and the United States since 1980, notwithstanding the increasing U.S. productivity advantage in these industries.

In figures 1.3a–1.3b, we present plots of the relative output prices of industries in which Japan had a productivity advantage in 1985. The time trends of relative prices in these industries during the period 1960–85 are very similar to those of industries in which the United States had a productivity advantage.

Table 1.9 **Index of Productivity in Motor Vehicles**

Year	Japan	United States
1979	.91639	.97490
1981	.89246	.88842
1983	.85502	.95674
1985	.85379	.98393
1980	.91050	.53853
1982	.86165	.84402
1984	.85545	1.02915

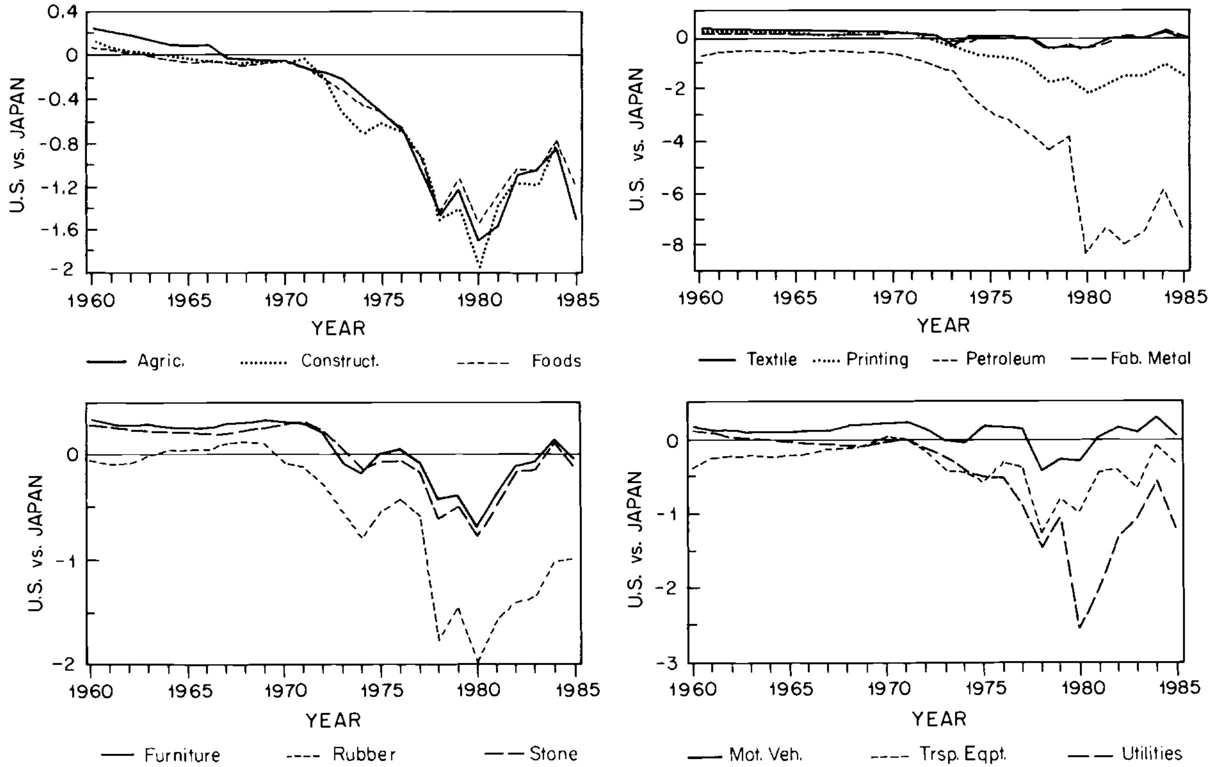

Fig. 1.3a Trends of proportional gap of denominated output prices

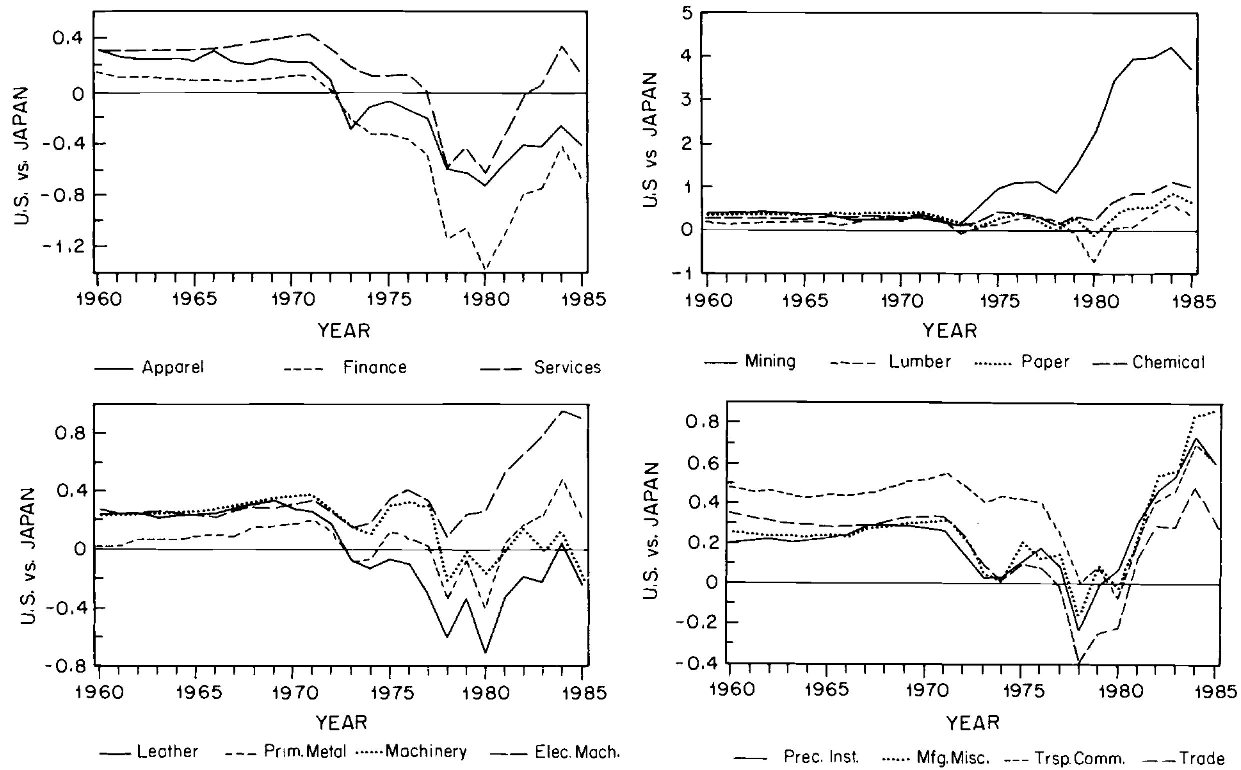

Fig. 1.3b Trends of proportional gap of denominated output prices

However, the price levels are lower in Japan, so that Japan has a clear advantage in international competitiveness. These features are especially evident in industries classified as type 7 in our industrial taxonomy.

1.4 Conclusion

Jorgenson (1988) has recently summarized the results of international comparisons between Japan and the United States. The period 1960–73 was characterized by substantial economic growth in the United States and very rapid economic growth in Japan. Capital input was by far the most important source of growth in both countries, accounting for about 40% of U.S. economic growth and 60% of Japanese growth. The period 1973–79 was dominated by the energy crisis, which began with drastic increases in petroleum prices in 1973. Growth slowed significantly in the United States and declined dramatically in Japan during this period. The growth of capital input remained the most important source of economic growth in both countries, but productivity growth at the sectoral level essentially disappeared.

During the period 1960–73, productivity growth in Japan exceeded that in the United States for almost all industries. After the energy crisis in 1973, there were very few significant differences between growth rates of productivity in Japanese and U.S. industries. In this paper we have extended these observations through 1985. An important focus for our work has been the assessment of longer-term trends in productivity growth. In particular, we have tried to establish whether or not the slowdown in productivity growth in Japan and the United States after the energy crisis has become permanent. For this purpose we have focused on productivity growth in both countries since 1979.

The second issue we have considered is the trend of industry-level productivity differences between the two countries. Jorgenson, Kuroda, and Nishimizu (1987) showed that almost every Japanese industry had a lower level of productivity that its U.S. counterpart in 1960. By the end of the period 1960–79 there were nine industries in which productivity gaps between the two countries had closed. These industries were primarily concentrated in producer's goods manufacturing and were focused on export-oriented industries. In the remaining 19 industries, productivity gaps between Japan and the United States remained in 1979. In this paper we have reexamined these findings in light of the experience accumulated during the period 1979–85.

