R&D Investment and Overseas Production: An Empirical Analysis of Japan's Electric Machinery Industry Based on Corporate Data

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This paper studies determinants of the decision to invest abroad. Among them, we follow the current mainstream theory of foreign direct investment so as to emphasize the stock of technological knowledge. We explicitly solve the optimal geographical composition (i.e. domestic vs. abroad) of the total production of companies. The analysis suggests that the relationship between technological knowledge and overseas production depends on relative prices of factors of production at home and abroad and on the elasticity of substitution between them. It is especially shown that under certain realistic assumptions, companies with a larger stock of technological knowledge have a lower proportion of production in developing countries, but have a higher proportion in developed countries exclusive of Japan. We test this hypothesis using corporate data of Japan's electric machinery industry. The empirical results are consistent with the theory. Besides the stock of technological knowledge, the paper investigates the explanatory power of other factors, such as company size, advertising intensity, and horizontal keiretsu.

I. Introduction

Overseas production by Japanese companies increased rapidly in the 1980s. For example, the 1993 White Paper of the Ministry of International Trade and Industry (MITI) reported that overseas production accounted for 6% of the total production of Japanese manufacturers in fiscal 1990, up from an estimated 3% in fiscal 1985.

In discussing foreign direct investment, both macroeconomic and microeconomic perspectives need to be examined. We must be concerned with both how the proportion of overseas production by an average Japanese company is determined and what kinds of companies tend to engage in overseas production. In this paper, we especially address the latter question through theoretical and empirical analyses of the electric machinery industry.[1]

We would like to thank seminar participants at Yokohama National University, University of Tokyo, Waseda University, Kobe University, Hitotsubashi University, and the Bank of Japan for their helpful comments and suggestions.

[1]We have chosen companies belonging to the electric machinery industry for two reasons. First, MITI (1988,

We can refer to Krugman (1983) as a representative macroeconomic theory of direct investment. Suppose that two countries (Japan and the United States, for example) are freely engaged in trade and direct investment. Further assume that labor is the only production factor and that the two countries are identically endowed in terms of labor. Products are differentiated, and specific technology is required to make each. Furthermore, each product faces identical demand and cost functions for all products. If we assume that only Japanese companies can produce 70% of all the products and that only U.S. companies can produce 30%, an equilibrium is reached in this model when Japanese companies with 70% of world output produce 50% in Japan and 20% in the United States. As the model predicts, the scale of overseas production by Japanese companies becomes larger as Japan's endowment of labor decreases and the number of products that can be made only by Japanese companies increases. It is reasonable to believe that the range of products Japanese companies can produce depends on past research and development (R&D) efforts to develop new products.

Which 20% (of the 70% of world output produced by Japanese companies) will be produced overseas? This microeconomic aspect is important when we evaluate how direct investment affects the employment, international payments position, and technological level of Japan and its recipient countries. For example, if a labor-intensive manufacturing process that uses no sophisticated technology is shifted overseas because of lower wages in a developing country, direct investment can create an employment problem in the low-wage region in Japan where this process had previously been located. If a leading company makes direct investment to monopolize the partner country's market, the host country becomes concerned about the undesirable consequences of monopoly. The microeconomic aspects of direct investment, despite their importance, have not yet received sufficient theoretical and empirical research.

From these standpoints, this paper investigates which company "characteristics" determine the proportion of overseas production. Among the characteristics, we follow the current mainstream theory of direct investment to emphasize the stock of technological knowledge.[2] As Hymer (1960) pointed out, when a company moves production

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1991) distinguishes it and the transportation equipment industry as the most outward industries in terms of share of overseas production and value of overseas fixed assets. Moreover, a good number of electric machinery companies have responded to questionnaires. Second, as shown in Goto, *et al.* (1986), the electric machinery industry includes manufacturers with the highest ratio of R&D expenses to total sales (such as makers of electronic application devices and electric machinery for power distribution and industrial use). Thus it is surmised that technological knowledge plays an especially important role in the production activities of the electric machinery industry.

[2]Theoretical analyses include Caves (1982), Helpman (1984), Markusen (1984), and Helpman and Krugman (1985). References to some empirical studies will be made in Section III. The amount of technology and knowledge that determine the advantage of a firm is called "stock of technological knowledge". In the following empirical studies, we have estimated "stock of technological knowledge" from past research and development data provided by firms, and this estimated figure is called "R&D stock" to distinguish it from theoretical values.

overseas, it is in a disadvantageous position in relation to local companies because of differences in terms of language, customs, and institutions. Despite these differences, however, a company will effect direct investment abroad in case where it will enjoy certain advantages. As in Krugman's theory (1983), the current direct investment theory emphasizes the stock of technological knowledge accumulated by R&D as the source of such advantages, for two reasons. First, it has the nature of a public good within any given company. Consequently, overseas affiliates of a company which enjoys abundant technological knowledge have advantages over local concerns. Second, a large transaction cost is associated with the transfer of technological knowledge across companies. Thus direct investment is often chosen over the sale or lease of technological knowledge to overseas producers.[3,4]

For these reasons, the stock of technological knowledge is one possible factor to explain the current situation in which Japanese companies are engaged in overseas production, despite the disadvantages vis-à-vis local companies. However, we cannot assert that Japanese companies with a greater stock of technological knowledge will always have a higher proportion of overseas production than other companies. It is true that the stock of technological knowledge yields benefits in the form of lower production cost or new products, but these benefits can equally be obtained regardless of whether the companies are engaged in domestic or overseas production. Those with a large stock of technological knowledge may decide to produce in the home country for exports and not overseas.

For a proper understanding of the relationship between the stock of technological knowledge and overseas production, the optimal geographical composition of the total production of companies must be explicitly solved.[5] We do this in the theoretical analysis contained in Section II.

The analysis suggests that companies with a greater stock of technological knowledge do not necessarily have a larger proportion of overseas production, and that the relationship between technological knowledge and overseas production depends on relative prices of factors of production at home and abroad, and also on the elasticity of

[3]Along with technological knowledge, such studies as Horst (1972) and Horaguchi (1992) emphasize the accumulation of marketing know-how from past advertising activity as the source of this advantage. However, the accumulated know-how from domestic advertising does not seem necessarily useful in overseas markets. In Horaguchi (1992) and in our own empirical analysis in Section III, advertising intensity is reported to be statistically insignificant in explanations of direct investment.

[4]This is referred to as the theory of internalization in the area of overseas direct investment overseas, which can be traced to Coase (1937) who explained company size in terms of reducing transaction cost. Our paper analyzes only a company's substitution between exports and direct investment and does not consider substitution between licensing and direct investment. On this point, *see* Ono (1985), Ethier (1986), and Horstman and Markusen (1987a). It is often pointed out that in comparison with other industries, the monopolization of technological knowledge through patents or the leasing or sale of patents is not important in the electric machinery industry. This is introduced in Section III.

