Overview of Japanese Industrial Technology Development

March 1989
OVERVIEW OF JAPANESE INDUSTRIAL TECHNOLOGY DEVELOPMENT

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OVERVIEW OF THE JAPANESE EXPERIENCE OF INDUSTRIAL TECHNOLOGY DEVELOPMENT

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APPENDIX
INTRODUCTION

i. This paper provides an overview of the experience of industrial technology development in Japan since World War II. It does not attempt to conduct new empirical work, partly due to the sizable existing literature. The main contribution of the paper is a broader and more systematic approach to understanding the process of industrial technology development in Japan.

ii. Chapter I presents a brief history of industrial technology development in Japan before World War II in order to place the subsequent development in perspective. It focuses primarily on the role of government.

iii. Chapter II briefly reviews the interaction between economic growth and technology development in the post-War era. It draws attention to the following facts: First, Japan’s high economic growth was heavily dependent on technology development i.e., successive introduction of new technologies and new industries. Second, it took substantial time and technological effort for newly introduced technology to generate sizable exports.

iv. Chapter III discusses the general environment, which has supported rapid industrial technology development: human resources development, domestic competition, and an active industrial policy. It points out that a remarkable expansion of science and engineering manpower took place in Japan. It also discusses three major factors that may have made a difference in the effectiveness of industrial policy-cum-protection compared with many developing countries today: fierce domestic competition, non-accommodative protection, and basic dependence on market initiatives and discipline.

v. Chapter IV reviews the experience of the regulatory and incentive policy for the importation of foreign technology, including government screening of technology imports and the role of a restrictive DFI policy. It also draws attention to public research institutions’ effective role in technology transfer.

vi. Chapter V turns to the experience of technology diffusion. It points out that the decentralized industrial organization in Japan—extensive subcontracting systems and subsidiary networks—was highly effective for technology diffusion, primarily due to increased incentives for technology users to innovate. It also discusses the government’s information and promotional measures for technology diffusion: measures for the development of quality control systems and measures for supporting technology diffusion to small and medium enterprises.

vii. Chapter VI discusses research and development policies. It points out that rapid growth in R&D capability was achieved in Japan with only modest R&D support from the government. It discusses both general and targeted support for R&D: fiscal and financial incentives, government-sponsored R&D schemes, research associations, national research laboratories, and the patent system.

viii. The Conclusion presents major potential lessons for developing countries and outlines an agenda for future research.
I. A SHORT HISTORY OF INDUSTRIAL TECHNOLOGY DEVELOPMENT BEFORE WORLD WAR II

A. Government Investment and Divestiture

1.01 The initial forward step toward industrialization was taken by the Japanese government, although extensive manual production activities already existed in traditional industries such as textiles, metal working and wood processing before the Meiji restoration (1869). In 1870, the Ministry of Engineering was created. It established government-owned factories in several sectors (textiles, shipbuilding, engineering, steel, paper, etc.). These factories were intended to demonstrate modern technology from abroad. Most factories were sold to the private sector in 1880 because of the fiscal crisis that resulted from civil war in Japan.

1.02 This divestiture provided the business foundation for the zaibatsu groups by offering the opportunity for the transformation of commercial capital into industrial capital. The divestiture was associated with the transfer of technological resources from the public sector to the private sector, since the government already had made a massive effort in developing human technical resources.

1.03 There was a substantial demonstration effect in the textile sector. Although technologies used in the government spinning factories were too capital intensive for private enterprises to adopt directly, they stimulated private enterprises to adapt modern technology and eventually to develop spinning technology fitting the Japanese environment of that time. The textile industry became a major export industry and led the industrialization of Japan.

B. Foreign Experts and the Educational System

1.04 During the 10 years from 1872 to 1881, the government invited thousands of foreign educators, engineers and other experts to provide assistance in running the government-owned factories and educational institutions.1/ The Ministry of Engineering allocated about 42% of its total budget

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2/ The government invited 3,762 foreign experts during these years. During the 20 years from 1872 to 1891, the government hired 5,526 foreign experts, and the private sector hired 8,313. Annual Statistics on Imperial Japan (in Japanese).
(1914-1918). Some of these Japanese institutions achieved major technological accomplishments and had a substantial impact on some industries, although their overall impact on industrial development was limited.

1.09 The Japanese prefectural governments established a number of institutions for testing and to provide technical guidance for regional industries. Beginning in 1906, the national government provided fiscal support for the establishment of these institutions. It is reported that some of them contributed substantially to the modernization of traditional small- and medium-scale industries and to the development of local-resource based industries.

D. Trade and the Incentives Regime

1.10 For 30 years after the Meiji Restoration, until around 1900, industrial development took place under an almost neutral trade regime. This was not necessarily a result desired by the Japanese government. It was not allowed to have independent authority over the formulation of tariffs until 1899. Until that year, tariff rates, which had been bound by an international treaty, were 5% or less (export was also taxed to a similar extent). Quantitative restrictions played no role until 1931.

1.11 After Japan regained authority over tariff formulation and until World War I, it raised tariffs gradually to increase revenues and to protect domestic industry. Although inflation associated with the war eroded tariffs substantially (with many tariffs specific), during the post-war global trend to protectionism, tariffs were raised again, with a stronger emphasis on protection through tariff escalation. The average tariffs (arithmetic average) were 4% (1893), 20% (1913), 11% (1924) and 30% (1938).

1.12 Sector-specific supports outside the tariff regime were provided mainly because of military concerns. The government provided subsidies to shipbuilding industries in 1896 after the Sino-Japanese War. The steel and automobile industries also received government support, including establishment of a national integrated steel mill in 1901. However, the aggregate importance of such measures was limited to less than 1% of income in the manufacturing sector from 1890 to 1938.

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5/ Forty-six such institutions were established from 1894 to 1925, based on the initiatives of prefectures and industrial cooperatives.

6/ Milton Friedman regards the free trade regime of Japan in the initial three decades of independence as one of the major success factors for industrialization, compared with the stagnation of industrial development in India after independence (*Free to Choose*, 1979, Harcourt Brace Jovanovich, Chapter 2).


8/ Ibid., p. 155.
1.13 **Shift of the Incentive Regime.** Light industry, especially textiles, which was the mainstay industry in Japan before World War II (accounting for 30% of industrial production and for 60% of industrial export in 1927-1936), developed under the free trade regime. The influence of the government on light industry development was limited mainly to technological support for quality improvement and control. The government made a larger impact on the development of heavy industries through tariffs, fiscal support and technological influence from the military, although heavy industries had not become major exporters before the war. This shift is more a reflection of the global tendency toward protectionism and increased military tensions in the early twentieth century than a reflection of an explicit industrial policy objective.

E. **Direct Foreign Investment**

1.14 Foreign firms began direct foreign investment (DFI) in Japan in 1899, mostly in technology-intensive sectors such as electrical machinery and automobiles. Most foreign investments were joint ventures, established through the initiatives of Japanese enterprises (especially importers) that encountered demands from foreign enterprises for equity participation in exchange for technology and equipment. Exceptions were rubber and automobile enterprises, wholly-owned by foreign investors.

(D-263a)
II. ECONOMIC GROWTH AND TECHNOLOGY DEVELOPMENT IN THE POST-WAR DECADES

A. Economic Performance

2.01 The Japanese economy recorded exceptionally high growth in the 1950s and 1960s, with annual real economic growth maintained at an average annual rate of 10% (see Table 1). The growth rate accelerated slightly in the 1960s, and although the growth rate declined sharply in the 1970s (after the first world oil crisis), the Japanese economy has maintained the best growth performance among developed countries. Labor productivity similarly recorded a very high growth rate in the 1950s and 1960s (Table 1).

<table>
<thead>
<tr>
<th>Table 1: MAJOR ECONOMIC INDICATORS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Growth Rate (GNP)</td>
</tr>
<tr>
<td>Growth Rate in Labor Productivity (Industry and Mining)</td>
</tr>
<tr>
<td>Investment Ratio %</td>
</tr>
<tr>
<td>Inflation (WPI)</td>
</tr>
<tr>
<td>Current Account (NB)</td>
</tr>
</tbody>
</table>

a/ Ratio in nominal figures.
b/ 1951-55 average.
g/ Total for each period.


2.02 Table 2 suggests that the productivity performance of the Japanese economy was consistently superior to that of the other developed countries in the 1960s and 1970s.

Initial Conditions for High Economic Growth

2.03 The Japanese economy, ravaged by World War II and lagging far behind the Western countries in technological levels, inherited a relatively well-educated population from before the war. In 1930 the percentage of the population enrolled at primary and secondary levels was 21.1% for Japan compared to 23.4% for the United States and 13.6% for Great Britain.²/

**Table 2: AVERAGE ANNUAL RATES OF LABOR PRODUCTIVITY GROWTH IN MANUFACTURING**

<table>
<thead>
<tr>
<th></th>
<th>1960-73</th>
<th>1973-80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>10.5</td>
<td>6.4</td>
</tr>
<tr>
<td>United States</td>
<td>3.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Canada</td>
<td>4.7</td>
<td>1.5</td>
</tr>
<tr>
<td>France</td>
<td>5.8</td>
<td>4.4</td>
</tr>
<tr>
<td>West Germany</td>
<td>5.5</td>
<td>4.5</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>4.3</td>
<td>1.6</td>
</tr>
<tr>
<td>Italy</td>
<td>7.3</td>
<td>3.8</td>
</tr>
</tbody>
</table>


2.04 Many private enterprises with skilled workforces operated in light industries such as textiles and in heavy industry sectors such as metals and machinery. The share of manufacturing was 30% of domestic output in the 1930s, similar to the share of more developed countries. GNP in Japan during that period is estimated to have been only US$700-800 per capita in 1979 prices.

B. **Contribution of Technological Progress to Economic Growth**

**Productivity Growth and Capital Formation**

2.05 Rapid technological development has been one of the primary propellants of Japan's post-war economic boom. Econometric investigations based on a growth-accounting formula suggest that more than 50% of the economic growth in 1950s and 1960s can be attributed to total factor productivity growth, and more than 20% specifically to advances in technical knowledge (Table 3). The high rate of capital formation, another major contributing factor to high economic growth, was encouraged by continuous acquisition and development of technology. A high domestic savings rate also was at least partly a result of high economic growth. The national gross saving rate increased from 26% in 1950-54 to 40% in 1970-74.

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Table 3: SOURCES OF ECONOMIC GROWTH

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Standardized Growth Rate</td>
<td>6.81</td>
<td>4.00</td>
<td>6.27</td>
<td>4.70</td>
<td>2.38</td>
</tr>
<tr>
<td>Total Factor Input</td>
<td>3.99</td>
<td>2.09</td>
<td>2.78</td>
<td>1.26</td>
<td>1.11</td>
</tr>
<tr>
<td>Labor</td>
<td>1.98</td>
<td>1.30</td>
<td>1.37</td>
<td>0.43</td>
<td>0.60</td>
</tr>
<tr>
<td>Capital</td>
<td>2.01</td>
<td>0.79</td>
<td>1.41</td>
<td>0.79</td>
<td>0.51</td>
</tr>
<tr>
<td>Output Per Unit of Input (Standardized)</td>
<td>4.86</td>
<td>1.91</td>
<td>3.49</td>
<td>3.46</td>
<td>1.27</td>
</tr>
<tr>
<td>Advances in knowledge &amp; others</td>
<td>1.97</td>
<td>1.19</td>
<td>0.87</td>
<td>1.51</td>
<td>0.79</td>
</tr>
<tr>
<td>Improved resource allocation</td>
<td>0.93</td>
<td>0.30</td>
<td>1.01</td>
<td>0.95</td>
<td>0.12</td>
</tr>
<tr>
<td>Economies of scale</td>
<td>1.94</td>
<td>0.42</td>
<td>1.61</td>
<td>1.00</td>
<td>0.36</td>
</tr>
</tbody>
</table>


2.06 Schumpeterian Process. The contribution of technological development also can be deduced from the rapid structural transformation of Japanese industry. The share of the machinery sector (general, electrical and precision machinery) expanded from 12% of total industrial production in 1951-55 to 40% in 1976-80. Its share in industrial export similarly jumped from 13% to 65% during the same period (see Table 4). "Roughly 40% of Japanese industrial output in 1970 was accounted for by new products, those that were included in the official production index only after 1950.11/" It is also estimated that 35% of the export growth from 1961 to 1971 was accounted for by new product developments, compared to 12% by improved price competitiveness.12/ The high economic growth of Japan was a process with Schumpecean attributes,13/ where the successive introduction of new industries and technologies was the major driving force (see Figure 1 in the Appendix 2 for an illustration by a Ricardian model).


13/ Ozawa, 1975, ibid, pp. 1-4. The growth with structural transformation of industries can be illustrated by a Ricardian model of continua of goods (see Figure 1 in Appendix 2). The growth of real income in Japan was achieved by the combination of productivity growth in existing industries and the improvement of the factoral terms of trade due to the addition of new industries in the economy.
Table 4: STRUCTURAL CHANGE IN JAPANESE INDUSTRY

<table>
<thead>
<tr>
<th></th>
<th>Industrial Production</th>
<th>Industrial Export</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>23.2</td>
<td>8.1</td>
</tr>
<tr>
<td>Textiles</td>
<td>14.0</td>
<td>4.9</td>
</tr>
<tr>
<td>Wood Products</td>
<td>14.5</td>
<td>2.1</td>
</tr>
<tr>
<td>Chemicals</td>
<td>10.0</td>
<td>15.4</td>
</tr>
<tr>
<td>Ceramic Products</td>
<td>4.6</td>
<td>2.8</td>
</tr>
<tr>
<td>Metal Products</td>
<td>17.6</td>
<td>18.5</td>
</tr>
<tr>
<td>Machinery</td>
<td>12.2</td>
<td>40.2</td>
</tr>
<tr>
<td>Miscellaneous Products</td>
<td>3.9</td>
<td>7.4</td>
</tr>
</tbody>
</table>


C. Industrial Technology Development and International Trade

Two Phases of Technology Development: An Evolutionary Process

2.07 In the initial stage of development (1950s and early 1960s), Japanese industries depended critically on importing foreign technology. Domestic R&D was relatively small, aimed mainly at assimilating foreign technology, and sharply focused on the commercialization of imported technology, including development of engineering know-how.

2.08 In the second stage of development (late 1960s and 1970s), Japanese enterprises developed their own extensive R&D capability, which led to an increasing number of new products and processes. Although Japanese enterprises kept importing much foreign technology, its content became more basic. Technology development in each industry followed similar phases of development, although the timing varied significantly.

From Domestic Sales to Exports

2.09 The two phases of technology development have been associated with distinctly different sales patterns. The first phase (importation and assimilation of foreign technology) initially was associated with sales to the domestic market (i.e., either import substitution or development of a new market in the domestic economy). Substantial export expansion became possible only when industry reached the second stage (development of indigenous products and processes).
2.10 Tables 5 and 6 provide crude evidence for the domestic market orientation of the first phase of technology development. Table 5 shows the sectoral shares of technology imports from 1949 to 1956 and the sectoral shares of industrial exports from 1951 to 1955 and from 1971 to 1975. The machinery sector, though accounting for about 50% of the technology imports from 1949 to 1956 in number of contracts, contributed little more than 10% of industrial exports from 1951 to 1955. The contribution of machinery exports to industrial exports exceeded 50% only in the 1970s.

Table 5: SECTORAL SHARE OF TECHNOLOGY IMPORTS AND GOODS EXPORTS (in percentage)

<table>
<thead>
<tr>
<th>Subsectors</th>
<th>Share in Technology Import (1949-56)</th>
<th>Share in Industrial Export a/</th>
<th>Share in Industrial Export b/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textiles</td>
<td>6</td>
<td>41</td>
<td>9</td>
</tr>
<tr>
<td>Chemicals</td>
<td>22</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>Metal</td>
<td>10</td>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td>Machinery</td>
<td>51</td>
<td>13</td>
<td>53</td>
</tr>
<tr>
<td>Others</td>
<td>11</td>
<td>20</td>
<td>7</td>
</tr>
</tbody>
</table>

\(a/\) Share in the number of technology licensing contracts approved by the Law concerning Foreign Investment, according to White Paper on Rationalization of Industry (in Japanese), MITI.

\(b/\) Yamazawa I., op. cit., p. 20.

2.11 Table 6 shows that sales distribution of licensed manufactures (manufacturing output under technology licenses) was highly biased toward the domestic market in early 1950s: except for textiles, more than 90% of production (99% for chemicals) was sold in the domestic market.

2.12 Toward the end of the 1950s, the sales of licensed manufactures were still highly oriented to the domestic market (Table 6) although export sales of licensed manufactures increased in importance in relation to industrial exports (Table 7).