We can summarize our conclusions as follows: after 1970, productivity growth deteriorated substantially in both Japan and the United States. An important issue is whether the productivity slowdown is a permanent feature of both economies. To resolve this issue we can consider average productivity growth rates in Japanese and U.S. industries over the period 1960–85, as shown in table 1.10. We conclude that productivity growth in Japan and the United States has revived somewhat since 1980. However, the growth rates

Table 1.10 **Average Productivity Growth Rates in Japan and the United States**

	Japan (%)	United States (%)
1960–65	1.478	1.993
1965–70	1.946	–.985
1970–73	.686	.941
1973–75	–1.481	–3.064
1975–80	.178	–1.058
1980–85	.760	.448

for the period 1980–85 are well below those for the period 1960–73, especially in Japan.

A second issue is whether productivity levels in Japan and the United States have tended to converge. While the mean of relative productivity levels between Japan and the United States has fallen since 1980, the variance has expanded rapidly. This implies that convergence of Japanese and U.S. levels of productivity during the 1960s has given way to sharply divergent trends in relative productivity by industry during the 1970s and, especially, during the 1980s. Figures 1.3a–1.3b provide our results on international competitiveness between Japan and the United States. The competitiveness of U.S. industries has been declining since 1980, due to more rapid growth of input prices in the United States and the appreciation of the dollar relative to the yen.

The industrial taxonomy presented by Jorgenson, Kuroda, and Nishimizu (1987) has proved to be relatively robust. The productivity trends by industry that was projected on the basis of earlier results have materialized with only a few exceptions. While the United States retains an overall advantage in relative productivity levels, there is a substantial number of industries where Japan has gained an advantage and seems likely to increase it. Perhaps equally important, the increase in the variance of relative productivity levels among industries has created opportunities for both countries to benefit from the great expansion in Japanese-U.S. trade that has already taken place. However, this increase is also an important source of "trade frictions" and will require continuing efforts at coordination of trade policies in the two countries.

Appendix

The industries in our data base for Japan are classified into 31 industrial sectors. For the United States, the industries are classified into 35 industrial sectors.[5] For international comparisons we have aggregated these industries to the 29 sectors given in table 1.1. To represent our bilateral models of production we require the following notation:

q_i = price of the output of the ith industry;
$p_{Ki}, p_{Li}, p_{Ei}, p_{Mi}$ = prices of capital, labor, energy, and other intermediate inputs in the ith industry;
$v_{Ki}, v_{Li}, v_{Ei}, v_{Mi}$ = value shares of capital, labor, energy and other intermediate inputs in the ith industry.

We represent the vector of value shares of the ith industry by v_i. Similarly, we represent the vector of logarithms of input prices of the ith industry by $\ln p_i$. We employ a time trend T, as an index of technology, and a dummy variable D, equal to one for Japan and zero for the United States, to represent differences in technology between the two countries. Under competitive conditions we can represent technology by a price function that is dual to the production function relating each industry's output to the corresponding inputs, the level of technology, and differences in technology between the two countries:

$$\ln q_i = \ln p_i'\alpha^i + \alpha_t^i T + \alpha_d^i D + \tfrac{1}{2}\ln p_i' B^i \ln p_i + \ln p_i'\beta_t^i T + \ln p_i'\beta_d^i D + \tfrac{1}{2}\beta_{tt}^i T^2 + \beta_{td}^i TD + \tfrac{1}{2}\beta_{dd}^i D^2, \quad (i = 1, 2, \ldots, I). \tag{A1}$$

For each industry the price of output is a transcendental or, more specifically, an exponential function of the logarithms of the input prices. We refer to these functions as *translog price functions*.[6] In this representation the scalars—$\alpha_t^i, \alpha_d^i, \beta_{tt}^i, \beta_{dd}^i$—the vectors—$\alpha^i \beta_t^i, \beta_d^i$—and the matrices, B^i, are constant parameters that differ among industries. These parameters reflect differences in technology among industries. Within each industry, differences in technology among time periods are represented by time as an index of technology. Differences in technology between Japan and the United States are represented by a dummy variable, equal to one for Japan and zero for the United States.

In analyzing differences in each industry's production patterns between Japan and the United States, we combine the price function with demand functions for inputs. We can express these functions as equalities between shares of each input in the value of the output of the industry and the elasticity of the output price with respect to the price of that input. These elasticities depend on input prices, dummy variables for each country, and time as an index of technology. The sum of the elasticities with respect to all inputs is equal to unity, so that the value shares also sum to unity.