[5]Miwa (1990) conducts an interesting empirical study concerning this problem.

substitution between production factors. In particular, it is shown that under certain realistic assumptions, companies with a larger stock of technological knowledge have a lower proportion of production in developing countries (i.e., the ratio of value added in developing countries to value added in Japan), but a higher proportion in developed countries exclusive of Japan. Why companies with a larger stock of technological knowledge have a smaller proportion of production in developing countries can be intuitively explained as follows: Suppose that substitutability between labor and technological knowledge is greater than between capital and technological knowledge. Then, companies with a larger stock of technological knowledge have a smaller labor input; consequently, they have less incentive to produce in developing countries where the wage rate is lower.

Empirical analysis in Section III tests this hypothesis. In previous empirical studies, either a discrete variable (either 0 or 1) corresponding to whether a company has overseas production or the value of the parent company's equity proportion has frequently been used to indicate the extent of a Japanese company's overseas expansion. In contrast, we use the proportion of overseas production (defined in this paper as the ratio of overseas value added to domestic value added), which is more appropriate as a measure of the scale of a company's overseas production. To obtain this variable, we referred to MITI's survey of overseas production activities for fiscal 1986. As the variable to measure the stock of technological knowledge, we used R&D stock calculated from the data of past R&D investment expenses for each company. To state the conclusion of our analysis in advance, we found a negative correlation between a company's proportion of production in developing countries and the R&D stock of the parent, as predicted by the theoretical model. Conversely, we found a positive correlation between the proportion of production in developed countries (exclusive of Japan) and the R&D stock of the parent.

Besides the stock of technological knowledge, this paper investigates the explanatory power of other factors which have been stressed as a company's characteristics in deciding the proportion of overseas production.

The first is a line of thought known as the Hymer (1960)-Kindleberger (1969) hypothesis, which claims that direct investment is principally undertaken by large companies with market power in order to exploit monopolistic profits. We will thus test the hypothesis that a larger company has a larger proportion of overseas production.

Second, although Japanese companies have rapidly expanded direct investment in the European Union (EU) and in the United States in recent years, much of that may very possibly have been made to circumvent trade barriers. If this is so, of all companies in the electric machinery industry, those manufacturing products that have often encountered import restrictions or antidumping charges from the EU and the United States should have a higher proportion of production in those countries. We will investigate to what extent such a relationship exists.

Third, concerning the investment activities of Japanese companies, the role of the main bank system and corporate groups (horizontal *keiretsu*) has recently attracted attention.[6] For example, Hoshi, Kashyap, and Scharfstein (1991) found that companies belonging to a corporate group are less subject to liquidity constraints in investment activities compared with those that do not. Based on this study, they conjecture that active foreign direct investment by Japanese companies may be attributable to the main bank system and corporate groups (Hoshi, Kashyap, and Scharfstein, 1989). In this context, it may be more difficult for lenders to monitor overseas investment than domestic investment, and the main bank system may be beneficial in considerably reducing the cost of gathering information. Then companies with a stable main bank relationship may have a larger proportion of overseas production. We will also investigate whether this relationship holds.

II. The Theoretical Foundation of Empirical Analysis

A. The Model

In this section, we construct a model of the trade and foreign direct investment activity of an oligopolistic firm and analyze the relationship between the stock of technological knowledge and overseas production. Consider a Japanese firm under monopolistic competition. Denoting its output in country i by x_i, labor input by L_i, capital input by K_i, and stock of technological knowledge by Z, we assume the following relationship among them:

$$X_i = f(L_i, K_i, Z) \tag{1}$$

It is assumed that the production function $f(\cdot)$ is strictly monotone-increasing for the range of $L_i>0$, $K_i>0$, and $Z>0$. It is also concave downward, twice continuously differentiable, and the isoquants are strictly convex with respect to the origin. Furthermore, $f(\cdot)$ is taken to be homogeneous of degree γ with respect to L_i and K_i (where γ takes a value between 0 and 1). That is, for any arbitrary non-negative values of L_i, K_i, Z, and γ, we have the following relationship:

$$f(\lambda L_i, \lambda K_i, Z) = \lambda^{\gamma} f(L_i, k_i, Z), \qquad 0<\gamma<1 \tag{2}$$

Z has no subscript i to indicate place of production because when the firm increases Z, it is thought to increase the productivity of subsidiaries not in just one country but in all countries worldwide. That is, we are assuming that the stock of technological knowledge has the characteristics of a public good within any given firm.[7]

[6]For details, *see* Horiuchi and Okazaki (1992) and Horiuchi and Zui (1992).

[7]Helpman (1984) and Markusen (1984) construct a two-country model of direct investment with this type of technology.

As Porter (1985) pointed out, the purposes of R&D investment by companies can be broadly classified as (i) to reduce production cost and (ii) to develop new products and increase value added. In the analysis below, we consider only of the first of these purposes. We will later show that the type of R&D investment undertaken for the second purpose does not influence the proportion of overseas production. As stated in Section I, however, we should remember that the second type of R&D investment is an important determinant of such macroeconomic variables as the total value of Japanese direct investment abroad.

In what follows, we are concerned with short-term analysis; thus we take Z to be given. Because of its very nature, technological knowledge is not easily transferable between companies, so the stock can be increased only by R&D activities over the long term. In contrast, L_i and K_i can be variable even in the short term. A value of γ less than one means that the short-term marginal cost curve slopes upward in each country.

Given the production function (1), we will derive the short-term marginal cost curve. To do so, we will consider the following cost minimization problem.
Cost minimization problem:

$$q_i \equiv \min_{K_i, L_i} r_i K_i + w_i L_i \tag{3}$$

subject to the following constraints,

$$\begin{aligned} &f(L_i, K_i, Z) = 1 \\ &L_i \geq 0 \\ &K_i \geq 0 \end{aligned}$$

where w_i and r_i denote the cost of labor and the cost of capital, respectively, in country i; q_i is the minimum variable cost necessary to produce one unit of output in country i. We call this unit production cost. The minimized value of q_i is a function of w_i, r_i, and Z. By making use of the fact that q_i is homogeneous of degree one with respect to w_i and r_i, we have the following relationship:

$$q_i = r_i g\left(\frac{w_i}{r_i}, Z\right) \tag{4}$$

By denoting the amount of output in country i by x_i, we can express the variable cost function (VC) and the short-term marginal cost function (MC) as follows.