2.13 This relationship suggests that the technology learning process tended to be supported by domestic sales in Japan. Exporting was difficult because of initial non-competitiveness and export restrictions associated with licensing (see Table 1 in the Statistical Appendix for market restrictions associated with licensing). It took considerable time and technological effort for newly introduced technology to generate sizeable exports, since enterprises had to overcome these obstacles through their own technological efforts.
### Table A: Sales Distribution of Licensed-Manufactures Between Export and Domestic Markets, 1950-60 (in percentage)

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical</td>
<td>93.1</td>
<td>91.3</td>
<td>98.1</td>
<td>97.6</td>
<td>98.2</td>
<td>98.3</td>
<td>96.2</td>
<td>95.2</td>
<td>92.3</td>
<td>89.9</td>
<td></td>
</tr>
<tr>
<td>Machinery</td>
<td>6.9</td>
<td>8.7</td>
<td>1.9</td>
<td>3.6</td>
<td>1.8</td>
<td>1.7</td>
<td>3.8</td>
<td>4.6</td>
<td>7.7</td>
<td>9.1</td>
<td>10.1</td>
</tr>
<tr>
<td>Non-electrical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machinery</td>
<td>1.5</td>
<td>0.8</td>
<td>3.6</td>
<td>3.7</td>
<td>9.2</td>
<td>8.3</td>
<td>9.1</td>
<td>9.3</td>
<td>6.3</td>
<td>5.7</td>
<td></td>
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<tr>
<td>Chemicals</td>
<td>99.1</td>
<td>98.9</td>
<td>95.9</td>
<td>90.5</td>
<td>82.1</td>
<td>82.9</td>
<td>83.0</td>
<td>82.0</td>
<td>80.7</td>
<td>85.8</td>
<td></td>
</tr>
<tr>
<td>Machinery</td>
<td>0.9</td>
<td>1.1</td>
<td>4.1</td>
<td>9.5</td>
<td>17.9</td>
<td>17.1</td>
<td>17.0</td>
<td>18.0</td>
<td>19.3</td>
<td>14.2</td>
<td></td>
</tr>
<tr>
<td>Iron and Steel</td>
<td>94.9</td>
<td>95.7</td>
<td>92.8</td>
<td>8.7</td>
<td>89.4</td>
<td>89.5</td>
<td>84.3</td>
<td>85.4</td>
<td>84.8</td>
<td>86.0</td>
<td></td>
</tr>
<tr>
<td>Machinery</td>
<td>5.1</td>
<td>4.3</td>
<td>7.7</td>
<td>17.3</td>
<td>16.6</td>
<td>10.5</td>
<td>15.3</td>
<td>14.6</td>
<td>15.2</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>143.4</td>
<td>34.1</td>
<td>40.7</td>
<td>31.3</td>
<td>42.2</td>
<td>43.6</td>
<td>40.9</td>
<td>42.2</td>
<td>43.6</td>
<td></td>
<td></td>
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<tr>
<td>Machinery</td>
<td>143.4</td>
<td>34.1</td>
<td>40.7</td>
<td>31.3</td>
<td>42.2</td>
<td>43.6</td>
<td>40.9</td>
<td>42.2</td>
<td>43.6</td>
<td></td>
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<tr>
<td>Textiles</td>
<td>66.6</td>
<td>65.9</td>
<td>59.3</td>
<td>68.7</td>
<td>57.8</td>
<td>56.6</td>
<td>59.1</td>
<td>57.8</td>
<td>56.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A = Domestic market  
B = Export market


### Table B: Sales of Licensed-Manufactures in Total Value of Exports by Industry, 1950-60 (in percentage)

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Electrical</td>
<td>6.8</td>
<td>11.7</td>
<td>6.3</td>
<td>31.2</td>
<td>26.4</td>
<td>20.2</td>
<td>17.3</td>
<td>29.1</td>
<td>64.5</td>
<td>43.8</td>
<td>50.2</td>
</tr>
<tr>
<td>Machinery</td>
<td>-</td>
<td>0.3</td>
<td>0.9</td>
<td>4.9</td>
<td>1.9</td>
<td>6.2</td>
<td>7.6</td>
<td>11.9</td>
<td>14.8</td>
<td>9.1</td>
<td>8.8</td>
</tr>
<tr>
<td>Non-electrical</td>
<td>-</td>
<td>0.2</td>
<td>0.2</td>
<td>1.3</td>
<td>2.8</td>
<td>7.6</td>
<td>8.6</td>
<td>10.2</td>
<td>15.7</td>
<td>25.2</td>
<td>24.3</td>
</tr>
<tr>
<td>Machinery</td>
<td>-</td>
<td>0.2</td>
<td>0.3</td>
<td>3.6</td>
<td>10.3</td>
<td>7.9</td>
<td>10.7</td>
<td>22.0</td>
<td>22.9</td>
<td>39.0</td>
<td>35.6</td>
</tr>
<tr>
<td>Chemicals</td>
<td>-</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>1.2</td>
<td>0.6</td>
<td>0.4</td>
<td>1.0</td>
<td>0.7</td>
<td>1.4</td>
</tr>
<tr>
<td>Iron and Steel</td>
<td>-</td>
<td>1.1</td>
<td>3.1</td>
<td>2.7</td>
<td>4.8</td>
<td>4.0</td>
<td>4.8</td>
<td>6.0</td>
<td>6.1</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>Machinery</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>


(D-263a)
III. GENERAL ENVIRONMENT THAT SUPPORTED RAPID INDUSTRIAL TECHNOLOGY DEVELOPMENT

A. Human Resources

1. The Educational System

3.01 The supply of professional manpower, especially in the field of science and technology, expanded rapidly in the 1950s and 1960s. Science and engineering enrollment increased from around 20,000 in 1955 to 90,000 in 1970. By 1971, Japan was already ahead of West Germany, France and the United Kingdom in the number of engineers and scientists per 1,000 population (1.9 for Japan, 1.4 for West Germany, 1.1 for France and 2.6 for the United States). The rapid expansion of professional manpower also was indicated by the decline in the ratio of starting salaries of university graduates to those of junior high school graduates--declining from 2.63 in 1954 to 1.54 in 1971.

3.02 The rapid expansion of the supply of professional manpower was demand-driven to a substantial degree. The government's plan to increase the number of scientists and engineers was "over-achieved" in the 1950s and 1960s, due to the rapid expansion in enrollment at private universities.

2. Training Supported by Enterprises

3.03 A major characteristic of Japanese vocational training is that it has been supported mainly by enterprises rather than by public vocational institutions, such as in Europe. Training is mostly on-the-job, through frequent rotation, but Japanese enterprises also offer seminars or formal training courses for employees. Some enterprises have established quasi-formal one-year education programs for employees. Many large enterprises finance graduate education abroad or in Japan. Self-learning also is strongly encouraged by enterprises, which provide a bonus to employees who obtain a certificate for such skills as computer programming. Many Japanese researchers obtain doctoral degrees by writing their theses after starting their careers in enterprises.

3.04 The extensive investment in training and education by Japanese enterprises clearly is supported by the unique "lifetime employment" system.

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16/ Science and Technology Agency, White Paper on Science and Technology (1974), Table 2.5.1, p. 327.


16/ Peck and Tamura, ibid., pp. 576-577.
widely adopted in Japan after the war. The ability of enterprises to appropriate investments in training is enhanced if employees work many years in these enterprises. Under this system, enterprises have greater incentives for general and long-term investment in human capital development. The lifetime employment system also enhances flexibility and employee willingness to learn new technologies. Employees are thus less concerned about the negative effect of new technology on their jobs. In fact, Japanese workers do not develop "property rights" to their jobs, as is usual with American, British and European employees.

3. Effect on Technology Development

3.05 The human capital factor (i.e., ample supply of engineers, highly skilled workers, workers' adaptability and trainability) was a major means for rapid technology development in Japanese industry. First, an ample supply of engineers (Table 8) enabled Japanese enterprises quickly to develop commercial products. Empirical studies point out the "cheap" supply of engineers as one of the main sources of the international competitiveness of Japanese industry.

Table 8: Annual Supply of Engineers (International Comparison)

<table>
<thead>
<tr>
<th></th>
<th>Japan</th>
<th>USA</th>
<th>W. Germany</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>0.6</td>
<td>0.4</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Graduates with the Bachelor's Degree in Engineering (thousands)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population (millions)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Indicators of Science and Technology, Science and Technology Agency of Japan, 1986.

11/ A recent empirical study, however, suggests that the average length of a career in an enterprise is not so different in Japan from other countries (Chapter 2 by Tachibana in The Economic Analysis of the Japanese Firms edited by Aoki M., North Holland, 1984). The main distinction is "white-collarization" of the Japanese blue-collar workers (i.e., blue-collar workers enjoy similar employment protection as white-collar workers) according to Koike K ("Human Resource Development," in The Political Economy of Japan, edited by Yamamura K. and Yasuba Y., Stanford, 1987, p. 293). Leibenstein H. emphasizes the existence of the lifetime employment "ideal" in Japan (Inside of the Firm, Harvard, 1987, pp. 203-208) rather than the observed length of career as an actual factor making a difference.

18/ Leibenstein, op. cit., p. 208. A labor union is also organized by enterprises, not by skills, in Japan.
3.06 Second, the high skill levels of Japanese workers enabled enterprises to use new technology effectively. Third, the high propensity of Japanese enterprises to invest in human capital compensated for a limited vocational training system and facilitated the continuous enhancement and restructuring of skills in response to technological and economic changes.

B. Domestic Competition

1. Market Structure

3.07 An empirical study of the Japanese industrial structure suggests that seller concentration in Japan was equivalent to or slightly lower than that of the United States in 1963, even though the size of the Japanese economy was 15% of that of the US in terms of GNP at that time. The weighted average four-firm concentration ratio was 35% for the Japanese manufacturing industry and 41% for the US manufacturing industry (Table 9).

Table 9: INDUSTRIAL CONCENTRATION a/ IN JAPAN AND IN THE USA

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Japan (1963)</th>
<th>USA (1963)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of</td>
<td>Share in</td>
</tr>
<tr>
<td></td>
<td>Industries b/</td>
<td>Shipment</td>
</tr>
<tr>
<td>80-100</td>
<td>46 (9.0)</td>
<td>5.4%</td>
</tr>
<tr>
<td>70-79</td>
<td>21 (4.1)</td>
<td>5.1%</td>
</tr>
<tr>
<td>60-69</td>
<td>29 (5.7)</td>
<td>2.7%</td>
</tr>
<tr>
<td>50-59</td>
<td>61 (11.9)</td>
<td>15.6%</td>
</tr>
<tr>
<td>40-49</td>
<td>56 (10.9)</td>
<td>12.6%</td>
</tr>
<tr>
<td>30-39</td>
<td>63 (12.3)</td>
<td>11.2%</td>
</tr>
<tr>
<td>20-29</td>
<td>79 (15.4)</td>
<td>14.2%</td>
</tr>
<tr>
<td>10-19</td>
<td>157 (30.7)</td>
<td>33.3%</td>
</tr>
<tr>
<td>Total</td>
<td>512 (100.0)</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Simple Average of Concentration 37.5% 38.3%
Weighted Average of Concentration 35.4% 40.9%

a/ Four-firm concentration.
b/ Four digit industrial classification.


20/ Japanese manufacturing is divided into 512 sectors, whereas US manufacturing is divided into 417 sectors. (The US classification is slightly more aggregated, implying a bias for lower concentration ratios in the US.) The weight is value of shipments.
3.08 Seller concentrations in Japan declined substantially due to deconcentration measures taken after the war, with the three-firm concentration ratio declining by 10% (Table 10). The substantial redirection of Japanese industry toward higher capital intensity and increased technological sophistication did not markedly increase the concentration ratio. It continued to decline in the 1950s and early 1960s, although increasing slightly in late 1960s and early 1970s (Table 10). 21/ 

Table 10: DEVELOPMENT IN INDUSTRIAL CONCENTRATION (Indices of concentration ratio over time)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C3 33</td>
<td>100</td>
<td>89.1</td>
<td>85.7</td>
<td>93.5</td>
<td>91.5</td>
<td>100.0</td>
<td>104.0</td>
<td>103.8</td>
</tr>
<tr>
<td>43</td>
<td>100.0</td>
<td>97.8</td>
<td>104.0</td>
<td>103.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>170</td>
<td>100.0</td>
<td>102.9</td>
<td>103.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>163</td>
<td>100.0</td>
<td>102.9</td>
<td>103.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C4 43</td>
<td>100.0</td>
<td>96.4</td>
<td>95.5</td>
<td>100.4</td>
<td>102.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>161</td>
<td>100.0</td>
<td>101.2</td>
<td>101.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C3 = Three firm concentration  
C4 = Four firm concentration


3.09 More detailed investigation of the Japanese market structure also suggests that although many industries in Japan have oligopolistic market structures, the number of industries where a single firm dominates the market (market share of a leading firm exceeding 50%) is very limited.

2. Sources of Domestic Competition

3.10 The major factors supporting a competitive market structure in Japan, which contrast with the concentrated market structure in many developing countries, are: the absence of artificial barriers to entry and growth, the oligopolistic rivalry among business groups, the large size of the domestic market, and an active competition policy implemented immediately after the war.

21/ The most aggregate measure of concentration (the share of 100 largest non-financial firms) continued to decline from 39% in 1964 to 33% in 1970 and to 25% in 1980.
3.11  (a) Absence of artificial barriers to entry and growth. Although the government sometimes intervened in the market to consolidate competition (e.g., entry restriction and promotion of mergers) before the liberalization of imports and direct foreign investment, the intervention was highly selective and largely market conformative. In the 1950s, the government affected the entry of new enterprises by regulating their access to foreign technology in those sectors where economies of scale were considered to play a major role. However, the government’s impact in most cases was limited to delaying entry. The government also promoted mergers and joint business ventures among domestic enterprises in some sectors, such as automobiles and computers, where foreign enterprises were regarded as having overwhelming market power. These efforts by the government were a preparatory step for liberalization in the 1960s and 1970s. Mostly, government intervention was not much more than making recommendations for restructuring. In most sectors there was no actual significant barrier to entry and growth artificially imposed by the government.

3.12  (b) Oligopolistic rivalry among business groups. The business groups of Japan, some with their origins in zaibatsu, compete fiercely among themselves in many business lines. There has been a tendency for these major business groups to establish operations in each major line of business. Although the presence of business groups may have been a barrier preventing entry by independent enterprises, oligopolistic rivalry among existing business groups has prevented the formation of stagnant monopolies.

3.13  (c) Large size of domestic market. The Japanese market in 1950 was already large compared with most developing countries today. The rapidly expanding domestic market supported a competitive structure by allowing entry of new firms, even though imports and direct foreign investment were restricted.

3.14  (d) Active competition policy. Antimonopoly reform measures taken during occupation in the late 1940s generally formed the basis for competitive behavior among existing firms and for entry of new firms in the post-war decades. Family-controlled zaibatsu conglomerates were dissolved, and a number of the largest firms (83 enterprises) were broken up. Cartels and monopolies established during the war were eliminated. An antimonopoly law, which outlawed private monopolization and the establishment of holding companies, among others, was enacted (1947); and many corporate executives (1,535 est.) were expelled from managerial positions. These reform measures reduced market concentration substantially and contributed to the enhancement and preservation of the competitive structure of the Japanese economy. 23/

22/ Such behavior is called "one set principle" in Japan. (Miyazaki Y. Economic Institutions in Post-War Japan (in Japanese), Shinhyoronsha, 1966).

23/ For an example, see Uekusa M., Theory of Industrial Organization, op. cit.
C. Activist Industrial Policy

1. Temporary Protection and Export Promotion

3.15 The Japanese Government provided temporary protection from imports and DFI to allow domestic enterprises opportunities to commercialize imported foreign technology profitably and to develop technological capability at home. Although their financial significance was modest, export promotion measures encouraged enterprises to sell in the international market, partly offsetting the anti-export bias of protection of domestic market and the overvalued yen in the 1950s.

3.16 (a) Temporary import restrictions. Quantitative restrictions administered through the foreign exchange control system played a major role in the 1950s. In 1955, only 16% of foreign exchange was allocated on an automatic approval basis. The primary motivation was the efficient use of scarce foreign exchange. The government administered the foreign exchange budget from 1949 to 1963, with external payments approved by the Government. Imports of an increasing number of goods were granted automatic approval. By 1960, 40% of foreign exchange was allocated through automatic approval.

3.17 The foreign exchange system also played a major role in protecting infant industries by limiting the supply of foreign exchange allocated for imports of competing goods while emphasizing industry import needs.

3.18 In 1960, the Japanese Government issued a general guideline for liberalizing foreign trade and exchange, to improve the balance of payments and to recognize the importance of international competitive pressure on rationalizing enterprises. The guideline aimed at removing all restrictions on foreign exchange transactions related to current accounts and reducing import quotas.

3.19 The share of imports not covered by quotas increased substantially, from 44% in 1960 to 88% in 1962 and 92% in 1963. However, the guideline made it clear that quantitative restrictions on imports competing with infant industries would be removed only at an appropriate future time. Consequently, liberalization of several emerging sectors proceeded in a phased manner after 1963: automobiles (1965), machine tools (1970), color film (1971), integrated circuits (1974), electronic computers (1975).

3.20 Tariff protection played a relatively small role in the 1950s when quantitative restrictions were pervasive but increased from the late 1950s to the early 1960s as quantitative restrictions were rationalized.

---

26/ The yen-dollar exchange rate, set at 360 yen per dollar in 1949, was not adjusted until 1971, although there were clear symptoms of its overvaluation in the 1950s and of its undervaluation in the late 1960s.