For each industry the value shares are equal to the logarithmic derivatives of the price function with respect to logarithms of the input prices:

$$v_i = \alpha^i + B^i \ln p_i + \beta_t^i T + \beta_d^i D, \quad (i = 1, 2, \ldots, I). \tag{A2}$$

We can define *rates of productivity growth*, say v_{Ti}, as the negative of rates of growth of the price of output with respect to time, holding the input prices constant:

$$\text{(A3)} \quad -v_{Ti} = \alpha_t^i + \beta_t^{i\prime} \ln p_i + \beta_{tt}^i T + \beta_{dt} D, \quad (i = 1, 2, \ldots, I).$$

Similarly, we can define *differences in technology* between Japan and the U.S., say v_{Ti}, as the negative of rates of growth of the price of output with respect to the dummy variable, holding the input prices constant:

$$\text{(A4)} \quad -v_{Di} = \alpha_d^i + \beta_d^{i\prime} \ln p_i + \beta_{td}^i T + \beta_{dd}^i D, \quad (i = 1, 2, \ldots, I).$$

The price of output, the prices of inputs, and the value shares for all four inputs are observable for each industry in the period 1960–85 in both countries. The rates of productivity growth are not directly observable, but average rates of productivity growth between two points of time, say T and T-1, can be expressed as the difference between a weighted average of growth rates of input prices and the growth rates of the price of output for each industry:

$$\text{(A5)} \quad -\bar{v}_{Ti} = \ln q_i(T) - \ln q_i(T-1) - \text{v}_i{}' \,[\ln p_i(T) - \ln p_i(T-1)], \quad (i = 1, 2, \ldots, I),$$

where the average rates of technical change are:

$$\bar{v}_{Ti} = \tfrac{1}{2}[v_{Ti}(T) + v_{Ti}(T-1)],$$

and the weights are given by the average value shares:

$$v_i = \tfrac{1}{2}[v_i(T) + v_i(T-1)].$$

We refer to the index numbers (A5) as *translog price indices* of the rates of productivity growth.[7]

Similarly, differences in productivity v_{Di} are not directly observable. However, the average of these differences for Japan and the United States can be expressed as a weighted average of differences between the logarithms of the input prices less the difference between logarithms of the output price:

$$\text{(A6)} \quad -\hat{v}_{Di} = \ln q_i(\text{JAPAN}) - \ln q_i(\text{US}) - \hat{v}_i{}'[\ln p_i(\text{JAPAN}) - \ln p_i(\text{US})], \quad (i = 1, 2, \ldots, I),$$

where the average differences in productivity are

$$\hat{v}_{Di} = \tfrac{1}{2}[v_{Di}(\text{JAPAN}) + v_{Di}(\text{US})],$$

and the weights are given by the average value shares

$$\hat{v}_i = \tfrac{1}{2}[v_i(\text{JAPAN}) + v_i(\text{US})].$$

We refer to the index numbers (A6) as *translog price indices* of differences in productivity.

Notes

1. Equivalently, these prices could be expressed in terms of yen.

2. Christensen, Cummings, and Jorgenson (1980, 1981) have compared aggregate outputs, inputs, and productivity levels for nine countries, including Japan and the United States. Their estimates of relative productivity levels are based on the methodology for multilateral comparisons developed by Caves, Christensen, and Diewert (1982a, 1982b). An alternative approach is presented by Denny and Fuss (1983).

3. A similar approach is employed by Conrad and Jorgenson (1985) in comparisons for 1960–79 among the Federal Republic of Germany, Japan, and the United States. This methodology is also used by Nishimizu and Robinson (1986) in comparisons among manufacturing industries in Japan, Korea, Turkey, and Yugoslavia.

4. The methodology was originated by Kuroda (1981).

5. This classification is a consolidation of that used by Jorgenson, Gollop, and Fraumeni (1987).

6. The translog price function was introduced by Christensen, Jorgenson, and Lau (1971, 1973).

7. Diewert (1976) showed that the index numbers employed by Christensen and Jorgenson (1973) are exact for the translog price function of Christensen, Jorgenson, and Lau (1971, 1973).

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Comment Robert M. Schwab

This paper is an ideal contribution to a volume on U.S. and Japanese productivity. It presents careful estimates of prices, inputs, outputs, and productivity for 31 Japanese and 35 U.S. industries for the period from 1960 to 1985. These estimates allow Jorgenson and Kuroda to ask and answer a wide range of interesting and important questions. Did the differences between Japanese and U.S. productivity growth rates narrow or widen during this period? Have levels of productivity converged? What can we learn by looking at patterns across industries?