$$VC_i(x_i) = x_i^{\frac{1}{\gamma}} q_i$$

$$MC_i(x_i) = \frac{1}{\gamma} x_i^{\frac{1-\gamma}{\gamma}} q_i \tag{5}$$

Next we will consider the optimal geographical composition of production for the

Japanese firm. We assume n countries, including Japan, and express the set of all countries by $N=\{1, 2, \ldots .n\}$. The firm is under monopolistic competition and can set different prices in different countries. There is no transportation cost and the tariff rate is zero in Japan. We denote the firm's sales volume, production volume, import volume, and export volume in country i by s_i, x_i, m_i, and e_i, respectively. The vectors of sales volumes in all countries are expressed as $s = \{s_1, s_2, \ldots\ldots, s_n\}$. Similarly, the vectors of production volumes, import volumes, and export volumes in all countries are denoted by x, m, and e. The total revenue function arising from sales in country i is given by $TR_i(s_i)$, and the tariff rate (specific duty) in country i is τ_i. The short-term optimization problem can then be formulated as follows.
Profit maximization problem:

$$\max_{s,x,m,e} \sum_{i \in N} \{TR_i(s_i) - \tau_i m_i - VC_i(x_i)\}$$

subject to the following constraints for all $i \in N$.

$$m_i - e_i = s_i - x_i \tag{6}$$

$$s_i \geq 0, x_i \geq 0, m_i \geq 0, e_i \geq 0 \tag{7}$$

$$\sum_{i \in N} x_i = \sum_{i \in N} s_i \tag{8}$$

As shown in Appendix 1, the necessary conditions for optimum production are given by the following.
(Case A) When production cost in country i is low and demand is small, country i becomes an exporter of goods and the following equation holds.

$$MC_i(x_i) = MC_J(x_J) \tag{9}$$

where country J refers to Japan.
(Case B) When production cost in country i is high and demand is large, country i becomes an importer of the goods and the following equation holds.

$$MC_i(x_i) = MC_J(x_J) + \tau_i \tag{10}$$

Although τ_i is the tariff rate (specific duty) of country i, it can also be thought of as approximating the measure of how closed the country's market is, with respect to non-tariff as well as tariff barriers.

Case A represents the type of direct investment in which the low-cost country becomes an export base, and case B represents the type of direct investment known as tariff jumping. MITI (1988) data show that the value of exports by North American subsidiaries of companies in the electric machinery industry to Japan and third countries (outside of North America) was only 1.5% of total sales in 1986. The value of exports by European subsidiaries to Japan and third countries (outside of Europe) was also small, only 2.6% of total sales. Thus production in these regions probably corresponded to Case B. On the other hand, the value of exports by subsidiaries in Asia (the bulk of direct investment in developing countries) to Japan and third countries (outside of Asia) was important, accounting for 22.2% and 20.1%, respectively, of total sales. Because of the low level of wages in Asian countries relative to Japan, it is reasonable to believe that production in Asia corresponded to Case A.

B. Stock of Technological Knowledge and Overseas Production

In what follows, we investigate the theoretical relationship between the stock of technological knowledge Z and the ratio of production in country i to production in Japan (x_i/x_J) for each case.

Case A. Investment in developing countries

Country L refers to a country to which Case A applies. In developing countries, wage rates are much lower than in Japan; thus the ratio of the cost of labor to the cost of capital is thought to be lower than in Japan. That is,

$$\frac{w_L}{r_L} < \frac{w_J}{r_J} \tag{11}$$

We have data from the U.S. Department of Commerce on labor costs faced by overseas subsidiaries of U.S. multinationals in different countries (Table 1) showing that the cost in developing countries is much lower than in Japan. However, labor cost in Japan reported in the table is, for several reasons, most likely different from that borne by Japanese companies. First, because of differences in terms of language, customs, and legal system, foreign companies (in this case, U.S. companies operating in Japan) pay higher wages than local (Japanese) companies. For example, Howenstine and William (1992) found that the total wage and salary payment per employee in 1987 paid by subsidiaries of foreign companies operating in the United States was 12% higher than that paid by U.S. manufacturers in the United States. The difference remained even when the authors controlled for difference in geographical location and industrial composition. Second, because the Japanese subsidiaries of U.S. companies have been in Japan for a relatively shorter period, the average age of workers may be lower; thus labor cost is lower than that of local companies under Japan's seniority wage structure.

We obtain the following equation from equations (5) and (9).

$$\frac{x_L}{x_J} = \left(\frac{q_J}{q_L}\right)^{\frac{\gamma}{1-\gamma}} = \left(\frac{r_J g\left(\frac{w_J}{r_J}, Z\right)}{r_L g\left(\frac{w_L}{r_L}, Z\right)}\right)^{\frac{\gamma}{1-\gamma}} \tag{12}$$

Equation (12) is independent of production cost and demand in third countries.

To know how intercompany differences in terms of stock of technological knowledge

Table 1

The Hourly Labor Cost of Production Workers Employed by Foreign Subsidiaries of U.S. Electric Machinery Producers by Country

(US$)

	1982	1989
Asia, the Pacific		
Japan	6.79	17.10
Australia	12.31	11.11
Taiwan	1.32	4.37
Hong Kong	1.65	4.14
South Korea	2.06	3.82
Singapore	1.99	3.70
Malaysia	1.36	1.95
Thailand	1.35	1.51
Philippines	1.07	1.50
Canada	10.01	14.40
Mexico	2.18	1.85
Europe		
Italy	9.19	15.31
West Germany	9.80	13.77
France	8.05	12.39
U.K.	6.27	11.52
Ireland	5.73	8.34

Note: Figures include cost of social security contributions paid by employers. Sample covers only those foreign corporations in which U.S. companies (excluding banks) have more than 50 % equity participation.

Source: U.S. Direct Investment Abroad: Benchmark Survey Data 1982,1989, U.S. Department of Commerce.

Z influence the ratio of foreign to domestic production (x_L/x_J), it is necessary only to analyze the effect of Z on the ratio of foreign to domestic unit production cost (q_L/q_J). As shown in Appendix 2, from the definition of function $g(\cdot)$, we get the following equation.

$$\text{sign}\left[\frac{\partial\left\{\dfrac{g\left(\frac{w_J}{r_J}, Z\right)}{g\left(\frac{w_L}{r_L}, Z\right)}\right\}}{\partial Z}\right] = \text{sign}[\sigma_{KZ} - \sigma_{LZ}] \tag{13}$$

where σ_{LZ} and σ_{KZ} are Allen's partial elasticities of substitution between labor and technological knowledge and between capital and technological knowledge, respectively (Allen [1938]). In equations (12) and (13), firms with a larger stock of technological knowledge have a smaller proportion of overseas production when $\sigma_{LZ} > \sigma_{KZ}$. This can be explained intuitively as follows: When labor and technological knowledge are easily substitutable, firms with a greater accumulation of technological knowledge have a relatively smaller input of labor. Consequently, these firms have little incentive to move production to developing countries that have lower wages.

Which of the two elasticities (σ_{LZ} or σ_{KZ}) is thought to be larger? The most direct way to answer this question would be to see the correlation between technological knowledge and the capital labor ratio of parent companies in Japan. By making use of the fact that each company in Japan faces the same relative factor prices, Appendix 2 shows that there should be a positive correlation between the two when $\sigma_{LZ} > \sigma_{KZ}$ and a negative correlation when $\sigma_{LZ} < \sigma_{KZ}$. Although a detailed examination will be made in Section III, we have found a positive correlation coefficient of 0.32 between "R&D intensity (I)" and the capital labor ratio.[8] This means that $\sigma_{LZ} > \sigma_{KZ}$.