22/ Japan became an IMF (Article 8) member in 1964.

26/ Japan accepted Article 11 of the GATT in 1963.
shown the estimated effective rate of protection for Japanese manufacturing industries in 1963, when the tariff levels were close to their peak.\textsuperscript{27} Thereafter, tariff protection was rationalized through a series of initiatives (Kennedy Round, 1967-71; unilateral reductions, 1972, 1976; Tokyo Round, 1980-87) reaching a level comparable to or lower than the other industrialized countries by the middle of the 1970s.

\subsection{3.21} (b) \textbf{Temporary restrictions on direct foreign investment} were liberalized more slowly than import restrictions. Although the Law concerning Foreign Investment (1950) opened up direct foreign investment in Japan, it was administered restrictively. The main concern in the 1950s was the foreign exchange shortage. Through a scheme called "yen-based investment," foreign investments that waived the right to repatriate profits and principal were approved liberally from 1956 to 1964. This permitted the entry of wholly-owned subsidiaries. Nevertheless, foreign investments outside the yen-based scheme were approved restrictively,\textsuperscript{28} so that foreign enterprises could retain only minority ownership.\textsuperscript{28}

\subsection{3.22} When Japan joined the IMF and the OECD in 1964, the yen-based investment scheme was abolished, and yen became a convertible currency. Although the OECD code on the liberalization of capital movement called for liberalization of DFI in Japan, among others, the government chose gradual liberalization (in five steps from 1967 to 1973). The establishment of wholly-owned subsidiaries became liberalized in all industries in 1973, with a small number of exceptions (integrated circuits, 1974, electronic computers, 1975, information processing and photosensitized material processing, 1976). The main concern remained foreign dominance over Japanese industry.

\textsuperscript{27} This calculation is not based on international price comparisons so it does not reflect the effect of remaining quantitative restrictions nor possible "water" in tariff protection.

\textsuperscript{28} The Law concerning Foreign Investment specified two positive criteria: (1) contribution to the development of important industries or public utility enterprises; and (2) contribution to the improvement of the balance of payments—and one negative criterion: adverse effect on the recovery of the Japanese economy.

\textsuperscript{29} There were 573 foreign ventures in Japan in 1964, out of which 289 were yen-based investments; 161 of these were wholly-owned subsidiaries of foreign enterprises. Most yen-based investments were small, probably due to the large foreign exchange risk. See Tsuruta T., \textit{Sengo Nihon no Sanyoo faizaku} (Industrial Policy in the Post-War Japan), 1977, Nihon Keizai Shinbun, pp. 115-120.
Table 11: Effective Rate of Protection and Productivity Growth of the Manufacturing Industry of Japan

<table>
<thead>
<tr>
<th>Industry</th>
<th>1963</th>
<th>1973</th>
<th>Total Factor Productivity Growth (1960-73 Annual Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>32.3</td>
<td>16.4</td>
<td></td>
</tr>
<tr>
<td>Textiles</td>
<td>34.3</td>
<td>18.6</td>
<td></td>
</tr>
<tr>
<td>Spinning</td>
<td>27.1</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td>Fabrics</td>
<td>44.6</td>
<td>15.5</td>
<td>-0.7</td>
</tr>
<tr>
<td>Garments</td>
<td>72.8</td>
<td>22.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Wood Products</td>
<td>14.0</td>
<td>16.1</td>
<td>1.5 (furniture)</td>
</tr>
<tr>
<td>Paper and Pulp</td>
<td>9.7</td>
<td>11.0</td>
<td>1.6</td>
</tr>
<tr>
<td>Publishing and Print</td>
<td>-16.7</td>
<td>-0.9</td>
<td>0.7</td>
</tr>
<tr>
<td>Leather and Rubber</td>
<td>30.9</td>
<td>12.3</td>
<td>1.5 (rubber)</td>
</tr>
<tr>
<td>Chemicals</td>
<td>33.4</td>
<td>8.8</td>
<td>3.6</td>
</tr>
<tr>
<td>Oil and Coal Products</td>
<td>19.5</td>
<td>7.1</td>
<td>-0.2 (petroleum)</td>
</tr>
<tr>
<td>Ceramics</td>
<td>22.2</td>
<td>8.1</td>
<td>2.3</td>
</tr>
<tr>
<td>Steel</td>
<td>30.1</td>
<td>17.1</td>
<td></td>
</tr>
<tr>
<td>Non-ferrous Metals</td>
<td>30.4</td>
<td>22.1</td>
<td>-1.1 (primary metal)</td>
</tr>
<tr>
<td>Metal Products</td>
<td>13.8</td>
<td>9.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Machinery</td>
<td>36.7</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td>General Machinery</td>
<td>23.0</td>
<td>8.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Electrical Machinery</td>
<td>30.9</td>
<td>5.4</td>
<td>3.5</td>
</tr>
<tr>
<td>Transportation Machinery</td>
<td>41.5</td>
<td>9.2</td>
<td>0.2 (motor vehicles)</td>
</tr>
<tr>
<td>Precision Machinery</td>
<td>34.9</td>
<td>10.4</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Note: Calculation is based on tariff, not on the direct price comparison.


3.23 (c) Export Promotion. The government also took various export promotion measures in the 1950s and 1960s, the major incentives being the following.30/

- **Priority allocation of foreign exchange.** Export performance was a main criterion for allocating foreign exchange.

- **Tax incentives.** From 1953 to 1963, income tax could be abated by 1% to 5% of export revenues, and from 1964 to 1971, accelerated depreciation was applicable to investments by export-oriented enterprises. During the same period, enterprises could also establish special reserves for overseas market development. A duty drawback system also was administered.

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Financial incentives. From 1946 to 1972, the Bank of Japan encouraged foreign exchange banks to provide exporters favorable pre- and post-shipment finance (1% to 2% lower than market interest rates) by discounting export bills at below-market interest rates. The Export and Import Bank of Japan was established in 1950 (initially as Japan Export Bank) to facilitate long-term financing for exports.

Export insurance. In 1950, the Government established an export insurance scheme, partly to cover the risks related to export and foreign investment, which were not insurable by private companies.

Others. The Japan External Trade Organization was established in 1954 as a promotional institution. The government also has administered an export inspection scheme to improve the reputation of Japanese goods.

Although no comprehensive assessment is available, the financial significance of these incentives was modest (the combined size of incentives through taxes and short-term financial measures was around 4% of export value).

### 2. Effects on Technology Development

**Potentially positive roles of temporary protection.** A key question is whether protection could have accelerated overall industrial technology development in Japan. Several factors that might have made protection effective, even though it was not the first-best instrument, are the following:

- Fragile financial status of Japanese enterprises after the war. Japanese enterprises derived low profitability using equipment inherited from war time. They also had not developed adequate internal financial resources. The financial system, especially the capital market, was underdeveloped, with equity markets playing a marginal role. Therefore, enterprises might have found it difficult to finance investment and the early learning process.

---


unless protection improved the financial profitability of industrial ventures.\textsuperscript{13/}

- Promoting entry into internationally monopolistic industry. Some industries for which the government granted protection domestically were monopolies controlled by foreign firms globally (e.g., computers and color film). Even though entry is desirable from the national (and possibly global) point of view,\textsuperscript{4/} enterprises could be inclined not to invest since entry in monopoly industries could drive down prices significantly. This economic bias against entry can become serious in technologically progressive monopolistic industries.\textsuperscript{35/} since sunk costs in those industries can be cumulative.

- Advantage of being the first in the investment race. In some industries the fast accumulation of market-specific investments, such as the development of distribution networks and customer relations, are critical in determining a firm's market share. When the speed of such investment is limited by available man-power, for example, temporary restriction on DFI could give the first mover advantage over foreign enterprises in the domestic market.\textsuperscript{36/}

3. Distinguishing factors of the industrial policy of Japan

3.26 A second question is why protective measures did not lead to industrial stagnation and inefficiency, as happened in many developing countries. There are three distinguishing factors in the exercise of industrial policy in Japan:


\textsuperscript{34/} This theoretical possibility was analyzed by Dixit A. K., and Kyle A. S., "The Use of Protection and Subsidies for Entry Promotion and Deterrence," AER, March 1985.

\textsuperscript{35/} Gilbert R. G. and Newberry D. M. G. point out the possible incentive bias favoring an incumbent monopolist to preempt technological opportunities from entrants ("Preemptive Patenting and the Persistence of Monopoly" AER, 1982, Vol. 782). When an entrant can obtain at most part of duopoly profit, even if entry is successful, while an incumbent monopolist can preserve monopoly profit by preemptive R&D and patenting, an incumbent has larger incentive for R&D.

\textsuperscript{36/} This theoretical possibility was analyzed by Matsuyama K. and Itoh M., "Protection Policy in a Dynamic Oligopoly Market," Discussion Paper (University of Tokyo), 1987.
(a) Preservation of fierce domestic competition. As discussed in the last section, Japanese enterprises were extremely competitive in the domestic market. The absence of substantial domestic entry barriers and a fairly large and growing domestic market prevented the formation of stagnant monopolistic enterprise through protection, even though competition from foreign investment and from imports was restricted. (See Table 12 for the share of DFI and imports in the domestic market of Japan.)

Table 12: SHARE OF DIRECT FOREIGN INVESTMENT AND OF IMPORT IN MAJOR INDUSTRIES (1965 AND 1975) (in percentage)

<table>
<thead>
<tr>
<th>Sales Share of Foreign Enterprises a/</th>
<th>Import Share b/</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>1975</td>
</tr>
<tr>
<td>Food</td>
<td>0.6</td>
</tr>
<tr>
<td>Chemical</td>
<td>3.7</td>
</tr>
<tr>
<td>Petroleum products</td>
<td>60.0</td>
</tr>
<tr>
<td>Rubber products</td>
<td>17.7</td>
</tr>
<tr>
<td>Non-ferrous metal</td>
<td>4.8</td>
</tr>
<tr>
<td>General machinery</td>
<td>4.4</td>
</tr>
<tr>
<td>Electrical machinery</td>
<td>2.4</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>2.5</td>
</tr>
<tr>
<td>All industry</td>
<td>1.4</td>
</tr>
</tbody>
</table>

a/ Sales share of foreign enterprise from 12th Survey on Foreign Enterprise, MITI.
b/ Import share from Input and Output Table, Administration Management Agency.

(b) Non-accommodative protection. Protection was considered temporary, especially after the government issued a general guideline for liberalization in 1960. Although the timing of the liberalization was contingent on the development of international competitiveness in each industry to a certain degree, liberalization of imports and of DFI was regarded as inevitable by each industrial enterprise—protection was far from being accommodative as is the case of many developing countries today. This
expectation of liberalization induced enterprises to invest heavily in the improvement of technology and to gain international competitiveness.37/

(c) Basic dependence on market initiatives and disciplines. It was rare that the government made direct investments in industrial projects when it was dissatisfied with the market. The basic approach of the government was to support initiatives by private enterprises while preserving their autonomy and accountability. The conflict between the regulatory and ownership functions of the government, often observed in many developing countries, did not occur in Japan.

(D-263a)

37/ One executive of the Japanese automobile company, recalling the rush for investment from the late 1950s to the early 1960s—the production capacity of this company increased by 10 times from 1956-1966—stated that "our company developed production and marketing plans which positioned our company in the international economy, under the recognition that liberalization of imports was inevitable. The countermeasures for liberalization converged eventually in competition among domestic producers for investment and for strengthening the mass production system (rather than in the consolidation of industry recommended by the government), [car imports were liberalized in 1965]." Recalling the fierce marketing competition that started in the early 1960s, he also stated, "The Japanese automobile industry entered into the period of super aggressive competition for marketing. The domestic car makers competed fiercely for market shares among themselves. There was common recognition among the Japanese automobile producers that liberalization of direct foreign investment would follow the liberalization of imports, and such expectation contributed to the highly aggressive nature of competition." From Morikawa H., Testimony for the Japanese Industrial History in the Post-War Era-II, (in Japanese), Mainichi Shinbun, pp. 41-42.
IV. IMPORT OF FOREIGN TECHNOLOGY AND ITS MASTERY

A. General Trends

4.01 Technology imports have played a critical role in the development of Japanese industrial technology. For example, in sectors such as steel and automobiles, which had existed as major industries before the Second World War, Japanese enterprises used foreign technology quickly to narrow the technology gap that had developed during the years of war and economic disruptions. Many new industries were established (petrochemicals and electronics), based on the rapid importation and adaptation of foreign technology.

4.02 As Tables 13 and 14 show, technology importation increased rapidly in number of contracts and cost in the 1950s and 1960s, although the ratio of external payment for technology to the total import bill was modest, amounting to 0.5% in 1953 and 1.8% in 1960. Figure 2 in Appendix 2 shows how quickly the Japanese chemical industry commercialized new technologies in succession. After the first world oil crisis, growth in technology assistance contracts was slow. The ratio of technology imports to private research and development investment declined to around 10% by the 1980s from more than 20% in the early 1960s.

Table 13: GROWTH IN EXPENDITURES FOR TECHNOLOGY IMPORT AND R&D INVESTMENT

<table>
<thead>
<tr>
<th>Period</th>
<th>Average Annual Growth Rate (%)</th>
<th>Technology Import</th>
<th>R&amp;D Investment</th>
<th>Private R&amp;D Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954-58</td>
<td>29.6</td>
<td>21.0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>1960-64</td>
<td>21.4</td>
<td>21.2</td>
<td>23%</td>
<td></td>
</tr>
<tr>
<td>1965-69</td>
<td>19.0</td>
<td>21.6</td>
<td>23%</td>
<td></td>
</tr>
<tr>
<td>1970-74</td>
<td>9.8</td>
<td>20.8</td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td>1975-79</td>
<td>6.2</td>
<td>11.0</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>1980-82</td>
<td>17.7</td>
<td>15.0</td>
<td>11%</td>
<td></td>
</tr>
</tbody>
</table>

a/ Average annual growth rate of the nominal expenditure for each time period.

b/ Ratio of expenditures.

### Table 14: NUMBER AND GROWTH OF TECHNOLOGY IMPORT

<table>
<thead>
<tr>
<th>Class A a/</th>
<th>Class B b/</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual Average</strong></td>
<td><strong>Annual Average</strong></td>
</tr>
<tr>
<td>Number</td>
<td>Growth Rate</td>
</tr>
<tr>
<td>1950-54</td>
<td>454</td>
</tr>
<tr>
<td>1955-59</td>
<td>575</td>
</tr>
<tr>
<td>1960-64</td>
<td>2,039</td>
</tr>
<tr>
<td>1965-69</td>
<td>3,926</td>
</tr>
<tr>
<td>1970-74</td>
<td>8,295</td>
</tr>
<tr>
<td>1975-80</td>
<td>7,846</td>
</tr>
</tbody>
</table>

a/ Technological assistance contract with the terms of contract or terms of payment equal to or more than one year.

b/ Technological assistance contract with both the terms of contract and the terms of payment less than one year.


#### 4.03 Effects of technology imports

Although difficult to evaluate the effect of technology imports quantitatively, most capital- and knowledge-intensive industries in Japan owe a substantial part of their technological foundation to foreign technology. According to one estimate, the proportion of industrial production and of industrial export directly due to technology licensing was 5.3% and 8.1%, respectively, in 1955. However, the same numbers were higher for the electrical machinery industry (31% and 24%, respectively). Perhaps more importantly, technology imports have provided opportunities for domestic enterprises to enhance their technological capabilities. Upgraded technological capabilities have in turn enabled these enterprises to import or develop technologies with higher sophistication. Many Japanese enterprises have successfully built up their highly competitive technological capabilities today through this process.

#### 4.04 The benefit of technology importation is enhanced when complemented by domestic R&D

One illustrative case in Japan is the introduction of the liquid oxygen process in steelmaking in the late 1950s, one of the most

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38/ One econometric estimation relating the change in TFP to R&D investment and technology imports showed the rate of return on technology imports was extremely high, although the statistical reliability of the estimated equation is low (Wakasugi R., 1986, op. cit., Chapter 8).

significant technologies introduced into the Japanese steel industry in the post-war decades. The Japanese steel industry had undertaken substantial R&D on that process, including experimentation on existing furnaces, before deciding to purchase the technology from an Austrian firm.\textsuperscript{40} The Japanese also improved the technology substantially in terms of processing time, effective utilization of discharged gas, and development of new furnace material. The adapted process was exported later.\textsuperscript{41} Domestic R&D efforts not only help enterprises "unbundle" foreign technology and identify the technology components most efficient for importation but also enhance the utility of imported technology. Japanese R&D was already fairly active in the 1960s. The ratio of non-military R&D expenditure to GNP was 1.3% in 1962, compared with 1.1% in France, 1.5% in West Germany and 1.6% in the United States.\textsuperscript{42} From 1957 to 1962, one-third of R&D expenditure by major Japanese enterprises was for modifying and improving foreign technology.\textsuperscript{43}

4.05 Costs of technology importation. The cost of foreign technology was substantial for importing enterprises. From 1949 to 1960, the average royalty payment for Class A technology agreement was 4.6% of sales, decreasing to 4.1% in 1963, and increasing to 5.3% in 1971.\textsuperscript{44} It was common for enterprises to pay royalties of 8% or more, and the median life of technical agreements was as long as 10 years.\textsuperscript{45}

4.06 Restrictions on the use of technology and, thus, on exports were extensive. About 60% of the technical agreements in 1962 had export restrictions, increasing to 76% by 1971 \textsuperscript{46} (Table 1 in the Statistical Appendix). For example, all four major technical assistance contracts between the Japanese and foreign automobile producers between 1952 and 1953 had restrictions on exports (i.e., complete prohibition of exports for two Japanese producers; prohibition of exports, with the possibility of negotiation, for one; and restriction of exports to the Eastern hemisphere for one).