The productivity estimates are derived in the sources-of-growth framework. In that framework, productivity growth over time within a country equals the difference between the growth rate of output and the share-weighted growth rates of inputs. Similarly, the difference in the level of productivity across countries at a point in time equals the difference in output less the share weighted differences in inputs. This approach is well developed in the literature, and many of the often-heard objections to growth accounting can be raised once again. For example, payments to capital are interpreted as the

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value of the marginal product of capital, ignoring capital utilization issues, adjustment costs, and so on. Growth accounting imposes an assumption of constant returns to scale at the industry level; if this assumption is wrong, then the paper's estimates of productivity growth include scale economies.

The paper's estimates of differences in economic performance are dramatic. Output grew about 2.5 times faster in Japan than in the United States during 1960–79. Roughly 80% of this difference was due to differences in input growth. The Japanese capital stock grew nearly three times as fast as the U.S. capital stock; differences in labor growth were much smaller. The remaining 20% represents differences in total factor productivity growth. These large differences in output growth and small differences in labor growth imply large differences in the growth of labor productivity (output per worker). Differences in total factor productivity explain about one-quarter of the difference in labor productivity, while the remainder is attributable to differences in the growth of capital per worker and intermediate input per worker.

There are some anomalies in the results for the individual industries. Consider motor vehicles, for example. Output in this industry grew much faster in Japan than in the United States during the twenty-five-year period covered in this study. Tables 1.3–1.5 in the paper attribute all of the difference in output to differences in inputs; estimated productivity growth was lower in Japan than in the United States. This may be correct, but I doubt it; certainly, it is at odds with Japan's growing role in the world automobile and truck markets and the widespread belief that Japanese auto firms are the models of efficiency and productivity. A more plausible explanation is that the results for this industry are symptomatic of some of the well-known shortcomings of growth accounting. In that framework we measure productivity growth as a residual, and therefore our estimates are contaminated by all sorts of measurement errors inherent in the data. In the aggregate, over a long time period, these errors will hopefully cancel and our estimates of productivity growth will be sound. If we focus on any single industry, however, we may not be so fortunate.

The paper's analysis of various subperiods is provocative. In the version of the paper presented at the conference, the authors conclude that during the 1960–70 economic "boom," productivity growth was substantially higher in Japan that in the United States. In the later years, particularly after the oil crisis began in 1973, differences in productivity growth between the two countries were insignificant.

I have two comments on this conclusion. First, it is inconsistent with some earlier studies of Japanese and U.S. economic performance. For example, Norsworthy and Malmquist (*American Economic Review,* 1983) estimated that average annual productivity growth in Japan was about eight-tenths of a percentage point higher during 1973–78 than during 1965–73, when the U.S. average fell two-tenths of a point; thus according to the Norsworthy-Malmquist estimates, the gap between Japanese and U.S. productivity growth widened after the oil shock. There are a number of possible explanations of these divergent results. The time periods in other studies do not match exactly; the studies use different data sets; some studies focus on economic aggregates while this study looks at individual industries. Still, these differences are puzzling and deserve further attention.

Second, if Jorgenson and Kuroda are correct, we are left with the question of why productivity trends converged. Perhaps Japan was more vulnerable to the oil shock than was the United States. Certainly the Japanese economy was more dependent on foreign oil, though it is not clear that increases in foreign oil prices would have a larger impact on productivity than would increases in domestic oil prices. Perhaps U.S. price controls shielded U.S. industries from some of the short-run effects of the oil shock, or perhaps differences in the structure of production were important. Since there are problems with the oil price shock story, and since there is at least some evidence that differences in productivity had already begun to narrow during 1970–73, I suspect that we need to look at additional explanations in order to understand this result.

One such explanation would draw on the "catching up" hypothesis. Advocates of this hypothesis might argue that Japan was operating well inside the best-practices production possibilities frontier after the war. Thus two avenues of growth were available: the frontier would shift out over time, and Japan would move closer to the frontier. When Japan had fully adopted all of the existing technology, Japanese productivity growth from that point forward would be roughly the same as that of other countries. This explanation of course has a testable implication; if it is correct, we would expect to find that differences in productivity growth were associated with differences in the level of productivity. The paper offers some evidence that suggests that this was, in fact, the case in some industries, but by no means all. It would therefore seem that catching up is a very complex phenomenon and one that deserves a good deal of attention in the future.

In sum, Jorgenson and Kuroda have made an important contribution to the literature on international productivity comparisons. Their analysis is meticulous, wide ranging, and provocative. I am certain that this paper will become one of the standard references in this field.