As another way to evaluate the relative sizes of σ_{LZ} and σ_{KZ}, we can also refer to past empirical studies on the elasticity of substitution among technological knowledge, labor, and capital, although very few studies have analyzed this issue. The underlying model of these studies, moreover, is not necessarily the same as the one used in our analysis; nor have the studies analyzed the same industries or countries. The estimated values of σ_{LZ} and σ_{KZ} differ widely from study to study.[9]

[8]However, double counting is a problem because our data on capital stock and number of employees include factor inputs for R&D.

[9]Kuninori and Miyagawa (1993) obtained the result that σ_{LZ} is greater than σ_{KZ} by estimating a trans-log cost function for the Japanese economy with the stock of technological knowledge, labor, capital, and energy as the production factors. On the other hand, Nadiri and Schankerman (1981) got the result that σ_{LZ} is smaller than σ_{KZ} by performing a similar estimation for Bell System (U.S.) with the stock of technological knowledge, labor, capital, and raw materials as the production factors. Nadiri and Prucha (1991) and Mohnen, Nadiri, and Prucha (1986) estimated a "dynamic factor input model" with the stock of technological knowledge, labor, capital, and

On the basis of the observed positive correlation between "R&D intensity (I)" and the capital labor ratio in our sample companies, we proceed with our analysis by assuming that the case of $\sigma_{LZ} > \sigma_{KZ}$ is the standard case. However, we do not rule out the possibility of $\sigma_{LZ} < \sigma_{KZ}$ and will consider this case additionally.

It seems probable that besides capital, highly skilled workers (those with high human capital content) are also a production factor that has a close complementary relationship with the stock of technological knowledge. In developing countries with cheap unskilled labor, skilled labor is often scarce. In our model, capital can be replaced by "labor with high human capital content" and labor by "labor with low human capital content." Firms with a larger stock of technological knowledge will then have a lower proportion of overseas production.[10]

Case B. Investment in developed countries

Let country D be one in which Case B applies. The U.S. Department of Commerce data summarized in Table 1 show that although the cost of labor in Japan was lower than in Canada and leading EU countries in 1982,[11] it was highest of all countries in 1989. This reversal was presumably attributable to the yen's appreciation since the Plaza Agreement in September 1985.[12] Thus it is reasonable to assume that in the decision making of

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raw materials and obtained cross-elasticities of demand for production factors, although they did not report the estimates of Allen's partial elasticities of substitution. By denoting the cross-elasticities of labor and capital demand with respect to the cost of R&D by $\eta_{LC}{}^{Z}$ and $\eta_{KC}{}^{Z}$, respectively, we have the following well-known relationship (*see*, for example, Hamermesh [1986]; also easily obtainable from equations in Appendix 2):

$$\sigma_{LZ} - \sigma_{KZ} = \frac{X}{\frac{\partial f}{\partial Z} Z} (\eta_{LC}{}^{Z} - \eta_{KC}{}^{Z})$$

where X is output, f is a production function, and Z is the input of technological knowledge. Because the first term on the right-hand side is positive, $(\eta_{LC}{}^{Z} - \eta_{KC}{}^{Z})$ and $(\sigma_{LZ} - \sigma_{KZ})$ have the same sign. Consequently, the results of Nadiri and Prucha (1991) and Mohnen, Nadiri, and Prucha (1986) imply that σ_{LZ} is greater than σ_{KZ} for the U.S. electric machinery industry and also for the Japanese and U.S. manufacturing industries, and that σ_{LZ} is smaller than σ_{KZ} for the Japanese electric machinery industry and the (West) German manufacturing industry.

[10]Although this is not the question of substitution between technological knowledge and different types of labor, many empirical studies since Griliches (1969) have analyzed the question of substitution across capital, non-production labor (presumably with a high human capital content), and production labor (presumably with a small human capital content). The chief results are summarized as a table in Hamermesh (1986). Many studies report that the substitution between non-production labor and capital is not as easy as the substitution between production labor and capital. Suruga (1991) got a similar result with time-series data on the Japanese manufacturing industry.

[11]Although labor cost in the United States is not revealed in the data, it is presumably slightly higher than in Canada.

[12]We have data on the labor cost of production workers for only two years of the 1980s, as reported in Table 1. But we do have data on the average labor cost of all workers for every year in the 1980s (*U.S. Direct Investment Abroad: Operations of U.S. Parent Companies and Their Foreign Affiliates*). These indicate that a reversal in the comparative cost of labor between Japan and other leading industrial countries occurred about 1985-86.

Japanese companies concerning overseas production until fiscal 1986, the cost of labor at overseas subsidiaries was higher than in Japan. On the other hand, we believe that the cost of capital differed little between Japan and other developed countries. First, capital movements between advanced industrial countries were extremely free in the 1980s with respect to both direct and indirect investment. Second, under tax conventions designed to avoid the double taxation of multinationals, there was little difference between tax burdens on the profits of overseas subsidiaries and those on domestic profits (*see* OECD [1991] for details). Nor was there much difference in private investment deflators across developed countries.

Thus we will mainly discuss the case where subsidiaries of Japanese firms in developed countries have a higher cost ratio of labor to capital than in Japan, namely,

$$\frac{w_D}{r_D} > \frac{w_J}{r_J} \tag{15}$$

However, we will also briefly consider the reverse case.

Japanese firms undertake production in developed countries despite the higher cost of labor (equation [15]) because they manufacture differentiated products and also because they have incentives to circumvent tariff and non-tariff barriers (equation [10]).

Unlike the case of investment in developing countries, this one yields no simple solution of the form (equation [12]) because the condition for the company's optimal behavior (equation [10]) includes the tariff rate. In order to derive the relationship between the stock of technological knowledge Z and the ratio of local production to domestic production (x_D/x_J), a solution must be found by combining all conditions for the company's optimal behavior.

By making assumptions for simplicity, we have basically reached a result opposite to what we got in the case of direct investment in developing countries, when the labor cost in the host country is higher than that in Japan (equation [15]). For example, in the presumably standard case where substitution between labor and technological knowledge is easy ($\sigma_{LZ} > \sigma_{KZ}$) and the cost of labor in the host country is higher than in Japan, companies with a greater accumulation of technological knowledge will have a higher ratio of overseas production to domestic production (x_D/x_J).[13] This is a consequence of

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[13]Assume that a firm produces in only two countries, Japan and developed country D, and that the price elasticity of demand in both is given by $1/(1-\delta)$. Demand in country i is denoted by

$$\omega_i P_i - \frac{1}{1-\delta}, \qquad 0<\delta<1$$

where p_i is the price set by the company in country i. Now assume further that because production cost is high or demand is great in country D, the company is exporting goods from Japan to country D. As shown in Appendix 1, the profit maximization conditions are

$$MC_J(x_J) = MR_J(x_J - e_J) = \lambda$$

and

$$MC_D(x_D) = MR_D(x_D - e_J) = \lambda + \tau$$

companies with a greater accumulation of technological knowledge having a greater tendency to circumvent tariffs by producing in foreign markets. Their labor input is smaller and they are thus less influenced by the higher cost of labor in the host countries.