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\textsuperscript{40/} See Peck and Tamura, op. cit., p. 557

\textsuperscript{41/} See a statement by an executive of a steel company, in Morikawa H., "Testimony for the Japanese Industrial History in the Post-War Era - II." op. cit., pp. 78-79.


\textsuperscript{43/} Ozawa T., 1974, op. cit., p. 69 (based on the survey by MITI conducted in 1962).


\textsuperscript{45/} Ibid.

\textsuperscript{46/} Ibid.
4.07 Causes of active technology import. Why then were the Japanese enterprises so active in technology import? A number of factors were responsible: high technological capability as illustrated in the above case of the liquid oxygen process, rapid economic growth itself, competitive pressures from domestic rivalry and government policies encouraging technology import. Among these factors technological capability is most fundamental since the commercial success of technology import is impossible without the capability to effectively utilize the technology in production system.

B. Government Measures

4.08 Here we concentrate our discussions on the four measures which seems to have affected technology import substantially. We do not discuss education and training system nor import restrictions, the effects of which on technology development were discussed in the last chapter.

1. Regulation of the Importation of Foreign Technology

4.09 All technological assistance contracts with foreign enterprises had to be approved in principle by the government. Until full-scale liberalization in 1968, "Class A" contracts with the terms of contract or the terms of payment exceeding one year had to be approved by the government under the framework of the Law concerning Foreign Investment. Similarly, the rest of technological assistance contracts (short term or "Class B" contracts) had to be approved under the requirements of the Foreign Exchange and Foreign Trade Control Law. Restrictions were liberalized only in steps. In 1950, the government announced a "positive list" (34 desired technologies, largely for improving efficiency in existing enterprises). Major liberalization took place in 1961 (shift to a negative list), 1963 (liberalization of technology importation up to US$30,000), and 1968 (full-scale liberalization with a few exceptions).

4.10 Objectives. Basic motivation for government intervention was to cope efficiently with the shortage of foreign exchange. The government's regulation of foreign technology importing was part of the extensive foreign exchange control system adopted in the 1950s. However, the concern clearly was not limited to the foreign exchange required for importing technology. The broad criteria set by the Law concerning Foreign Investment were:

- contribution to the development of "important" and public utility industries, and
- contribution to the improvement of the international balance of payments.

The law also dealt with the fairness of technology contracts and adverse effects on the national economy's recovery.

4.11 Effects of regulation. Government regulations affected the amount of technology imported, domestic R&D, the industrial structure, industrial organization, and the price of foreign technology.
4.12 **Effect on the amount of technology imported and on domestic R&D.**
The net effect on technology imports is not clear, since the regulation played two conflicting roles: to restrict technology imports deemed not urgent but to promote technology imports by securing rationed foreign exchange. In 1964, 4.6% of applications were rejected and 4.7% were left pending.47/ The restrictive policy may have discriminated against technology importation by small non-established firms.48/ However, the restrictive effect was limited mainly to delaying the timing of technology imports, since in any event there was successive liberalization of the policy. Although one of MITI's approval criteria was the possible effect on the development of indigenous technology, it is reported that in most cases this criterion did not receive much weight.49/ Therefore, the protective effect on domestic R&D was also unlikely to have been substantial.

4.13 **Effect on the structure of industries.** Since technology importation was closely associated with investments, especially in the 1950s, regulation of technology imports also affected allocation of investment resources. The regulations gave priority to industries with high potential for foreign exchange earnings or savings and to basic industries (heavy and chemical industries) producing intermediate goods and capital goods. This suppressed the demand for consumer-goods technology.50/ Therefore, the regulation tilted the investment pattern toward the trade sector, especially toward basic industries, although this effect could not have been permanent given the liberalization of the regulation in the 1960s.

4.14 **Effect on industrial organization.** Since the regulation was applied at the level of specific enterprises, not at the sector level, it affected industrial organization within sectors. It put priority on importing by enterprises with high technological capacity and discouraged duplicate imports. The objective in controlling duplicate technology was to use imported technology effectively, first in the construction of plants of efficient scale, and second, in avoiding excess capacity.51/ The government

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48/ One executive of a now giant electronics firm recalls the initial difficulty he had in persuading the government to approve the import of technology for transistor circuit in 1953, when his company was still a small venture (Morita A., *Made in Japan*, 1986, E.P. DUTTON, pp. 65-66).


was also concerned with ensuring competition in the domestic market so it allowed sequential entries of additional firms.\(^{52/}\)

4.15 The effect on industrial organization could have been permanent if incumbent firms had pre-empted the market. However, the government allowed new entries even in the petrochemical sector,\(^{53/}\) where concern over excessive entries was serious and the regulation of technology imports played the most critical role for regulating investment. Therefore, it is not likely that the regulation on technology import substantially shifted industrial organization in the direction of increased concentration.

4.16 **Effect on the price of technology.** The government's regulation reduced the price of technology by reducing competition among Japanese enterprises in an oligopolistic bargaining process. The government also delayed its approval or made it conditional on revisions of agreements that would become favorable to Japanese enterprises.\(^{54/}\) One notable example of coordinated technology importation involved the introduction of the liquid oxygen process in steel making. Four competing steel producers in Japan introduced the technology through one producer under the guidance of the government.\(^{55/}\) Such intervention was not systematic, since cases of competitive technology importation also are reported.\(^{56/}\)

4.17 The government's attempt to reduce market restrictions was not successful, however, as seen from the high proportion of technology agreements that included export restrictions (Table 1 in Statistical Appendix).

**Analysis and Lessons from the Regulation of Technology Importation**

4.18 **Facilitation of Technology Importation.** One important function of the regulation was to secure and guarantee long-term foreign exchange payment for imported technology. Within the constraint of fixed parity, the regulation appears to have functioned well in financing the expanding technology inflow without causing disruption in spite of the overall shortage of foreign exchange in the 1950s.

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\(^{52/}\) Ibid.

\(^{53/}\) Ibid., p. 554-557.


\(^{55/}\) Ibid.

\(^{56/}\) It is reported that three major chemical companies competitively introduced technology for polypropylene from a single foreign company (Morikawa H., op. cit., pp. 112-113).
4.19  Upgrading the industrial structure. Although the regulation on technology imports was only one of the policy instruments used for promoting the development of basic industries (heavy and chemical industries), the regulation itself was a blunt instrument with some side effects. It could not stop domestic enterprises from investing in consumer goods industries, based on domestically available technology, and it might prevent enterprises from saving resources through the use of new technology.

4.20  Preventing excessive entry. Temporary or even permanent restrictions on firms' entry can increase economic efficiency through the effect on the larger scale of production, the quicker learning-by-doing process and the economization on entry costs, including royalty payments. However, government intervention for this purpose requires highly detailed information on technology and the nature of competition; implementation of entry restrictions is not easy. Further, consideration of the optimal domestic industrial organization becomes largely irrelevant when the economy is integrated with the world economy, except for international oligopolistic industries. Competition will induce domestic enterprises to select an adequate scale of operation as well as adequate speed of learning. In the case of Japan, the necessity for government intervention in industrial organization arose partly due to the utilization of protection as a tool of industrial policy.

4.21  Improving terms of contracts. The government's coordination of the cooperative importation of technology clearly improves the terms of contracts. A caveat is that it might also facilitate collusive restriction of investments by domestic enterprises unless competition is encouraged explicitly.

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37/ Some scholars argue that industrial structure target itself lacked adequate justification (e.g., Komiya R., "Introduction," in Industrial Policy of Japan, Komiya R. et al., op cit.). He argues that industries which meet the two criteria set by the government (i.e., high income elasticity and fast technological progress) would develop by themselves.

38/ The other instruments include protection, tax credit and soft loan.

39/ For example, it can be readily shown that free entry equilibrium can have too many enterprises in the Cournot-Nash competition. (Schmalensee R., "Is More Competition Necessarily Good?" Industrial Organization Review, 1976, Vol. 4). It can also be shown that productivity growth of smaller less efficient enterprises can reduce the national welfare in the Cournot-Nash competition.

60/ Some scholars, however, argue that the tendency of "excessive" competition in the Japanese economy was a result of industrial policy pursued in early years itself, since it offered insurance against recession and tended to allocate premium resources (e.g., foreign exchange) according to market share (e.g., Imai K., et al., Price Theory, (in Japanese), Vol. 3, Iwanami, 1972, p. 254).
4.22 The direct involvement of the Japanese government in the contract negotiation process per se may not have been effective—as the high proportion of export restrictions in the contracts shows—since the government by itself does not affect the alternatives or opportunities available to technology buyers and sellers. The restrictions on DFI change alternatives available to technology sellers, however. (Section B-3 discusses Japan’s experience.)

2. Fiscal Incentives for the Introduction of New Technology

4.23 Objectives and measures. The Government introduced various fiscal incentives for encouraging the introduction of new technology and/or new products. Table 15 lists major fiscal incentives (tax and tariff abatement and special depreciation) that were effective in the 1950s and 1960s. These measures are classified into two groups: measures, such as accelerated depreciation of important machinery, that encouraged industrial investment broadly (introduced in the early 1950s); and measures, such as income tax exemptions for commercializing new products, which were targeted more to new products or processes.

4.24 The estimated size of these fiscal incentives as a percentage of corporate taxes is not large. In Table 15, the sum of the first three tax and tariff measures is estimated at only 4.2% of corporate taxes in 1955 (Table 2 in Statistical Appendix). The sum of the first four measures of accelerated depreciation is estimated at 2.6% of corporate taxes in 1958. The importance of broad-based investment incentives declined sharply in the early 1960s.

4.25 Effects. Some econometric studies suggest that in the 1950s fiscal incentives were fairly effective in raising the level of private investment. 61/ It is reported that the accelerated depreciation scheme helped enterprises not only by increasing their rate of return from investment but also by reducing credit risks for banks. Targeted measures, such as tax exemptions for commercializing new products, also played an important role in developing new industries. 62/ In their infant stages, such sectors as synthetic fibers, synthetic rubber, fertilizer, petrochemicals and antibiotics benefited substantially from this scheme.

4.26 Analysis and lessons. Since much technology was introduced in Japan in already embodied form (i.e., new machinery) in the 1950s, and many enterprises did not have easy access to financial resources due to their financial fragility, broad fiscal incentives for modernizing capital stocks seem to have been important in promoting the introduction of new technology from abroad. At a later stage, incentives became more narrowly focused on research and development and its commercialization.

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61/ Peckman J.S. and Kaizuka K. quote two such studies in the chapter on taxation in Asia’s New Giant, op. cit., p. 368.

### Table 15: FISCAL INCENTIVES FOR INTRODUCTION OF NEW TECHNOLOGY

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Fiscal Credit Granted</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. Abatement of Tax and Tariff</strong></td>
<td></td>
</tr>
<tr>
<td>A. Income tax exemption for commercializing new important products (1923-66).</td>
<td>Tax on the income generated from the production of new products designated by the government was fully exempted for about four years.(^a)</td>
</tr>
<tr>
<td>B. Reduction of the withholding tax on external payment associated with important technical licensing (1953-67).</td>
<td>The withholding tax was reduced by 10% (later 15%).</td>
</tr>
<tr>
<td>C. Import duty exemption for importing important machinery (1951-65).</td>
<td>Imported duties on machinery designated by the government were exempted. The eligible machinery were (1) raw or highly efficient industrial machinery, (2) machinery difficult to be manufactured in Japan, and (3) machinery necessary for industrial development.(^b)</td>
</tr>
<tr>
<td>D. Income tax credit for the increase in expenditures for research and development (1966-present).</td>
<td>(^c) If a firm's annual, R&amp;D expenditure exceeded the peak amount in previous years, 25% of the excess was allowed as a tax credit.(^c) The credit was raised to 50% for the portion of the excess alone 15% of the amount spent in the previous peak year. The credit has been limited to 10% of the corporation income tax.</td>
</tr>
<tr>
<td><strong>II. Accelerated Depreciation (^d)</strong></td>
<td></td>
</tr>
<tr>
<td>A. Important machinery (1951-61).</td>
<td>50X additional depreciation for the first three years, relative to the ordinary depreciation schedule.</td>
</tr>
<tr>
<td>B. Machinery for rationalization (1952- ).</td>
<td>50X depreciation in the first year.</td>
</tr>
<tr>
<td>C. Machinery for testing and research (1958-1963)</td>
<td>50X, 20X and 20X depreciations for the first, second and third year respectively.</td>
</tr>
<tr>
<td>D. Machinery for commercializing new technology (1950-1965).</td>
<td>50X depreciation for the first year</td>
</tr>
<tr>
<td>E. Equipment produced for the first time in Japan (1964 to 19____).</td>
<td>One third depreciation for the first year</td>
</tr>
<tr>
<td>F. Machinery for the modernization of small and medium size industry (1963 to 19____).</td>
<td>One third additional depreciation for the first three years.</td>
</tr>
</tbody>
</table>

\(^a\) Before the revision of 1957, this scheme was used to be applied not only to the commercialization of new products but also to the production of such products as minerals and coal.  
\(^b\) The major revision took place in 1960. The scheme was transformed to serving the prevention of industrial pollution, etc., from earning industrial development.  
\(^c\) Currently 20% of the excess can be counted as a tax credit.  
\(^d\) Right hand column describes incentives applicable from 1958-60. Major curtailing took place in 1961, with some incentives integrated in the statutory schedule of depreciation.  

**Sources:**  
Wakasugi R., op cit., Chapter 12.  

(D-263b)
Given adequate access to capital markets, broad-based investment incentives are a blunt measure for encouraging the introduction of new technology. The size of investment does not necessarily denote significant technology, and enterprises with adequate financial resources may be encouraged to undertake inefficient investment because of the incentives. Therefore, the shift to a narrow focus was appropriate.

3. Effects of the Restrictive Policy on Direct Foreign Investment

Small role of direct foreign investment. Japan offers a unique example of industrial development where DFI played a very limited role. This was partly because the Japanese economy was not regarded as an attractive investment just after war and also because the government had instituted its restrictive policies.

Effects on technology development. Restrictive policies on DFI had two opposing effects on technology development in Japan. Such policies, on the one hand, retard technology development, leading to the loss of the opportunity to introduce new and more efficient technology through foreign investment. Technical licensing is an imperfect substitute because technology exporters generally are less willing to supply technology without management control. They tend to attach restrictive conditions on the use of technology (i.e., on exports) even if they license the technology.

However, in Japan, the cost of restriction on DFI does not seem to have been large. Domestic enterprises were able to acquire technology in an unbundled manner and to improve and develop it, thus enabling the rapid growth of output and exports in most major industries. Indirect evidence for this is that DFI in Japan has not increased substantially since the 1970s, even after full liberalization. However, the cost of restriction would have been larger without Japan's strong post-war technological and entrepreneurial ability.

On the other hand, the restriction on DFI promoted technology licensing and protected domestic technology development. In some cases it gave the Japanese government bargaining power in obtaining concessions in technology licensing. One exceptional case is the government's intervention for the licensing of integrated circuit technology by Texas Instruments. Texas Instruments was seeking permission to establish a wholly-owned subsidiary in Japan but agreed to establish a joint venture instead and to grant licenses to four Japanese enterprises.62

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62/ Quoted in Peck H. and Tamura S., "Technology," op. cit., p. 552. The economic benefits could have outweighed the economic cost in this particular case. On the cost side were two elements: the royalty fee paid by the Japanese firms, and the delayed use (four years) of more efficient semi-conductor technology in Japan. The application for investment was filed in 1964, and the matter was not resolved until 1968. On the economic benefit side were three elements: more competitive supply of integrated circuits, transfer of part of the rent to the Japanese producers, and possible technological spillover to other products.
4.32 **Analysis and Lessons.** The limited cost of the restrictive policy on DFI in Japan seems to have depended largely on the following factors: first, the level of technological capability of Japanese enterprises was already high in the 1950s. Second, enterprises in developed countries, especially the US, were more willing to sell technology in the 1950s for several reasons (e.g., technologically dominant position of the US enterprises, low expectation of competition from the Japanese enterprises, etc.).

4.33 The selective restriction on foreign investment in Japan was a complement to the import restrictions to protect infant industry. A liberal foreign investment regime, coupled with infant industry protection, would have encouraged investment simply to avoid import restrictions. This could have pre-empted opportunities for domestic enterprises to develop technological capability by dominating the market in some industries and would have transferred rents (due to protection) abroad. Thus, a very important characteristic of the liberalization process of Japan was that import liberalization preceded or took place simultaneously with liberalization of DFI.