C. Derivation of Estimation Equations and Generalization of the Model

We will specify regression equations and discuss issues abstracted for the sake of simplicity from the theoretical section.

Regression equations

To test our theory, we must find solutions to some problems.

First we must choose the available data that correspond to the firm's ratio of foreign to domestic production (x_D / x_J). Although data are available on the production of overseas subsidiaries in value terms, none have been available on volume or prices. To focus on overseas production, we have analyzed only overseas subsidiaries engaged in production. However, there is a possibility that some perform only cosmetic processing of the goods manufactured by their parents to circumvent trade barriers. In a subsidiary of this kind, the value of production may be large when actual manufacturing activity is small. Thus we have decided to use the "ratio of overseas value added to domestic value added" as the explanatory variable in our empirical analysis. Under certain conditions, it can be shown that the relationship between technological knowledge and the ratio of overseas to domestic production is directly translated to the relationship between technological knowledge and the ratio of overseas to domestic value added.[14]

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where λ is the imputed product price in Japan; τ is the tariff rate in country D ; x_j and x_D are production levels in Japan and country D ; and e_j is the export of the product from Japan. By differentiating these conditions, we get

$$d\left(\frac{x_D}{x_J}\right) = \frac{x_D}{x}\left\{ C_1\frac{dq_J}{q_J} - C_2\frac{dq_D}{q_D} \right\}$$

where $C_2 > C_1 > 0$ when $\tau > 0$. From this we get the text results. Furthermore: (1) firms with a greater stock of technological knowledge choose a higher ratio of production in developed countries to production in Japan when $(w_D/r_D) < (w_J/r_J)$ and $\sigma_{LZ} < \sigma_{KZ}$; and (2) firms with a smaller stock of technological knowledge choose a higher ratio of production in developed countries to production in Japan when $(w_D/r_D) < (w_J/r_J)$ and $\sigma_{LZ} > \sigma_{KZ}$ or when $(w_D/r_D) > (w_J/r_J)$ and σ_{LZ} is sufficiently larger than σ_{KZ}. When $(w_D/r_D) > (w_J/r_J)$ and σ_{LZ} is not sufficiently larger than σ_{KZ}, the outcome is indeterminate.

[14]We make the following assumptions. First, the price elasticity of demand for the product is $1/(1-\delta)$ and is identical for all firms and all products where $0 < \delta < 1$. Second, the input of the intermediate product needed to manufacture one unit of output fixed and the input coefficient Ψ is identical for all firms. Because of arbitrage, the price of the intermediate product p_M is identical for all countries and all firms. Third, the value of production is obtained by multiplying the volume of production by the local sales price. Under these assumptions, marginal cost in country i can be expressed as

$$MC_i(x_i) = \frac{1}{\gamma} x_i^{\frac{1-\gamma}{\gamma}} q_i + \psi p_M$$

The relationship between x_i, x_j, q_i, and q_j, which can be derived by substituting the above equation into equations (9) and (10), is identical to the relationship obtainable if we assume there is no input of the

Second, we need to measure the company's stock of technological knowledge. We decided to estimate the "R&D stock" from the parent company's past real R&D expenses and to use that as the variable to measure the stock of technological knowledge.

Third, because companies usually produce many goods, we face the problem of being able to observe only the R&D stock aggregated for all goods and the proportion of overseas production averaged for all goods. Because counting the number of goods produced by a company is difficult, a variable must be appropriately chosen to measure its size and thus standardize the R&D stock. Assume for simplicity that the production function of each product is separable and that the stock of technological knowledge is specific to the making of each product.[15] Given the factor prices in each country, as the stock of technological knowledge for use in manufacturing a product increases, so does the amount of production, but the growth rate of production is less than the growth rate of technological knowledge.[16] Consequently, we can expect a positive correlation be-

intermediate product. Consequently, the relationship between output ratio (x_i/x_j) and stock of technical knowledge Z is the same regardless of whether the intermediate good is taken into account. On the other hand, the ratio of value added in country i to value added in Japan is expressed as

$$\frac{(p_i - \psi p_M)\, x_i}{(p_J - \psi p_M)\, x_J}$$

When country i is a developing country (Case A),

$$p_i = p_J = \frac{MC_J}{\delta} = \frac{\lambda_1}{\delta}$$

where λ_1 is the imputed price of the product in the exporting country. Consequently, we have a similar relationship between the ratio of foreign to domestic value added and the stock of technological knowledge to the previously shown relationship between the ratio of foreign to domestic production and stock of technological knowledge. When country i is a developed country (Case B), the value added ratio is given by

$$\frac{(\lambda_1+\tau_i) - \delta\psi p_M}{\lambda_1 - \delta\psi p_M}\frac{x_i}{x_J} = \left(1 + \frac{\tau_i}{\lambda_1 - \delta\psi p_M}\right)\frac{x_i}{x_J}$$

Suppose that value added in Japan is positive because Ψ is relatively small, then the above equation implies that there is a similar relationship between the ratio of foreign to domestic value added and stock of technological knowledge to the previously shown relationship between the ratio of foreign to domestic production and stock of technological knowledge.

[15]As before, we assume that R&D stock has the characteristics of a public good within the same company, such that it can be shared between the parent company and its affiliates. However, we are assuming that different R&D stocks are needed to produce different goods.

[16]We make the same assumptions as in Appendix 1. By the definition of q_i and equation (A-17), we then have

$$\frac{Z}{q_J}\frac{\partial q_J}{\partial Z} = -\frac{1}{\gamma} Z f_Z$$

where f_Z is evaluated in the neighborhood of the solution to the cost minimization problem. On the other hand, we have from equation (5)

$$\frac{Z}{x_J}\frac{dx_J}{d_Z} = \frac{\gamma}{1-\gamma}\left\{-\frac{Z}{q_J}\frac{\partial q_J}{\partial Z} + \frac{Z}{\lambda_1}\frac{d\lambda_1}{dZ}\right\} < \frac{Zf_Z}{1-\gamma}$$

The last inequality is a result of $d\lambda 1/dZ < 0$ as shown in Appendix 1. And, because we assume a production function that does not exhibit increasing returns to scale, we have $Zf_z \leq 1-\gamma$. Thus, it is shown that $(Zdx_j)/(x_j dZ) < 1$.

tween "average R&D stock per product" and the "ratio of R&D stock to value added in Japan," even for aggregated figures. Thus we will use the "ratio of the R&D stock to value added in Japan" instead of the unobservable former variable.

The basic regression equations are given by

$$LDCV_i = a_L + b_L R\&DINT_i + u_{Li} \tag{16}$$

$$DCV_i = a_D + b_D R\&DINT_i + u_{Di} \tag{17}$$

where $LDCV_i$ (DCV_i) is the ratio of the value added of the subsidiaries of parent i in developing (developed) countries to value added in Japan; $R\&DINT_i$ is the ratio of parent company i's R&D stock to value added in Japan.

In the presumably standard case of $\sigma_{LZ} > \sigma_{KZ}$ and $(w_L/r_L) < (w_J/r_J) < (w/r_D)$, we expect b_L to be negative and b_D to be positive. When the stock of technological knowledge is not specific to the manufacture of a product, the stock of technological knowledge per product becomes greater than the observed value of $R\&DINT_i$. The difference becomes greater as the company produces a greater variety of products. In our standard case, we therefore expect the sign of the coefficient of "company size" to be negative when $LDCV_i$ is the dependent variable; we expect it to be positive when DCV_i is the dependent variable.

R&D investment to develop new products

So far, our analysis has considered the relationship between the stock of cost-saving technological knowledge and the proportion of overseas production. We will now examine how the estimation equation will change when we consider the additional functions of R&D: to develop new products and to increase value added.

How developing new products or increasing value added yields advantages to a firm may be modeled in many ways (for details, *see* the models considered in Krugman [1990]). In principle, we can consider these ways as an increase in the number of goods a company can produce (a number that was previously considered fixed) or as an upward shift in the demand curve the company faces. Because both the dependent and independent variables in our estimation equations (16) and (17) are averages for all goods, they are independent of the number of goods the company can produce. Consequently, even if some constant proportion of R&D investment is undertaken to develop new products, equations (16) and (17) are still valid. Also, even if the stock of technological knowledge raises the demand curve for the company, the proportion of overseas production remains unaffected as long as the same demand shift occurs in all the countries.

The setting-up cost and overseas expansion

For a Japanese firm to commence production overseas, there are various set-up costs such as legal fees to establish a subsidiary, the cost to install capital equipment, and the hiring of new employees. When we consider these costs, we must modify our analysis in the following two ways.

First, set-up costs are a sunk cost: Once the investment is made, it cannot be recovered. Thus, a company's decisions regarding overseas production must by dynamic in nature. For example, should circumstances in the past have led the company to enter a foreign market, it will be reluctant to withdraw from that market even if it begins to lose money there, unless it expects losses to continue for a long time. This is because by withdrawing from the foreign market, the company is relinquishing all potential profits from foreign production, which may again become advantageous.[17] Because our corporate data cover only one year of overseas production, however, this type of dynamic consideration was not included in our analysis.

Second, a sizable portion of set-up cost is considered to be fairly uniform for each factory, regardless of the scale of production.[18] Over the long term, this type of scale economy must be operative at home and abroad. We therefore cannot argue that companies with a larger optimal scale of production are more likely to have a larger proportion of overseas production. But set-up costs may be particularly substantial for initiating overseas production because of the additional expenses associated with learning new customs, legal systems, and markets, not to mention languages. We should then expect that companies with larger optimal scales of production are more likely to have a larger proportion of overseas production. This conjecture is a result of the following reasoning. If we consider direct investment to be motivated by a lower foreign wage rate, the variable cost reduction from producing in foreign countries with lower wages will outweigh the higher set-up costs of initiating overseas production only in companies with sufficiently large optimal scales of production. Thus, only larger companies will find it advantageous to start overseas production. This type of mechanism must be considered when the estimated influence of the scale variable on the proportion of overseas production in our empirical analysis is interpreted.

III. Empirical Analysis of the Direct Investment of Japanese Companies

A. The Data

Before proceeding with empirical analysis, we will explain the data. The principal sources are two: (1) some of the questionnaire responses from "Basic Survey of Overseas Business Activities" (hereafter referred to as Basic Survey) conducted every three years by MITI's International Business Affairs Division; and (2) annual securities reports submitted to stock exchanges by listed companies. The summary results of the Basic

[17]The term hysteresis has been applied to this type of phenomenon in which there are several long-term equilibria and the outcome depends on history. (*See*, for example, Baldwin and Krugman [1989]).

[18]Horstman and Markusen (1987b) analyzed the decision to effect direct investment overseas by assuming a constant set-up cost per plant.

Survey in 1987 are reported in MITI's *Third Basic Survey of Overseas Business Activities: Summary Statistics of Overseas Investment.* Compared with other statistical sources on direct investment (for example, those published by the Ministry of Finance or the Bank of Japan), the Basic Survey has several characteristics. As a questionnaire survey, the sample does not contain all direct investments.[19] Although this is a weakness, the Basic Survey has advantages over other statistical sources. First, it provides individual company flow data on such variables as total sales, fixed investment, value of purchases, and the identities of lenders by financial year (our available data is for fiscal 1986). Second, it provides stock data on such variables as fixed assets, balance of debt by creditor, and information on capital formation. Third, it includes separate data for foreign subsidiaries (direct and indirect) and for parent companies in Japan. As a survey of foreign subsidiaries, the Basic Survey provides probably the most detailed data available.

For our analysis, we used some individual company data of the electric machinery industry presented in the third Basic Survey conducted in 1987. It covered Japanese companies (parents) that had reported participation in the management of foreign subsidiaries up to the end of March 1987. For a direct subsidiary to be included in the survey, more than 10% of its equity must, in principle, be owned by its Japanese parent.[20] For an indirect subsidiary, more than 50% of its equity must be owned by a direct subsidiary, which in turn has more than 50% equity participation by its Japanese parent. Thus the survey covers almost all situations where a Japanese parent company establishes a regional management company or a financing company, which in turn establishes a manufacturer. It should be noted, however, that our study covers only those situations in which both the parent company and its foreign subsidiaries belong to the electric machinery industry. Thus the study excludes, for example, those situations in which the parent belongs to the precision instrument industry, although the foreign subsidiary is in the electric machinery industry. According to the third issue of *Summary Statistics of Overseas Investment*, 52 of 446 foreign subsidiaries reported that while their parents were in the electric machinery industry, they themselves were in other industries. Conversely, 287 of 681 foreign subsidiaries reported that while they themselves were in the electric machinery industry, their parents belonged to other industries. Of those 287 subsidiaries, 236 reported that their parents were in non-manufacturing industries (such as services and commerce).[21]

The data we obtained include 126 parent companies (of which 69 were listed on stock exchanges in 1986) and 465 foreign subsidiaries: all belong to the electric machinery

[19]Of 7,112 overseas subsidiaries in all industries receiving questionnaires in the third Basic Survey, 4,570 (64.4%) responded.

[20]Even if the proportion of Japanese equity ownership is less than 10%, equity investment is considered as foreign direct investment when a permanent or close economic relationship with a foreign company has been established. Thus these cases are included in the sample of the Basic Survey.