4.34 Using the DFI restriction for increased access to foreign technology can easily backfire. The host country can lose both technology and investment. Even with access to foreign technology, there is no guarantee that domestic enterprises can yield profits high enough to pay royalty fees, and the fees may put firms at a disadvantage in competition with foreign firms.

4. **Intermediation by Public Research Institutions and Universities**

4.35 **Role of intermediation.** Foreign technology can be introduced at various stages of technology development: at the purely scientific stage, the developed but commercially unestablished stage, and the commercially viable stage. The more developed a country's R&D capability, the more technology is imported at earlier stages of that development. Public research institutions and universities can potentially import technology at the earlier stages of development, undertake necessary further developments and transfer the developed technology widely to industrial enterprises. This intermediation plays an important role in quickly exploiting new technological opportunities, when the R&D capability of industrial enterprises is still underdeveloped.

4.36 **The intermediation process in Japan.** Most notably in electronics, public institutions such as the Electrotechnical Laboratory (ETL) of MITI, the

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66/ Some of these reasons were discussed by Ozawa, "Japan's Technological Challenge to the West," op. cit., pp. 25-30.

65/ Assuming that temporary import restriction is the only available measure for infant industry development and is welfare-improving, the combination of different import and foreign investment regimes would be the following: restricted import and foreign investment --> free trade and restricted foreign investment --> free trade and free foreign investment --> restricted import and free foreign investment.
research laboratory of NTT, and the University of Tokyo played a key role in advancing the commercial application of new electronics technology. As an example, ETL played a major role in introducing electronics technology through its development of transistor-based computers and its development of semiconductors.\(^{66}\)

- ETL successfully developed the prototype of a transistor-based computer in Japan in 1956.\(^{67}\) Based on this, it provided technical guidance to several Japanese companies in their efforts to develop transistor-based computers commercially. The contribution of ETL was not limited to the transfer of basic design concepts but included the transfer of design and engineering know-how.

- ETL, which closely followed the early progress of the US research and discovery of semiconductors in 1947, undertook development of various semiconductor devices in the 1950s and was successful in developing the prototype of integrated circuits in Japan in 1959. ETL accepted a number of engineers from private enterprises as trainees—200 trainees in the transistor research office alone. These engineers subsequently led the development of the semiconductor business in many enterprises.

4.38 Analysis and lessons. A public research institution potentially can play a useful technology support role even in a country where the basic mission is to absorb foreign technology. Capable public research institutions accelerate the introduction of foreign technology that is still at the commercially unproven stage but which has substantial potential for wide industrial application.

4.39 It is not necessarily efficient to confine such institutions' roles to basic research, especially in developing countries. They can undertake development research—which private enterprises cannot, either because of low appropriability or because of fragmented R&D capability in the private sector—and can disseminate the developed technology to enterprises, to the national advantage. The important point is the complementary use of technological resources.

4.40 There is a caveat though. Once private industry has developed its own R&D capability, it is generally a waste of resources for public research institutions and universities to continue extensive development work. ETL, for example, withdrew largely from prototype development in industrial technology and reoriented itself to more basic research in the late 1960s, when industrial enterprises enhanced significantly their own R&D capability.

\(^{66}\) The following cases are based on Matsuo H., *Electrotechnical Laboratory, (in Japanese)*, 1987, Computer Age Corp., and interviews with a planning official of ETL.

\(^{67}\) It was the third in the world, following Bell Laboratory and IBM. It was the first as a stored-program transistor-based computer in the world.
V. DIFFUSION OF TECHNOLOGY

A. Strong Viability of Small and Medium Enterprises

5.01 Another major characteristic of post-war technology development in Japan has been its rapid diffusion, especially to small and medium enterprises. Although a substantial gap in productivity and wages still exists between large enterprises and small and medium enterprises, the latter have kept up with rapid technological advances and thus have maintained their importance in the national economy. The share of enterprises with fewer than 300 employees was 74% of total manufacturing employment in 1957; it was 74% again in 1981. Moreover, small and medium enterprises have recorded a level of profitability similar to large enterprises. Profits per total asset for small and medium enterprises were 3.9% on average from 1971 to 1981 and 3.3% for large enterprises.

B. Subcontracting System

5.02 The subcontracting system works as an important mechanism of technology transfer. In Japan, 65% of small and medium enterprises produce under subcontracting arrangements, and 82% of them are specialized in subcontract production. The subcontracting system is most extensive in the machinery and textile sectors. In the transportation machinery sector, 81% of small and medium enterprises were subcontractors in 1981, and 88% of them are

68/ In 1986, the average wage of manufacturing enterprises with 30-90 employees was 65% of that of manufacturing enterprises with more than 500 employees (Table 3 in the Statistical Appendix). The value-added per employee of manufacturing enterprises with 20-99 employees is 49% of that of manufacturing enterprises with 300 or more employees. The longer-term statistics suggest that although the wage gap expanded in the early 1950s, it narrowed substantially by the early 1960s and has been more or less stable ever since (Figure 3 in the Appendix 2). It is generally recognized that the Japanese economy shifted from a labor surplus economy to labor shortage economy around 1960 (see Minami, 1981, ibid.).

69/ The Small and Medium Enterprise Agency of MITI, Basic Survey on Industry. A small and medium enterprise, which produces 80% or more output under subcontracting, is defined as a firm specialized in production for subcontracting. The percentages in the text are in terms of number of establishments and are based on a 1981 survey.
specialized in subcontracting.\textsuperscript{70/} Subcontracting is extensive in Japan due to less extensive vertical integration.\textsuperscript{71/}

5.03 Subcontracting involves long-term comprehensive and implicit contracts, which can involve technical guidance, supply of working capital, leasing of equipment, and risk sharing by a parent firm. The system also provides strong incentives and pressures for a subcontractor to innovate (see Appendix 3 for a typical transactional arrangement). A parent firm typically takes charge of developing design and specifications and provides necessary technical assistance to subcontractors.\textsuperscript{72/} A subcontractor undertakes production according to instructions. Since many subcontracting firms have high technical capabilities, a parent firm's inspection procedure for delivered components may be nonexistent. Japan substantially owes its strong international competitiveness in the machinery sector to the high efficiency of its subcontractors.

5.04 Conflicting views on the efficiency of the subcontracting system exist, however. Some claim that its only advantage is of second best nature, as a palliative to distortions in the economy's factor prices and retirement system.\textsuperscript{73/} A subcontractor is regarded to be viable only in a segmented labor market. This view also emphasizes the possible distortion from the monopoly power of a parent firm.\textsuperscript{74/} Accordingly, as distortions in the economy are eliminated, the subcontracting system should be replaced either by vertical integration by a parent firm, or by development of independent large-scale component producers.

5.05 A more recent alternative view,\textsuperscript{75/} however, is that the subcontracting system has potential efficiency advantages over vertical integration or purely market-based transaction schemes. Since subcontractors are independent economic entities subject to competition among themselves (Appendix III), they have stronger incentives for innovation and efficiency than do vertically

\textsuperscript{70/} The subcontracting system in the machinery sector is multi-layered. It is reported that one automobile producer has 168 primary subcontractors, 4,700 secondary subcontractors and 31,600 tertiary subcontractors (Quoted by Yokokura T., "Small and Medium Enterprises," in Industrial Policy of Japan, op. cit., p. 458).

\textsuperscript{71/} The difference in the degree of vertical integration is very clear in the comparison of the Japanese automobile industry with the American industry.

\textsuperscript{72/} A subcontractor with high technical capability develops design and specifications of components for approval by a parent firm.

\textsuperscript{73/} Caves and Uzuka, Industrial Organization, 1976, op. cit.

\textsuperscript{74/} A law was enacted in 1956 aimed at preventing unfair business practice by a parent firm such as unfairly delaying payment.

\textsuperscript{75/} Masahiko Aoki, "Innovative Response Through Quasi Tree Structure" (in Japanese), Contemporary Economics, 1984 summer.
integrated production units. Moreover, subcontractors can also depend on technological input from a parent firm and can share technological information more closely among themselves, to avoid duplication and make up for the lack of coordination in technological efforts, unlike the case of purely independent firms.

5.06 Although not conclusive, the following propositions may be drawn:

- The persistence of the subcontracting system may well reflect the efficiency of such organizational arrangements. In particular, the subcontracting system often may be more efficient in technology diffusion than vertical integration, due to strong competitive pressure among subcontractors and the higher appropriability of such innovation for subcontractors.

- Competition among parent companies has led to the increasing efficiency of the subcontracting network in terms of organizational structure, such as the development of subcontractors with advanced and specialized technology, integrated inventory control systems, and also sophistication of the contractual relationship.

C. National Development of a Quality Control System

History and Promotional Efforts 76/

5.07 Japanese enterprises have attained an excellent reputation as producers of high quality products. This was not the case just after the war.77/ when Japanese producers were known more for cheap low-quality products.

5.08 One of the major contributing factors for this rapid and dramatic improvement of quality was the national development of a quality control system, which took place mostly from 1950 to 1965. A survey conducted by the Japanese Government in 1969 showed that: (a) the percentage of factories preparing for the introduction of statistical quality control was 5% from 1945 to 1949; 20% from 1950 to 1954; 24% from 1955 to 1959; and 33% from 1960 to 1965; (b) by 1969, 91% of surveyed factories practiced statistical quality control; (c) 85% of factories introduced quality control voluntarily rather than in response to outside requests; (d) 54% of factories had completed the development of enterprise standards. (See Appendix III for the details of the

76/ This part is based on Industrial Standard in Japan - 20 Year History, 1969, MITI (in Japanese).

77/ The occupation authority found that many products produced in Japan did not meet the standard of the United States. For an example, finding that communication equipments produced in Japan had frequent troubles, the occupation authority sponsored a seminar on statistical quality control for the Japanese manufacturers of communication equipment and demonstrated its implementation in one Japanese factory.
This survey shows that the quality control system had progressed rapidly in the 1950s and early 1960s and was extensive by 1969.

5.09 In 1945, two non-profit organizations promoting quality control were established: the Japanese Standards Association and the Union of Japanese Scientists and Engineers. They have played a major role through reports and journals, research activities, seminars, lectures and conferences, and technical consultation. Other promotional associations, such as the Japan Productivity Center, the Japan Management Association, and the Operations Research Society of Japan also have contributed to the spread of modern management methods among Japanese enterprises.

5.10 In 1949, the Industrial Standardization Law was enacted, establishing the legal framework for developing the industrial standard system and for administering the certification system linked to the standard. (National standardization activities had started in 1921.) The certification system apparently encouraged enterprises to adopt quality control systems, as evident in the above survey. The government started the scheme of prize grants to the best certified factories in 1953 and provided technical assistance to enterprises planning to introduce standards. The government also strengthened its export inspection scheme in 1955 to improve international reputation of the quality of Japanese exports.

5.11 Direct contact with foreign experts in the late 1940s and early 1950s also had a significant influence on the spread of the quality control system. In particular, the seminars by Dr. W.E. Deming conducted at various places in Japan around 1950 aroused great interest among Japanese industrialists. A study group on quality control traveled to the US in 1958, one of many study groups organized by the Japan Productivity Center.

5.12 Television and radio courses on quality control in 1956 and 1957 contributed to its spread, especially among small and medium enterprises. Increased consumer awareness of quality (from around 1960) also encouraged the

---

78/ There existed two predecessor organizations promoting the utilization of industrial standards before this time.

79/ An enterprise is authorized to attach a special certification mark on its products, pending on the government's examination of its factories.

80/ Among those factories which introduced quality control system, 30% mentioned preparation for the application for the JIS (Japan Industrial Standard) certification as one of the motivations.

81/ Later a prize named after Dr. Deming was created to commend a factory which achieved substantial accomplishments in the practice of quality control system.

82/ From 1955 to 1961, the Japan Productivity Center sent about 2,500 persons to the United States under the US government's economic assistance program.
trend. The Japan Consumers Association, established in 1961, started monitoring and testing the quality of consumer products.

**Extensive Adoption of the Quality Control System**

5.13 Quality control in Japan is carried out with the participation of shopfloor workers formed as quality control circles within an enterprise (Tables 16 and 17)—it is not a responsibility limited to a group of professional engineers. Workers follow the standard set by the professional engineers but also study and suggest possible sources of improvement in products and production processes and implement necessary measures. Although the concept of Total Quality Control (TQC), which emphasizes the managerial or organizational approach to quality control, was first advocated by a US scholar, it has been implemented much more effectively in Japan than in the USA. The causes for the extensive development of the quality control system in Japan seem to be:

(a) the high level of education of Japanese workers;

(b) the Japanese management style, leaving greater managerial autonomy to factories, which thus encourages innovation and improvement at the shopfloor level;

(c) fierce competition for quality, especially in the consumer goods market; and

(d) nationwide promotional efforts, including the administration of the Japan Industrial Standard.

**Table 16: Percentage of Workers in Establishments With QC-Circle Activities, by Size of Firm and Existence of Trade Unions, 1977 (percent)**

<table>
<thead>
<tr>
<th>Number of Employees in Firm</th>
<th>Total</th>
<th>With Trade Unions</th>
<th>Without Trade Unions</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,000 and over</td>
<td>77.2</td>
<td>77.4</td>
<td>67.3</td>
</tr>
<tr>
<td>1,000-4,999</td>
<td>58.5</td>
<td>59.1</td>
<td>53.6</td>
</tr>
<tr>
<td>300-999</td>
<td>42.9</td>
<td>43.9</td>
<td>39.1</td>
</tr>
<tr>
<td>100-299</td>
<td>33.3</td>
<td>34.6</td>
<td>31.7</td>
</tr>
</tbody>
</table>

Table 17: ASSESSMENT OF QC-CIRCLES BY MANAGEMENT
BY SIZE OF FIRMS, 1977
(percent)

<table>
<thead>
<tr>
<th>Number of Employees in Firm</th>
<th>Successful</th>
<th>Not Successful</th>
<th>In Between</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,000 and over</td>
<td>83.4</td>
<td>7.6</td>
<td>8.6</td>
<td>0.4</td>
</tr>
<tr>
<td>1,000-4,999</td>
<td>67.2</td>
<td>15.9</td>
<td>16.4</td>
<td>0.5</td>
</tr>
<tr>
<td>300-999</td>
<td>32.7</td>
<td>28.2</td>
<td>18.9</td>
<td>0.2</td>
</tr>
<tr>
<td>100-299</td>
<td>45.3</td>
<td>37.6</td>
<td>15.6</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Source: Same as Table 16.

D. Policies and Institutions Supporting Technology Diffusion to Small and Medium Enterprises

5.14 The Japanese government has developed comprehensive policies and institutions supporting small and medium enterprises (SME), covering:

(1) financial assistance (e.g., the establishment of specialized financial institutions, small business investment companies and a credit guarantee system);

(2) tax abatement (e.g., lower corporate income taxes, accelerated depreciation);

(3) assistance for technology development (see below and Appendix IV);

(4) provision of consultation and guidance, information and training (see below and Appendix V);

(5) assistance for infrastructure development and for joint business arrangements (e.g., industrial estates, joint facilities);

(6) establishment of the legal framework for the formation of associations (including possible formation of rationalization and recession cartels); and

(7) establishment of the legal framework protecting SMEs against large enterprises (e.g., against delays in payment to subcontractors).

5.15 The thrusts of SME policies have shifted over time. Until the mid-1950s the major objective was to stabilize the distressed financial situation of SMEs, many of which faced severe constraints in borrowing and
competition among themselves. Later the main objective was to promote modernization of SMEs, especially through modernization of equipment and consolidation of enterprises (expansion of the scale of business). By the 1970s, the major focus had shifted to the promotion of smooth adjustment of SMEs to the appreciation of the yen and increased competition from developing countries, as well as to the promotion of "knowledge" intensification.

3.16 Assistance for capital formation and for expansion of the business scale through financial and tax measures may have played a more important role in raising the efficiency and technological level of SMEs during the second period than measures specifically targeted to technology acquisition. Many SMEs still faced borrowing constraints, as reflected in capital-cost differences (at least 50%) between large enterprises and SMEs. The size of these differences is not readily explainable by transaction costs, as is the case in the USA.

Measures for Technology Diffusion

5.17 Measures promoting technology diffusion are classified into four areas: provision of information on new technology, subsidization of the commercialization of new technology, provision of training to enhance absorptive capacity, and promotion of adaptive research and development.

5.18 Information. Japan's prefectural governments play a major role in administering information programs. Regional research and testing institutions funded by the prefectural governments provide technical guidance and testing services, organize lectures and training courses, and disseminate information on new technology through publications for SMEs (see Appendix V for an example of the services provided by the Tokyo Metropolitan Industrial Technology Center).

5.19 Although no overall assessment of the technology diffusion activities of regional testing and research institutions exists, there are

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84/ The Small and Medium Enterprise Basic Law enacted in 1965 defined the objectives of the SME policies: (a) rectify the disadvantages faced by SMEs due to economic and social constraints, (b) support self-help of SMEs, and (c) enhance productivity and transactional conditions.