[21]For example, a Japanese trading company may have equity participation in a foreign concern that belongs to the electric machinery industry.

industry.[22] We use 34 listed parent companies and their 253 subsidiaries because the information necessary for regression analysis (for example, the stock of technological knowledge and value added of subsidiaries) could be obtained only for these companies. The Basic Survey identifies the company with the largest equity participation as the parent when more than one has invested in a foreign subsidiary.

B. The Choice of Dependent and Independent Variables

We will explain the variables we used to analyze the determinants of direct investment by Japanese companies that belong to the electric machinery industry. They are broadly classified into (1) variables that measure the stock of technological knowledge, our primary interest; (2) dummy and other variables used to control other factors; and (3) variables used to test the validity of existing studies.

1. *The dependent variable: the proportion of overseas production*

We use the proportion of overseas production as the dependent variable to measure the scale of overseas production of Japanese companies and to analyze its determinants. The proportion of overseas production is the ratio of the scale of production by foreign subsidiaries to the scale of production by the parent company in Japan. The problem is which variable to use to measure the scale of production for the parent and its foreign subsidiaries. The independent variables used in past studies include a discrete variable (which takes the value of one or zero) for overseas production (Horst [1972]; Grubaugh [1987]; Belderbos [1992]; Hennart and Park [1992]); the balance of overseas investment and lending (Kimura [1989]; Horaguchi [1992]); and the number of foreign subsidiaries or of employees with overseas assignments (Horaguchi [1992]). Other candidates include the sales volume, production volume, capital stock, number of employees, and gross value added of foreign subsidiaries. Except for "value added," however, serious measurement problems exist. First, the "balance of overseas investment and lending" does not include the reinvestment undertaken by foreign subsidiaries by means of borrowing or use of retained earnings. Second, the *Summary Statistics of Overseas Investment* shows that the average size of foreign subsidiaries and average number of employees sent from parents differ widely across host countries. Thus the "number of foreign subsidiaries" and "number of employees with overseas assignments" are both inappropriate as measures of overseas production. Third, "sales volume" and "production volume" are also inappropriate as measures of the scale of production when the degree of vertical integration differs across companies. For example, some sell final

[22]In *General Survey of Companies with Overseas Operations in 1988*, Toyo Keizai Shinposha reported that 133 of the 189 listed companies in the electric machinery industry (as classified by the Tokyo Stock Exchange) had foreign affiliates at the end of 1986. However, these included sales subsidiaries with no production subsidiary.

products manufactured with a minimum of processing of raw materials and parts purchased from their parent companies. If the volume of purchases is large, the value of sales or production also becomes large despite the small scale of manufacturing operations. Fourth, the real "capital stock" of parents may be calculated from the time-series data in annual securities reports. But it is not possible to get an estimate of the real capital stock of foreign subsidiaries because the fixed property value as reported in the Basic Survey is based on book value. Real values cannot be calculated because data on book value are available only for fiscal 1986. Moreover, an estimate of capital stock from the fixed property of overseas subsidiaries cannot be made because the proportion of land in the total value of fixed property is unknown. Finally, the term "number of employees" is problematic given the difficulty of controlling for the difference in labor quality across countries.

For these reasons we used the ratio of the gross value added of the subsidiary to the gross value added of the Japanese parent (called proportion of overseas production) for fiscal 1986 as the variable to measure the degree of overseas activity. The use of value added can avoid the measurement problems mentioned above and is appropriate as a measure of the scale of production activity. When equity participation of the parent in overseas subsidiaries is less than 100%, we get the value of overseas gross value added by multiplying the gross value added of the subsidiaries by the proportion of equity participation. When more than one company has participation in one subsidiary, we first determined the identity of the other partner(s) from Toyo Keizai Shinposha's *General Survey of Companies with Overseas Operations*. In case where the partner was an overseas subsidiary of the parent (for example, a regional management company), we obtained the overall proportion of equity participation by taking into consideration the proportion of equity participation in that subsidiary.[23] How to obtain the value added of both the parent company and its subsidiaries is described in Appendix 3.

As the theoretical model points out, the effect of technological knowledge on the proportion of overseas production differs greatly, depending on whether the host country is a developing country with low labor cost (Case A) or a developed country with high labor cost (Case B). In a standard situation, we surmise that a greater stock of technological knowledge would reduce the proportion of overseas production in Case A and increase it in Case B. So instead of looking at the overall proportion of overseas

[23]For example, when a Japanese company (head office) has a 60% equity share in a Mexican subsidiary and its North American regional management company (in which it has a 100% ownership share) has a 40% equity share, the company's share of equity participation in the Mexican subsidiary is

$$(0.6 + 1 \times 0.4) \times 100 = 100\%.$$

To be strict, if parent companies in Japan have parent-subsidiary relationships with one another, the equity share in a foreign subsidiary should also be adjusted on a consolidated basis. But because the sample does not include all potential parent companies in Japan, we decided to ignore this complication.

production, our analysis will break down overseas production by type of host country.[24] Although the breakdown should ideally be based on unit labor cost, it is not possible to obtain data on this for all countries from the benchmark surveys of the U.S. Department of Commerce (on which Table 1 is based). Thus the breakdown is based on per capita GNP in 1986.

First, as developing countries that correspond to Case A, we chose those classified as "upper middle income countries" or lower by the 1988 issue of the World Bank's *World Development Report* on the basis of per capita GNP in 1986. All Asian (except Japan), Latin American, and African countries are included. The one with the highest per capita GNP in 1986 was Singapore (US$7,410).

On the other hand, as developed countries corresponding to Case B, we chose North America (United States and Canada) and member states of the EC from among those classified as "industrial market economies" in the *World Development Report*.[25] Table 1 shows that the unit labor cost of two EC countries—the United Kingdom and Ireland—was already lower than Japan's in 1982. (Note that the data came from a U.S. source.) We consider the entire EC as one entity, however, because it is an economic area with common trade policies. In this breakdown of countries, Australia, New Zealand, and Spain are not included as either developing or developed countries, even though they are major host countries for Japanese investment. In the gross value added of overseas subsidiaries, they constituted 5.06%. When we included them among the

[24]Kimura (1989) and Belderbos and Sleuwaegen (1993) also performed regression analysis by dividing the host countries into developed countries and South East Asian countries (or NIES) on the presumption that determinants of direct investment by Japanese companies differ between the two regions. Kimura found that in developed countries, the coefficients of the number of patents, the number of products, and total sales (company size) were all positive and significant. He also found that in NIES the coefficients of the share of vertical transactions and the degree of diversification were negative and significant, but that those of total sales were positive and significant. Belderbos and Sleuwaegen found that, in developed countries (North America and Europe), R&D expenditures and marketing intensity, in addition to capital intensive production and liquidity are positively related to the decision to invest; in South East Asia, the decision to invest is mainly related to the development of human resources and organizational skills. Hennart and Park (1992) and Chang and Kogut (1992) also made empirical studies of Japanese direct investment in the United States. They found that besides the coefficients of such corporate variables as R&D intensity, production experience in the U.S., and market shares, the coefficients of trade barriers and other industry variables were positive and significant. Thus direct investment in developed countries is determined differently from that in Asia; the tendency for technical knowledge to exert a positive influence on direct investment is greater. Besides these studies, Kogut and Chang (1991), an empirical analysis at the industry level, treated U.S. investment by Japanese companies as a move to obtain advanced technology from the United States; this hypothesis was reexamined by Drake and Caves (1992). These studies, however, do not base their regression equations on any substantial microeconomic foundations.