86/ There exist 184 regional research and testing institutions in industry and mining, across 47 prefectures, many of which (around 40%) were established before the war.
reports on successful cases and their characteristics.\textsuperscript{87} For example, the testing institution for dyeing and weaving, established in Aichi Prefecture in 1925, played an important role in diffusing new dyeing and weaving technology to local industry, although the major role was played by weaving machine dealers. Another case involved the testing and research institution established in 1959 at Hamamatsu, which contributed substantially to the diffusion of precision machining technology and quality control among the local components industry. In both cases, research institutions were established in response to the strong demand from local industry.\textsuperscript{88} The research conducted at the institutions was highly practical, closely focusing on tasks of direct interest to the factories.

5.20 In addition to information activities of testing and research institutions, prefectural governments administer programs for technical assistance through a technology exchange forum. These services are used by local SMEs on request.\textsuperscript{89} They also sponsor meetings among SMEs from different business sectors to create opportunities for active technology transfer and exchange.

5.21 **Subsidization of the commercialization of new technologies.** In addition to the measures specifically applicable to SMEs, fiscal and financial incentives mentioned in Table 15 all apply to SMEs. In particular, the government developed equipment modernization and business consolidation programs in many subsectors of SME and promoted their implementation through broad incentives in the 1960s.\textsuperscript{90} In recent years, the incentives became more focused on the adoption of new technologies, R&D, training, etc.

5.22 **Promotion of adaptive research and development.** National and regional research institutions and the Small and Medium Business Corporation have undertaken generic R&D, which SMEs cannot tackle adequately. Since 1955


\textsuperscript{88} Kobayashi T. reports as follows: A textile trade association in Aichi prefecture petitioned the prefectural government to establish a testing institution for dyeing and weaving in 1925 by offering contribution of land, a factory and some funds. Similarly, enterprises in Hamamatsu area petitioned for the prefectural government to establish a testing and research institution in 1959. SMEs belonging to a metal association, together with large enterprises and Hamamatsu city authority, shouldered four ninths of the total cost. The rest were paid by the government.

\textsuperscript{89} SMEs are charged only a relatively small fee for their access to most of these services. The rest of the cost are born by the national and local government (Appendix V).

\textsuperscript{90} Yokokura T. reports, however, that no major differences were observed between subsectors supported by modernization programs and the other subsectors in terms of labor productivity and capital labor ratio (Yokokura, op. cit., 46).
the government has provided subsidies selectively to R&D projects of SMEs.91/ The government also provides financial assistance to the commercialization of new technology through "soft" loans from the Small and Medium Business Finance Corporation and through partial credit guarantees.

5.23 Training. Local government in Japan administer various training programs for SME engineers and tech

Finance Corporation administers supplementary training programs and provides training for the staff of local research and testing institutions.

E. Analysis and Lessons

5.25 The Japanese industrial market has strong internal forces for diffusing technology, due to high degree of competition. Suppliers of equipments under competitive pressures do not hold back their efforts to market new products as widely and quickly as possible. Enterprises in competitive markets do not fail to recognize the advancement of technology introduced by their competitors and try to imitate it.

2.26 Subcontractors or subsidiaries prevalent in organizing industrial production in Japan are decentralized units, subject to strong competitive pressures. Rapid technology diffusion depends critically on the efforts of these decentralized units for higher efficiency.

5.27 No doubt the high absorptive capacity of Japanese enterprises is another major factor in technology diffusion. As for government intervention, the most effective diffusion policies may well be the provision of training and educational opportunities.

5.28 The government's promotional and information policies also can play a useful role to accelerate the diffusion process of technologies, since there exist some constraints on the market mechanism.92/ However, their success depends on how closely their services are in line with industrial needs. In notable success cases of regional research and testing institutions.

91/ Enterprises, in turn, are obliged to present the research results at an official seminar, in order to promote their dissemination. Enterprises also are obliged to pay back the subsidy, contingent on the contribution of R&D (in the case of prototype development) to their profits.

92/ There exist several constraints on purely market based technology diffusions. Since there exists externality in the reputation concerning quality, enterprises may wish to have a free ride on the reputation established by other enterprises. In fact some regional research and testing institutions in Japan originate from the testing centers established by local cooperatives to internalize reputational externality at a local industry level (see Kobayashi, op. cit., pp. 199-203). Other constraints include externality due to imitation and monopolistic undersupply of information.
in Japan, industries took the initiative for their establishment and were influential in deciding the services these institutions would provide. The industrial standard system encouraged enterprises to adopt quality control system, only because its certification had credibility.

5.29 Successful diffusion requires adaptive R&D, but the appropriability of adaptive R&D can be low in some technology areas for SMEs. This is because of the large number of imitators and competitors and the smaller possibility for patent protection. The provision of incentives for this type of R&D, even at the development stage, could be useful.

(D-263a)
VI. RESEARCH AND DEVELOPMENT

A. Domestic R&D Efforts

Japanese R&D grew rapidly for most of the post-war era. Its real expenditure maintained high real annual growth: 16% from 1955-1965, 8.8% from 1965-1975 and 7.3% from 1975-1985 (see Table 4 in the Statistical Appendix). The growth of the number of scientists and engineers, real research expenditures, and the ratio of R&D expenditure to GNP exceeded those of other major industrial countries from the mid-1960s to the early 1980s (Table 18). Consequently, Japanese R&D intensity compares favorably with any major industrial country in terms of the ratio of R&D expenditure to GNP and the ratio of researchers to population (Table 19).

Table 18: Growth in National R&D Efforts (Annual Growth Rate) (percent)

<table>
<thead>
<tr>
<th>Scientists and Engineers a/ (1966-81)</th>
<th>5.9</th>
<th>4.7</th>
<th>3.4</th>
<th>2.8</th>
<th>1.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Research Expenditure a/ (1965-85)</td>
<td>7.6</td>
<td>6.3</td>
<td>3.2</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>R&amp;D Expenditure/GNP b/ (1965-85)</td>
<td>3.2</td>
<td>2.8</td>
<td>2.3</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>


b/ Science and Technology Agency (Japan), Indicators of Science and Technology, 1986. The growth rate of France is from 1965 to 1982.
Table 19: R&D INTENSITY OF NATIONAL ECONOMY

<table>
<thead>
<tr>
<th></th>
<th>Japan a/</th>
<th>West Germany</th>
<th>USA</th>
<th>France</th>
</tr>
</thead>
</table>

a/ The research expenditure of Japan is overstated due to the inclusion of the salaries of all faculty of Japanese universities as R&D expenditure. However, its effect is estimated to be around 10% (see Peak M. and Tamura S., op. cit., pp. 558-559).

Source: Science and Technology Agency (Japan), "Indicators of Science and Technology." 1986.

6.02 Table 20 shows that for 1984 Japan was ranked second, after the United States, in terms of patents granted and was third in receipts for technology exports. The proportion of the Japanese applications in the total patent applications in the USA increased from only 0.2% in 1955 to 16.6% in 1984 (see Table 5 in the Statistical Appendix). Quantitative assessment of R&D performance is difficult but tends to show a high return on R&D. The rapid development of Japan's R&D capability has been a major support for the successful importation of technology and for continuing industrial success after the era of rapid technology importation ended. It enabled Japanese

92/ The number of patents granted is likely to overstate the technological output of Japan, partly because patent application is very active in Japan (the rejection rate is about 50% for Japanese applications and 25% for American applications in their national patent offices). (See Okimoto D.I. and Saxonhouse R., "Technology and the Future of the Economy," in The Political Economy of Japan, Vol. I, edited by Yamamura K. and Yasuba K., 1987, Stanford University.)

enterprises not only to improve the efficiency of established industries but also to add new industries continuously.

Table 20: SOME OUTPUT MEASURE OF R&D

<table>
<thead>
<tr>
<th>Japan</th>
<th>USA</th>
<th>UK</th>
<th>Germany</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patents Granted to National Scientists and Engineers in 1984 a/ (1,000)</td>
<td>81 (11)</td>
<td>94 (38)</td>
<td>16 (2)</td>
<td>46 (6)</td>
</tr>
<tr>
<td>Receipt for Technology Export in 1984 b/ (b yen)</td>
<td>165</td>
<td>1,930</td>
<td>205</td>
<td>123</td>
</tr>
</tbody>
</table>

b/ Science and Technology Agency (Japan), 1986, op. cit.
c/ The numbers in brackets are patents granted by the US Patent Office.

6.03 Much of the increased R&D effort by Japanese industry has been funded and implemented by the private industry--67% in 1969, both funded and performed (compared to 38% and 70% respectively for the US). These ratios increased to 82% and 77% respectively by 1985.64/

6.04 Further, increased national R&D effort has been supported by the growing number of enterprises performing R&D--increasing by 50% from 1965 to 1985. Japanese firms with under 1,000 employees accounted for 14.6% of all R&D expenditures in 1985.65/ although this ratio has been declining. The corresponding number for the US is 4.1%.66/

3. R&D Policies

1. Fiscal and Financial Incentives

6.05 The government has taken various measures in order to promote and complement R&D efforts by industry: tax incentives (Table 15) and conditional and soft loan (Table 22 for an explanation of the scheme). Counting government research contracts as subsidies, the ratio of total fiscal and financial

95/ Indicators of Science and Technology, op. cit., p. 68.
96/ Quoted by Okimoto and Saxonhouse, op. cit., p. 398.
incentives to the sum total of R&D expenditures and payment for technology imports has been relatively small (Table 21). From 1957 to 1980, the peak annual ratio was 14% (1958), and the bottom ratio was 1.5% (1966).

Table 21: RATIO OF INCENTIVES TO THE SUM OF R&D EXPENDITURE AND EXPENDITURE FOR TECHNOLOGY IMPORT

<table>
<thead>
<tr>
<th>Year</th>
<th>Conditional Loan &amp; Research Contract</th>
<th>Tax Incentive</th>
<th>Soft Loan b/</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957-60</td>
<td>0.7</td>
<td>7.3</td>
<td>0</td>
<td>8.0</td>
</tr>
<tr>
<td>1961-64</td>
<td>0.3</td>
<td>5.4</td>
<td>0</td>
<td>5.8</td>
</tr>
<tr>
<td>1965-68</td>
<td>0.9</td>
<td>2.5</td>
<td>0</td>
<td>3.4</td>
</tr>
<tr>
<td>1969-72</td>
<td>1.5</td>
<td>1.7</td>
<td>0</td>
<td>3.3</td>
</tr>
<tr>
<td>1973-76</td>
<td>1.5</td>
<td>1.5</td>
<td>0</td>
<td>3.1</td>
</tr>
<tr>
<td>1977-80</td>
<td>1.2</td>
<td>1.1</td>
<td>0</td>
<td>2.4</td>
</tr>
</tbody>
</table>

a/ Repayment obligation of conditional loans is not taken into account, so that this table is an overstatement of the subsidy.

b/ Includes only the soft loans provided by the Japan Development Bank. The incentive component is calculated as a difference between the prime lending rate and the interest charged by the Bank.


6.06 Tax incentives. Japanese tax credits for incremental R&D expenditure apply broadly to R&D activities without favoring particular technology or phase. Although this tax incentive is generally regarded as a clever scheme to reduce the marginal cost of R&D substantially without incurring a large fiscal burden, doubt has been expressed about whether they have been a factor for rapid expansion of R&D. First, the net present value of the tax credit is not large, even if a tax credit is fully applied, since greater...

27/ It is said that the R&D tax credit in Japan served as a model for the US tax credit system introduced under the Economic Recovery Act of 1981. (Okimoto and Saxonhouse, 1987, op. cit.).

28/ Peck M. and Tamura S., "Technology," op. cit., p. 569. Mansfield (1986) reports that R&D tax incentives in the United States, Canada and Sweden, which are similar to that of Japan, are estimated to have increased R&D expenditures by only about 1%, based on a survey of firms. (Mansfield E., "The R&D Tax Credit and Other Technology Policy Issues," May 1986, AER, PP. 190-1983).
Table 22: MAJOR INCENTIVE SCHEMES FOR R&D: CONDITIONAL LOAN, FINANCIAL ASSISTANCE AND GOVERNMENT-Sponsored R&D IN 1960s AND 1970s

<table>
<thead>
<tr>
<th>Incentive Scheme</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Conditional Loan</strong></td>
<td>Fiscal support granted (around 50% of R&amp;D cost) must be repaid, depending on the profit generated by the technology or on the success of the development project. Patents or any other research results belong to enterprises.</td>
</tr>
<tr>
<td>a. Important technology in industry and mining (1950- ).</td>
<td>Eligible R&amp;D projects are chosen out of applications from industry on the competitive basis, according to criteria set by the government.</td>
</tr>
<tr>
<td>b. Technology improvement for SMEs (1967- ).</td>
<td>The same scheme but eligibility restricted to small and medium enterprises.</td>
</tr>
<tr>
<td>c. Computer development (1972- ).</td>
<td>Targeted support for the development of computer and aircraft industry.</td>
</tr>
<tr>
<td>d. Aircraft development (1968- ).</td>
<td></td>
</tr>
<tr>
<td><strong>2. Financial Incentive</strong></td>
<td>Below market interest rate loan to cover around 50% of project cost (financing period up to 15 years).</td>
</tr>
<tr>
<td>a. Loan by the Japan Development Bank (1951- ).</td>
<td>Soft loan is provided to the commercialization of new technology, development of heavy machinery, and commercialization of new machinery.</td>
</tr>
<tr>
<td>b. Loan by Small and Medium Business Finance Corporation (1970- ).</td>
<td>Soft loan is provided to the commercialization of new technology and to the prototype development of new machinery.</td>
</tr>
<tr>
<td><strong>3. Government-Sponsored R&amp;D</strong></td>
<td>The patents originated from research usually belong to the government and are available to any enterprise (i.e., nonexclusively), including a participating enterprise.</td>
</tr>
<tr>
<td>a. Large-Scale project (1966- ).</td>
<td>The government identifies R&amp;D projects, which cannot be undertaken by private enterprises in spite of high social return, and sponsors their implementation (16 completed projects and 7 ongoing projects in 1987).</td>
</tr>
</tbody>
</table>

Brochure of Agency of Industrial Science and Technology, AIST of MITI, *op. cit.*

(D-263d)
expenditure in one year will reduce the tax credit the next year by setting a higher base for that year. If a firm renues its record of R&D expenditure every year, the net present value of the tax credit for incremental R&D is:

\[
\frac{1}{20\% \left(1 - \frac{1}{1+i}\right)} = \frac{1}{i+1}
\]

assuming that the real interest rate \(i\) is 5\%. Existing tax incentives reduce the marginal cost of R&D only by a very modest percentage. Second, a tax incentive does not give a further incentive to firms that plan to devote a steady level of resources to R&D, nor to those with small or no income tax liability relative to R&D spending. It also tends to disfavor R&D-intensive enterprises, since there is a limit on the tax credit (10\% of income tax).

6.07 **Financial incentives for R&D.** Conditional loans for the development of important technology in industry and mining had a substantial incentive effect on R&D in its infant stage. R&D projects supported by this type of loan accounted for 15\% to 40\% of total expenditures for industrial R&D in the 1950s. This type of loan's importance in terms of a general incentive for R&D declined sharply in the 1960s, however.

6.08 In the 1970s, conditional loans targeted to the development of strategic technology for computers and aircraft were important. Notable examples in the computer industry included development of "3.5"-generation computers (from 1972-76) and large-scale integrated circuits (VLSI) (from 1976-79). The first support program was launched in response to the crisis of the Japanese computer industry, which faced the withdrawal of foreign partners from the computer industry due to the dominating success of IBM's system 370 and the liberalization of the domestic market scheduled in 1975. National R&D expenditure on information technology tripled from 1971 to 1976, helped partly by targeted support from the government. The second computer support program was launched in response to the challenge of the "future system" that IBM was said to have started developing. Government support covered 40\% of total R&D expenditure for developing the process

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99/ See Table 15 for an explanation of the R&D tax credit in Japan. 20\% of incremental R&D can be deducted from income tax.


technology of VLSI. Support in these two areas is generally judged highly successful in developing the competitive technology of the Japanese computer industry.

6.09 **Financial incentives for commercialization.** Total incentives provided through financial schemes were not large, although Table 21 somewhat underestimates this. Its calculations do not account for any risk premium. Loans provided by the Japan Development Bank focused mainly on the commercialization stage of new technology. Before 1985, no other official financial scheme directly supported R&D. R&D was largely financed by private enterprises through earnings and by borrowing long-term working capital from commercial banks. In 1985, the Japanese Government established the Japan Key Technology Center with private industry. This provides capital investment and loans, with interest contingent on the success of R&D in fundamental technologies. Japan Development Bank loans also were expanded to cover the construction of special infrastructure for basic research.

2. **Government-Sponsored R&D Schemes**

6.10 The government started the national R&D program in 1966 to strengthen domestic R&D capability. This program was launched in preparation for foreign investment liberalization, scheduled in the late 1960s. Under the program, the government identifies projects, based on close consultation with industry, universities and national laboratories, and implements projects based on research contracts with private enterprises and complementary research by national laboratories and universities. Participating companies often further benefit from a three-year, non-exclusive, discounted royalty, or reduced license fee, for patents resulting from projects. In 1987 sixteen projects had been completed and eight were in progress.

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104/ For example, Flamm, op. cit., Imai (1987), op. cit., Wakasugi (1986), op. cit.

105/ Peck M. and Tamura S., "Technology," op. cit., pp. 568-569. According to them, the selection criteria are: (a) high social return, (b) inability of private enterprises to undertake projects because of large investment, long term gestation period, absence of profit motives, high risk and so on, (c) projects should utilize technologies that can be clearly specified; extensive basic research should not be required, and (d) projects should be carried out cooperatively by universities, government laboratories and industry.

106/ Completed projects include the development of an earlier generation of large-scale computer, an electric car, water desalination system, pattern information processing, FMS laser, and C chemical technology. Peck M. and Tamura S., ibid. Participating enterprises often shoulder part of the cost (Wakasugi R. (1986), op. cit., p. 130).
6.11 Despite no overall assessment at this stage, it is safe to say that just as conditional loans private initiatives have been strongly reflected in the selection of R&D projects.\(^{107}\) Given the close link with industry, government-sponsored R&D did not cause serious inefficiency due to the detachment from market needs, although the focus on basic areas of R&D might have been weak.\(^{108}\)

3. **Research Associations**

6.12 The law on research associations (1961), to give legal status to cooperative research organizations,\(^{109}\) had as its main motive the efficient use of limited R&D resources. From 1961 to 1983, seventy one research associations were established. The government took a leading role in their establishment, since research associations often have been used as implementing organizations for government-assisted R&D projects. For example, the large-scale conditional loans in the computer industry were provided to three competitive research associations for development of the 3.5-generation computer, and to one research association for the VLSI. The government also provides general incentives for the formation of research associations by allowing participating enterprises to write off their association dues, by allowing research associations accelerated depreciation of their fixed assets, and by applying reduced property taxes and registration taxes on the assets. Research associations are dissolved when specific research tasks are accomplished.

6.13 Research associations have two advantages.\(^{110}\) First, they act as a forum where researchers share information and cooperate for the development of new technology. This is particularly important in Japan where researchers' mobility is limited due to the lifetime employment system. Second, research associations promote research in generic or basic areas, where individual firm's appropriability is limited.

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109/ The following descriptions are based on Research Association in Mining and Industry (in Japanese), AIST, MITI.

6.14 To combat the possible anti-competitive effect of cooperative research,\textsuperscript{111/}\textsuperscript{112/} credible competition from imports was effective, (e.g., from IBM in the case of research cooperation). Also, since cooperation through research associations covers only specific research tasks and is dissolved afterwards, and since such tasks focus on generic areas, competitive R&D for actual product development is unhindered. A research cooperative has no legal authority in limiting competing R&D nor R&D done by non-member enterprises.

4. **National Research Laboratories**

6.15 These have played an important complementary role for private R&D although they utilize a modest part of R&D resources (Table 23), 3% of R&D expenditure and 2% of researchers.

<table>
<thead>
<tr>
<th>Table 23: PRIVATE VS. PUBLIC UTILIZATION OF R&amp;D RESOURCES</th>
<th>Private Organization</th>
<th>Public Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing Enterprise</td>
<td>Research Institutes g/</td>
<td>National Corporation</td>
</tr>
<tr>
<td>R&amp;D Expenditures (b yen) 1985</td>
<td>9,544</td>
<td>270</td>
</tr>
<tr>
<td>Researchers 1986</td>
<td>239,792</td>
<td>4,512</td>
</tr>
<tr>
<td>g/ Includes only resources for science and engineering fields.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source: Science and Technology Agency, Indicators of Science and Technology.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.16 The national research laboratories and public research cooperatives\textsuperscript{113/} have served five objectives: basic research not undertaken by universities; applied research involving large-scale research equipment; technology transfer; research that private industry cannot adequately undertake (e.g., pollution issues); and research for the establishment of standards, testing methods and norms.\textsuperscript{114/}

\textsuperscript{111/} Sharing R&D reduces the incentive for each enterprise to undertake R&D, possibly leading to the decline in industry-wide R&D. Cooperation in R&D can also be utilized as a collusive mechanism to restrict industry-wide R&D. The incentive for using cooperative research agreements as a mechanism to restrict R&D becomes stronger when product market competition among members is intense. (Se Katz M.L., "An Analysis of Cooperative Research and Development," Rand Journal of Economics, Winter (1986)). One famous case is the US anti-trust suit against cooperative R&D among US automakers for fuel emission control.


\textsuperscript{113/} Public corporations have been established to undertake large-scale science based R&D (e.g., atomic energy, space and energy).

6.17 National research laboratories also have promoted private R&D. They have provided basic technological information in the planning stages of private R&D. With MITI, they have played a leadership role for cooperative R&D. In addition, they have contributed to the assessment of private R&D assisted by the government. They have also transferred the skills related to R&D to private enterprises by accepting researchers as trainees.

6.18 A special characteristic of Japanese national research laboratories is that they have been able to maintain close links with industry for the following reasons:

- Much interaction between researchers in national laboratories and in enterprises through seminars, trainee systems, etc.
- Schemes such as government-sponsored R&D projects to provide opportunities for interaction between national laboratories and industry; and
- National research laboratories maintaining their technological leadership.

5. Patent System

6.19 Japan has a long history of patent protection and now exhibits very active patenting activities. One special feature of the patent system is the protection of a utility model. In recent years, more than 40% of the world patent applications have been filed by the Japanese (closer to 30% if we exclude utility models).

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115/ Ibid.
116/ The first regulation for patent was established in 1885 and Japan acceded to the Paris Convention in 1899, accepting applications by foreigners.
117/ The legislation took place in 1905, using the German system as a model. Protection of shorter duration (10 years) is granted to a utility model (15 years for patent). West Germany, Japan, Italy and Spain are major countries that protect utility models.
118/ The number of patents applied for worldwide in 1984 was 1,107-thousand, of which 487-thousand (58% patent and 42% utility model) were in Japan; 9% of patent applications in Japan were made by foreigners.
6.20 The well-established patent system has apparently encouraged R&D efforts. Besides its positive impact on the appropriability of R&D, it has provided a mechanism of evaluating and recognizing the technological efforts of workers by the patent experts. In particular, many Japanese enterprises have a special incentive system encouraging employees to create inventions and make suggestions for improving efficiency. The patent system has provided a useful criterion for implementing such system. Protection of less-innovative inventions by utility model has widened the participation in inventing activities in Japan.

C. Analysis and Lessons

6.21 The government support to R&D has played only a modest role in the rapid growth of Japanese industry's R&D capability. The Japanese industry has upgraded its technological capability through the process of assimilating foreign technology. Increasing production efficiency due to the sophistication of the skills of production workers has allowed the Japanese enterprises to successfully commercialize new technologies (see Appendix VI for interaction between production efficiency and R&D.) A narrowing technology gap with the rest of the developed countries and increased competition from newly industrialized countries have also pressured Japanese enterprises to invest heavily in R&D.

6.22 Government intervention played a limited but useful role through:

- General fiscal and financial incentives for R&D. Tax credits based on incremental R&D expenditure could be more effective, if the base amount is fixed or linked to the average industrial R&D instead of being linked to the R&D of the enterprise in question.

- Adequately targeted fiscal and financial incentives. These can be far more efficient than general R&D incentives in improving the national R&D performance, since the market tends to overinvest in

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119/ The quantitative assessment of its impact is difficult. Based on a survey of empirical evidence in other developed countries, Stoneman (1987) concludes however that in most industries patents are not considered of vital importance (except in pharmaceuticals) and that other means of protecting returns are available, although patents might be important for major innovations (Stoneman, P., The Economic Analysis of Technology Policy, Oxford, 1987, p. 114).


121/ As proposed by Mansfield (1986). "The R&D Credit and Other Technology Policy Issues," op. cit. The US government is currently considering the modification of its tax code to make the tax credit for R&D permanent.
patentable or easy-to-conceal technology, and underinvest in basic or generic technology. Successful cases of government assistance in Japan demonstrate potential usefulness of such an approach in developing countries. 122/

- Cooperative R&D through research associations. Design and management of cooperative R&D often requires effective and credible leadership by the government, since cooperative R&D inherently involves a "free-rider" problem.

- Close link between industry and national research laboratories. They have provided basic information for the planning of private R&D, a leadership role for cooperative R&D and assessment of government-assisted R&D. They have also transferred R&D skills to private enterprises through trainee system. Government funded research programs in Japan has explicitly promoted such interaction.

- Patent protection. This plays an important role in cultivating the inventiveness among enterprises and people by providing a mechanism for evaluating and recognizing their inventions. The protection of utility model may be a useful approach for developing countries.

(D263a)

122/ Nelson L.R. and Winter S.J. (1982) point out the information constraint as a major constraint on the effective design of government support for industrial R&D. The reason is that an enterprise in rivalry does not want to disclose information necessary for designing effective government program, if such program can also benefit its competitors. The government could end up supporting inefficient projects. (See An Evolutionary Model of Economic Change, Harvard, pp. 383-395.) This problem seems to have been less severe in Japan at least in its catching-up process, since competition with a dominant foreign enterprise was often more important than competition among domestic enterprises, cooperative R&D mainly focused on generic and basic area, which could be identified by partly utilizing the experience of foreign countries, and the Government could play a role of effective and credible agent among participating enterprises.
VII. CONCLUSION

A. Summary of Major Lessons

7.01 The first potential lesson from Japan’s experience with industrial technology development is the importance of a strong and flexible education system. The remarkable expansion of science and engineering manpower in Japan has been one of the critical factors enabling the rapid technological absorption by Japanese enterprises as well as the rapid growth of their R&D capability. The conscious government effort to expand science and engineering education, as well as the strong response of the private educational system to the increasing demand for technical manpower from industry, have enabled such expansion. In many developing countries the education and training system is still weak and nonresponsive to market forces.

7.02 The second potential lesson is the importance of a competitive environment. In Japan, although some sectors were heavily protected from imports and DFIs, there has been active domestic competition and protection from imports and DFIs have been temporary and non-accommodative of inefficiencies. Active competitive forces have generated strong pressures for technology import, technology diffusion and R&D. Competition has dictated the choice of technology to be imported and to be developed. The main role of government and public research institutions has not been to target particular commercial applications of technologies and to force them on enterprises but rather to expand the scope of technological opportunities available for enterprises. Initiatives for commercialization have been left to enterprises.

7.03 The third potential lesson is the importance of a broad-based approach to industrial technology development. There exists a high degree of complementarity between technology import, R&D and efficient production system. In the case of Japan active technology import, active R&D and efficient production system have been strongly reinforcing each other. One of the major strengths of the Japanese industrial system is high technological capability of the workers in factories of large enterprises as well as in small and medium enterprises. Their high technological capability has allowed profitable utilization of new technologies and thus in turn has enabled the Japanese enterprises to actively develop and import new technologies. In this sense, technology development in Japan has not been engineered by a limited number of high-technology firms nor by a small group of engineers in research laboratories of large enterprises. It owes much to the widening technology base of the economy, extensively involving small and medium enterprises as well as production workers. Technology policies and institutions have also facilitated this process through broad based measures, such as the strong education system, the extensive technology support network for small and medium enterprises, the development of standards and their dissemination, and the introduction of patent protection for utility models.

7.04 Potential lessons in each area of technology policies are the following:
(a) Technology import. The Japanese experience suggests that due to the monopolistic nature of technology markets, the government can potentially improve the efficiency of technology import by limiting competition among domestic enterprises for foreign technology and by restricting DFI. However, since such policies involve complicated tradeoffs, they do not have general validity. The regulations of Japan themselves were flexible and became liberalized. The sequencing of liberalization in Japan (liberalization of DFI preceded by the liberalization of trade) made a good economic sense, compared with the reverse sequencing in many countries. On the promotional side the Japanese experience shows that public research institutions and universities can potentially help domestic enterprises quickly assimilate new technology opportunities by complementing their weak R&D capabilities.

(b) Diffusion of technology. The extensive information and promotional policies developed in Japan seem to have contributed to the rapid diffusion of technologies across the economy, although its contribution is likely to have been modest. The Japanese experience confirms that the success of these policies depends on how much closely their services are in line with industrial needs, in turn on the participation of industries in designing services and on the credible technological leadership of the government institutions.

(c) Research and development. The Japanese experience shows that industries have strong internal forces to upgrade R&D capability, given the competitive environment and strong and flexible technical education system. The Japanese experience also suggests that the government can potentially improve the national R&D performance by both general and targeted policy interventions, given the tendency of the market for overinvestment in proprietary technology and for underinvestment in basic or generic technology. As for a general policy intervention, the introduction of patent protection of utility model could be a useful approach for developing countries. In Japan it has stimulated the participation of a wide class of enterprises and individuals in inventions not only by improving the appropriability of their technological efforts but also by providing a system of evaluation and recognition. As for a targeted policy intervention, a scheme of cooperative R&D through research associations could be a useful model for developing countries too, although targeted interventions require a credible technological leadership of the government institutions.

B. Research Agenda

7.06 Impact of protection on technology development. Although protection is generally inefficient, liberalization by itself does not guarantee the ideal (first-best) outcome. This is because there is a theoretical possibility that selective protection can accelerate the national performance of technology development through its potentially favorable effects on improving the financial fragility of emerging enterprises, overcoming pecuniary externalities in internationally oligopolistic industries, and securing the "first mover" advantage, etc. Detailed investigation of the Japanese experience might offer insight regarding the importance of these considerations as well as the characteristics of the first-best intervention.
7.07 **Contributions of industrial organization and Japanese management.** The Japanese economy has a distinctive industrial organization system and management style. Rapid technology diffusion owes much to these institutional mechanisms, although not designed explicitly by the government. These mechanisms have recently attracted renewed attention from researchers due to their viability, but further evaluation of their efficiency and their relevance to developing countries would be useful.

(D263a-WP)
### Table 1: Market Restrictions Imposed on the Japanese Partners of Technology Agreements

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>No market restriction (%)</td>
<td>36.2</td>
<td>21.7</td>
<td>22.7</td>
<td>24.0</td>
<td>29.6</td>
<td>27.1</td>
</tr>
<tr>
<td>Market restriction (%)</td>
<td>63.8</td>
<td>78.3</td>
<td>77.3</td>
<td>76.1</td>
<td>70.5</td>
<td>73.0</td>
</tr>
</tbody>
</table>

Out of which market restricted only to:

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan (A)</td>
<td>10.1</td>
<td>29.2</td>
<td>30.9</td>
<td>48.3</td>
<td>48.9</td>
<td>34.5</td>
</tr>
<tr>
<td>Japan, S. Korea, Taiwan (B)</td>
<td>5.4</td>
<td>4.4</td>
<td>4.0</td>
<td>1.6</td>
<td>2.6</td>
<td>1.7</td>
</tr>
<tr>
<td>S and S.E. Asia (C)</td>
<td>25.7</td>
<td>26.4</td>
<td>22.2</td>
<td>12.3</td>
<td>10.1</td>
<td>6.2</td>
</tr>
<tr>
<td>C and Europe</td>
<td>3.3</td>
<td>0.8</td>
<td>0.3</td>
<td>0.3</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Any country except the Communist bloc</td>
<td>4.2</td>
<td>2.5</td>
<td>0.9</td>
<td>0.5</td>
<td>8.0</td>
<td>10.3</td>
</tr>
<tr>
<td>Others</td>
<td>15.1</td>
<td>14.9</td>
<td>19.0</td>
<td>13.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>952</td>
<td>1,535</td>
<td>1,259</td>
<td>1,860</td>
<td>2,227</td>
<td>2,430</td>
</tr>
</tbody>
</table>


(D-263a)
### Table 2: Tax Abatement Due to Special Tax Measures (FY1950-63)

<table>
<thead>
<tr>
<th></th>
<th>FY1950</th>
<th>1955</th>
<th>1960</th>
<th>1963</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Special depreciation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Important and rationalization machinery</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>(b) Machinery for R&amp;D and for commercialization of new technology</td>
<td>0</td>
<td>28</td>
<td>15</td>
<td>45</td>
</tr>
<tr>
<td>(c) Other special depreciation a/</td>
<td>0</td>
<td>0</td>
<td>25</td>
<td>93</td>
</tr>
<tr>
<td>(d) Machinery for modernization of small and medium enterprises</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>2. Introduction of new technology</td>
<td>5</td>
<td>81</td>
<td>121</td>
<td>79</td>
</tr>
<tr>
<td>(a) Income tax exemption for producing important products</td>
<td>3</td>
<td>55</td>
<td>45</td>
<td>12</td>
</tr>
<tr>
<td>(b) Reduction of withholding tax on payment for important foreign technology</td>
<td>0</td>
<td>6</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>(c) Tariff exemption for importing important machinery</td>
<td>0</td>
<td>20</td>
<td>60</td>
<td>59</td>
</tr>
<tr>
<td>3. Tax-free reserve and allowance b/</td>
<td>5</td>
<td>147</td>
<td>171</td>
<td>90</td>
</tr>
<tr>
<td>4. Export promotion c/</td>
<td>0</td>
<td>38</td>
<td>115</td>
<td>275</td>
</tr>
<tr>
<td>5. Others</td>
<td>0</td>
<td>53</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Sum d/</td>
<td>5 (0.6)e/</td>
<td>347 (18.1)</td>
<td>356 (9.7)</td>
<td>737 (8.2)</td>
</tr>
<tr>
<td>Sum (1 and 2)</td>
<td>5 (0.6)</td>
<td>109 (5.7)</td>
<td>261 (4.6)</td>
<td>362 (4.0)</td>
</tr>
<tr>
<td>cf. corporate income tax rate (%) e/</td>
<td>42</td>
<td>40</td>
<td>38</td>
<td>37</td>
</tr>
</tbody>
</table>

a/ Includes special depreciations for mining, housing investment for rent and regional development.
b/ Includes reserves for price-fluctuation, extraordinary risk, drought, etc.
c/ Includes income tax deduction for export (1953-63), special reserves for overseas market development (1964-72), special depreciation for export (1964-71), reserves for overseas investment loss (1964-71).
d/ This table grossly overestimates the actual tax abatement, since it neglects completely the value of postponed tax payment.
e/ A number in bracket is a proportion to corporate income tax.
f/ Corporate income tax by the Central government in FY1987 is 43.3%. (30% for small and medium enterprises up to a certain limit.)


(D-263e)
Table 3: SMALL AND MEDIUM ENTERPRISES a/ IN JAPAN

<table>
<thead>
<tr>
<th>Year</th>
<th>Manufacturing</th>
<th>Non-Primary Industries</th>
<th>Manufacturing</th>
<th>Non-Primary Industries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957</td>
<td>541 (99.4) b/</td>
<td>3,452 (99.7)</td>
<td>5,473 (73.5) b/</td>
<td>16,222 (82.8)</td>
</tr>
<tr>
<td>1963</td>
<td>616 (99.4)</td>
<td>3,886 (99.6)</td>
<td>7,247 (69.6)</td>
<td>21,763 (79.9)</td>
</tr>
<tr>
<td>1969</td>
<td>733 (99.4)</td>
<td>4,624 (99.4)</td>
<td>8,680 (69.0)</td>
<td>27,414 (78.3)</td>
</tr>
<tr>
<td>1973</td>
<td>809 (99.5)</td>
<td>5,358 (99.4)</td>
<td>8,929 (70.5)</td>
<td>31,530 (79.5)</td>
</tr>
<tr>
<td>1981</td>
<td>868 (99.5)</td>
<td>6,230 (99.4)</td>
<td>9,551 (74.3)</td>
<td>37,206 (81.4)</td>
</tr>
</tbody>
</table>

a/ Employees less than 300 (or less than 100 in wholesale, or less than 50 in retail and services).

b/ Proportion to the total establishments or employment.

Source: Coordinating Agency, "Business Statistics."
Table 4: R&D EXPENDITURE OF JAPAN

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D Expenditure (Nominal, Billion Yen)</td>
<td>62</td>
<td>144</td>
<td>426</td>
<td>1,195</td>
<td>2,622</td>
</tr>
<tr>
<td>R&amp;D Expenditure (Real, 1975 = 100)</td>
<td>10</td>
<td>27</td>
<td>43</td>
<td>67</td>
<td>100</td>
</tr>
<tr>
<td>Annual Growth Rate of Real R&amp;D Expenditure (the past 5 years)</td>
<td>-</td>
<td>22</td>
<td>10</td>
<td>15</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Sources: Science and Technology Survey, Administrative Management Agency of Japan.

Table 5: THE PROPORTION OF THE JAPANESE APPLICATIONS IN THE TOTAL PATENT APPLICATIONS IN THE MAJOR INDUSTRIALIZED COUNTRIES

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>0.2</td>
<td>1.0</td>
<td>2.4</td>
<td>5.1</td>
<td>8.5</td>
<td>10.1</td>
</tr>
<tr>
<td>West Germany</td>
<td>0.1</td>
<td>0.4</td>
<td>2.0</td>
<td>5.8</td>
<td>7.2</td>
<td>8.1</td>
</tr>
<tr>
<td>Britain</td>
<td>0.1</td>
<td>1.2</td>
<td>2.3</td>
<td>5.8</td>
<td>6.8</td>
<td>7.3</td>
</tr>
<tr>
<td>France</td>
<td>0.1</td>
<td>1.1</td>
<td>2.0</td>
<td>5.3</td>
<td>6.0</td>
<td>6.6</td>
</tr>
</tbody>
</table>

Sources: Annual Reports of the Patent Office (Japan).

Table 6: INDUSTRIAL R&D (INTERNATIONAL COMPARISON)

<table>
<thead>
<tr>
<th></th>
<th>Japan</th>
<th>USA</th>
<th>West Germany</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D Expenditure</td>
<td>2.0</td>
<td>3.6</td>
<td>3.0</td>
<td>3.5</td>
</tr>
<tr>
<td>The Proportion of Government Funding (%)</td>
<td>3.1</td>
<td>34.2</td>
<td>26.5</td>
<td>23.1</td>
</tr>
</tbody>
</table>

Sources: Science and Technology Indicators of Japan, MITI (1988).
Figure 1: GROWTH WITH STRUCTURAL TRANSFORMATION

In this diagram of the Ricardian Model of the continuum of goods,1/

$W$ stands for Real income of Japan

$W^*$ = Real income of the rest of the world

B = Trade Balance Line, and

A = Competitive Line

The growth process of Japan can be interpreted as a combination of the shift of the competitiveness line from AA to A'CEA and the shift from A'CEA to A'CE'A'. The first shift represents productivity gain of existing industries, that brings about the increase of real income, the extent of which is at most the productivity gain of these industries. The second shifts represents the addition of new industries into the industrial structure due to the import of new technologies. The latter can bring about the increase of real income, the extent of which exceeds the productivity gain of existing industries, due to the improvement of the factoral terms of trade from E to E.

1/ A similar account was given to the Korean experience (the combination of worsening relative unit labor cost and expanding export) by Dornbusch R. and Park Y. (Korean Growth Policy, Brookings Papers on Economic Activity, 1987, 2nd Volume.)
conference on "Japan's Chemical Industry" and "Economic Development in Japan. The 20 Years"

Source: Selected from table on p. 67, Chapter 1, Book 12, The 20 Years of Conference on Tokyo, 1986.

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FIGURE 3

WAGE DIFFERENTIAL BY THE SIZE OF EMPLOYMENT
OFENTERPRISES (MANUFACTURING)

(Proportion to the average wage of enterprises
with 500 or more employees)

APPENDIX III

NATURE OF CONTRACTS IN SUBCONTRACTING SYSTEM

We describe briefly the major characteristics of contracts between an automobile assembler maker and its subcontractor, in order to illustrate the existence of powerful incentive scheme for higher efficiency, largely based on the insightful empirical work by B. Asanuma (1984).

Incentives for higher efficiency work through the following four mechanisms:

(a) Competitive selection of a subcontractor. The selection of a subcontractor for a particular component depends heavily on competition among subcontractors. It takes place for each introduction of a new car model normally in every four years. The amount of contracts which a particular subcontractor can get depends on the result of competitive bidding process.\(^1\) The selection, however, also reflects the contribution made by subcontractors to a parent firm in the past. Moreover, exclusive reliance on a particular subcontractor is avoided by the practice of "two-vendor policy," where a parent firm divides the work between two or more suppliers.

(b) Association of subcontractors as technology transfer mechanism and as a safeguard against opportunism.\(^2\) Supplier associations organized by types of components provide frequent contact opportunities among suppliers and a parent firm. Through these associations subcontractors can diffuse technology and experience quickly among themselves. They also function as a mutual monitoring mechanism to prevent opportunism among members.

(c) High appropriability and pressure built in the contract for higher efficiency. The unit price agreed during the above selection process is fairly rigid with respect to the changes taking place within subcontractors, so that they can appropriate cost reduction efforts. Although unit price is adjusted each time when renewing a contract and in every six months in order to reflect changes in environment (e.g., design change, price increase in raw materials, increased product market competition), a parent firm usually does not allow subcontractors to pass through wage increase or energy cost increase into the unit price increase. Subcontractors are expected to absorb these cost increases by productivity increase.

---

1/ A parent firm can also both make and buy, although it is rare (Williamson O. (1985), *op. cit.*., pp. 120-24).

2/ Williamson O. (1985), *ibid.*
(d) Incentive for design improvement and for higher technological capability. The suggestions for better component design by subcontractors are rewarded through various mechanisms. Even if design revision reduces the material and processing costs, the unit price can be maintained to secure higher margin. The parent firm may reward subcontractors only by non-pecuniary method (e.g., awarding a prize) but it certainly strengthens the position of the subcontractor in the negotiation over the contract for the next round of automobile production. The subcontractors with high technological capability can participate in the design of a model itself and thus can secure higher return from subcontracted work.

There exist the following risk bearing relationship (a parent firm shoulders more of business risk):

(a) Investment cost (e.g., tool or die cost) specific to the production of subcontracted components are fully born by a parent firm, irrespective of the realized amount of automobile sales (the investment can even be financed by a parent firm for a lease to the subcontractor).

(b) Amount of order is strictly proportional to the sales of automobiles. Subcontractors, therefore, are not guaranteed revenue.


O. Williamson, The Economic Institution of Capitalism, 1985, the Free Press.
APPENDIX IV

1969—SURVEY ON STATISTICAL QUALITY CONTROL (SQC) AND ENTERPRISE STANDARD

1. The survey was conducted in February 1969 by MITI.

2. Sample: 5,195 factories (1/3 of factories with employment of 100 or more and 1/174th of factories with employment from 10 to 99).

Replies: 1,566 factories (32.8% for factories with employment of 100 or more and 5.8% for factories with employment from 10 to 99).

Distribution by size: 1,041 factories belong to large enterprises (employment with 300 or more or capital exceeding 50 million yen) and 524 factories belong to small and medium enterprises.

3. Main Results

(a) Ratio of enterprises which practice SQC

(i) By size of enterprises
Factories belonging to large enterprises - 94%
Factories belonging to small and medium enterprises - 87%

(ii) By sector

<table>
<thead>
<tr>
<th>Metal Processing</th>
<th>Machinery</th>
<th>Electric Equipment</th>
<th>Chemical</th>
<th>Textile</th>
<th>Wood Processing</th>
<th>Food</th>
<th>Publication</th>
<th>Daily Necessities</th>
</tr>
</thead>
<tbody>
<tr>
<td>93%</td>
<td>86%</td>
<td>92%</td>
<td>95%</td>
<td>92%</td>
<td>86%</td>
<td>90%</td>
<td>77%</td>
<td>94%</td>
</tr>
</tbody>
</table>

(b) Timing when preparation for the introduction of SQC was started

<table>
<thead>
<tr>
<th></th>
<th>Proportion of Enterprises</th>
<th>Accumulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945-49</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>1950-54</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>1955-60</td>
<td>24</td>
<td>49</td>
</tr>
<tr>
<td>1961-65</td>
<td>33</td>
<td>82</td>
</tr>
<tr>
<td>1966-</td>
<td>16</td>
<td>98</td>
</tr>
</tbody>
</table>
(c) Status of the development of enterprise standard

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Has been fully developed</td>
<td>54%</td>
<td>38%</td>
</tr>
<tr>
<td>Under the process of development</td>
<td>36%</td>
<td>48%</td>
</tr>
<tr>
<td>Others</td>
<td>10%</td>
<td>14%</td>
</tr>
</tbody>
</table>
APPENDIX V

THE TOKYO METROPOLITAN INDUSTRIAL TECHNOLOGY CENTER

1. Background

There exist 184 regional testing and research institutions with a total staff 7,073 in 1985 in Japan. The Tokyo Metropolitan Industrial Technology Center with a staff size of 213 is one of the largest. It was established in 1970, as a result of the merger of the Industrial Promotion Center established in 1921 and the Electric Research Laboratory established in 1924. This Center provides technological support to small and medium enterprises in Tokyo (the number of target enterprises is said to be 40,000 to 50,000), as described below. The annual budget in FY1985 was about $8 million (converted at $ = 150 yen), (around 20% of its budget funded by enterprises).

2. Major Activities

(a) Testing (Fee is charged)

The Center undertakes various tests, inspections and analysis on equipment, parts and materials for those small and medium businesses not equipped with testing and inspection facilities and issues certificates of results. The Center also provides technical guidance through these tests with a view to assist business in technical development and quality improvement. It conducted about 65,000 testing in FY1984.

(b) Research (Mainly funded by the local government. Some support from the national government)

The Center selects those themes which meet industrial and administrative needs and conducts varied research on energy-saving, resource-saving and labor-saving techniques, techniques for preventing pollution, quality improvement, techniques for ensuring safety, development of new products and techniques, etc. The Center works on about 50 themes, of which three to five constitute larger special studies. The results of these studies are supplied to small and medium businesses through technical consultations, guidance tours and lecture meetings and are also made available to the public through research reports and meetings. It also undertakes research contract from enterprises.

(c) Guidance

(i) Technical guidance (Free). To improve the technical level and productivity in small and medium businesses, the Center provides guidance and consultation on a wide range of fields including machinery, metals, electricity, chemistry and industrial arts.
(ii) **Open Guidance Room** (Fee is charged). For those small and medium businesses not equipped with testing and research facilities, the Center has installed various measuring equipment, testing equipment and machine tools which can be used for nominal charges, while providing technical guidance for them.

(iii) **Supply of technical information** (Free). The Center publishes the TMIC News once a month. The Center also publishes various technical pamphlets as technical guides for small and medium businesses.

(iv) **Guidance tours** (Free). The Center organizes guidance tours to those plants faced with technical problems to provide appropriate guidance on the spot and to solve such problems. The Center also organizes a touring energy assessment bus to provide better guidance for small and medium businesses on energy-saving. The Center visits around 800 factories annually.

(v) **Technical advisors** (Free). The Center also sends out technical advisors commissioned by the Tokyo Metropolitan Government, who possess technical skills, to those small and medium businesses engaged in the development of new products or techniques to help them solve problems.

(vi) **Training of technical experts** (Fee is charged). The Center organizes training courses and lecture meetings for technical personnel in small and medium businesses so that they will acquire advanced techniques. These courses and lecture meetings are given in the evening to suit employers and employees. They cover about 40 themes a year for the duration ranging from 1 to 60 days.

(vii) **Technical Exchange Plaza** (Free). The Center helps organize groups of small and medium businesses of different fields for exchanging different experiences and views to facilitate technical transfer and exchange.

(D-263e)
INTERACTION BETWEEN PRODUCTION EFFICIENCY AND R&D

1. Increased R&D improves production efficiency. However we would like to also emphasize the reverse causality in the context of the Japanese experience: Higher production efficiency allows an enterprise to serve a larger market. The enterprise with a larger market in turn has a larger incentive to introduce a new technology, since it can apply the technology more widely. Thus higher production efficiency causes more R&D.

2. Formally we can illustrate the above proposition by using a simple model of a monopolistic competition:

\[ (1) \pi = PQ - M(t,C) Q - C \]

where \( \pi \) stands for profit
\( P \) stands for price
\( Q \) stands for output
\( M \) stands for marginal cost
\( t \) stands for production efficiency
\( C \) stands for R&D expenditure for cost reduction.

We assume that \( M_t < 0, \ M_C < 0, \ M_C > 0 \) and \( M_{ct} = 0 \).

The profit maximization requires

\[ (2) \quad P + Q \frac{dP}{dQ} - M = 0 \]
\[ (3) \quad -MCQ - 1 = 0 \]

For a simplicity we assume that the demand \( Q(P) \) has a constant elasticity. In this case

\[ (2') \quad P = \phi M(t,C); \quad \phi \text{ constant mark up} \]

The second-order condition of the profit maximization requires that

\[ (4) \quad \left| \begin{array}{c} P' - \phi M_c \\ M_c Q M_{cc} \end{array} \right| = QP' M_{cc} + \phi M_C^2 < 0 \]

If we differentiate \( (2') \) and \( (3) \) with respect to \( t \),

\[ (5) \quad P' dQ = \phi (M_t dt + M_c dC) \]
\[ (6) \quad M_{cc} Q dC + M_c d\alpha = 0, \text{ given } M_{ct} = 0 \]
Consequently

\[ dC = - \frac{\phi M_t M_c}{Q P' M_c + \phi M_c^2} \] \hspace{1cm} (7)

\[ dQ = - \frac{M_c}{M_c} Q \ dC \] \hspace{1cm} (8)

Given (4), \( dC > 0 \) and \( dQ > 0 \) for \( dt > 0 \).

That is, increased production efficiency increases not only output but also R&D. In the following figure, higher production efficiency shifts the schedule determining output to the left. Consequently both output and R&D expenditure increase.

(R&D Expenditure)
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Japanese Direct Foreign Investment: Patterns and Implications for Developing Countries, February 1989</td>
</tr>
<tr>
<td>2</td>
<td>Emerging Patterns of International Competition in Selected Industrial Product Groups</td>
</tr>
<tr>
<td>3</td>
<td>Changing Firm Boundaries: Analysis of Technology–Sharing Alliances</td>
</tr>
<tr>
<td>4</td>
<td>Technological Advance and Organizational Innovation in the Engineering Industry</td>
</tr>
<tr>
<td>5</td>
<td>The Role of Catalytic Agents in Entering International Markets</td>
</tr>
<tr>
<td>7</td>
<td>Reform of Ownership and Control Mechanisms in Hungary and China</td>
</tr>
</tbody>
</table>