[25]Here the EC includes these ten countries: the United Kingdom, France, West Germany, Belgium, Ireland, the Netherlands, Italy, Luxembourg, Greece, and Denmark (In Italy, Luxembourg, Greece, and Portugal, the 34 companies in our sample had no subsidiaries). We excluded Spain because it became a member of the EC in January 1986. The direct investment of Japanese companies in Spain before then cannot definitively be considered as a direct investment in the EC.

industrial countries, the results were but slightly different from those we got by including only North America and the EC.[26] Within the industrial countries, trade barriers in North America and the EC may differ greatly.[27] Thus we will also perform regression analysis separately for each of these regions.

In summary, we use the following variables as the dependent variable. (The value added of foreign subsidiaries is adjusted by the equity proportion of the parent.)

The proportion of production in developing countries:

(total value added of foreign subsidiaries in developing countries)/(gross value added of the parent)

The proportion of production in developed countries:

(total value added of foreign subsidiaries in developed countries)/(gross value added of the parent)

The proportion of production in North America:

(total value added of foreign subsidiaries in North America)/(gross value added of the parent)

The proportion of production in the EC:

(total value added of foreign subsidiaries in the EC)/(gross value added of the parent)

2. *Data on R&D stock*

The variable for each company that plays the central role in explaining the proportion of overseas production is the stock of technological knowledge. To obtain this variable, we derived the stock of R&D from the time series of the R&D expenses of each company.[28] Two kinds of public data exist regarding R&D expenses on an individual company level: annual securities reports submitted to stock exchanges (securities report data), and survey data in Toyo Keizai Shinposha's *Quarterly Report of Listed Companies*

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[26]The per capita GNP of Singapore was higher than that of Ireland and Spain; thus whether that country should be removed from the category of developing countries is a question. However, as seen in Table 1, unit labor cost was significantly lower in Singapore than in Japan, the United Kingdom, and Ireland in 1982 and 1989. Therefore we included it among the developing countries.

[27]Deardorff and Stern (1986) estimated an index of non-tariff barriers of leading industrial countries in terms of tariff equivalents. In their study, the United States had a much lower import barrier against electric machinery than the EC had.

[28]Empirical studies have used R&D expenses or the number of patents (Kimura [1989]) for the year in question as a proxy for the stock of technical knowledge. Because we are interested in the accumulation of technical knowledge, the use of flow values creates theoretical problems. Using the number of patents occasions the following problems. Patents differ widely in economic value; some companies may be reluctant to obtain them, fearful that important technology will be made public and copied by competitors. Much important technology is the know-how resulting from practical efforts to rationalize mass-production processes. Some point out that the source of the technical advantages of the Japanese machinery industry comes from know-how other than that represented by patented technology. *See* Cohen and Levine (1989), Cockburn and Griliches (1989), and Komiya (1992).

(Quarterly Report data). Securities report data list R&D expenses as sales and general administrative expenses and as part of the production cost, making it possible to obtain a fairly long time series (going back to 1969). Of these items, the R&D expenses recorded under sales and general administrative expenses are mainly those incurred by corporate research sections. Those in the production cost are incurred at a company's manufacturing plants. The problem, though, is that most companies make no separate accounting of R&D expenses included in the production cost. Moreover, it is well known that the amount of R&D expenses included in this category is too big to be ignored (*see* Goto, Honjo, Suzuki, and Takinozawa [1986]). On the other hand, R&D expenses in the Quarterly Report data are large relative to those reported by the securities report data for the same period, implying that they may include some of those in the production cost and payment for research conducted by outside companies. But the shortcoming of Quarterly Report data is that they are only available from after 1982 (for only five years), when comprehensive surveys began.

We therefore derived three types of stock of technological knowledge from the above two sets of time-series data of R&D investment expenses by using an appropriate deflator and the perpetual inventory method, similar to the approach by Goto, *et al.* (1986). Then, as in equations (17) and (18), we got a measure of the R&D stock's intensity by dividing the stock of technological knowledge by the gross value added of the parent. For details, *see* Appendix 3.

R&D stock intensity (I): Obtained from the time series of R&D expenses as reported in the section on sales and general administrative expenses of annual securities reports.

R&D stock intensity (II): Obtained from the time series of questionnaire data on R&D expenses as reported in Toyo Keizai Shinposha's *Quarterly Report of Listed Companies.*

R&D stock intensity (III): Obtained by estimating the R&D expenses in production cost on the basis of the difference between R&D expenses reported in Toyo Keizai data and those in the section on sales and general administrative expenses of annual securities reports.

We created these three data sets because of the incompleteness of public data on R&D expenses. Of the three measures, "R&D stock intensity (I)" is desirable because, having been taken straight from annual securities reports, it has no arbitrariness. The problem is that it excludes the R&D expenses that are included in production cost. But this problem is not serious if the ratio of R&D expenses in sales and general administrative expenses and those in production cost differ only slightly across companies. The other two measures are based on the conjecture that the Toyo Keizai data include the R&D expenses in production cost. The problem with these is that their derivations are based on several assumptions (for example, that the ratio of R&D expenses at research sections to those at manufacturing plants remains constant). As another limitation, time-series data can be obtained for only a short sample period.

As data on corporate R&D expenses, we used only the data for the parent companies. In reality, however, R&D expenses are also reported by the overseas subsidiaries producing electric machinery. This deserves some comment.

According to the Basic Survey, many overseas subsidiaries producing electric machinery either did not respond to the questionnaire or reported that their R&D expenses were nil. Even for those that responded positively, the amount of R&D expenses was very small compared with the amount spent by their parent. In fiscal 1986, for example, the average reported value of R&D expenses by subsidiaries was ¥476 million, versus the average of ¥9,236 million for the parents. Moreover, because data on subsidiaries are available only for fiscal 1986, obtaining stock figures from flow data is impossible. Thus we decided not to include the R&D expenses of subsidiaries in obtaining the stock of technological knowledge of the parent companies.[29]

3. *Other explanatory variables*

In choosing explanatory variables other than "R&D stock intensity," we used the following two criteria: (1) variables needed to control for factors other than the stock of technological knowledge; (2) variables needed to verify the validity of past studies and to test the effect of corporate groups (horizontal *keiretsu*). Corresponding to the former are "industry dummies" and the "years of experience with overseas production"; corresponding to the latter are "company size," "advertising intensity," and "*keiretsu* " dummies.

The first purpose of using industry dummies is to control for the differences in technology across industries. Although the analysis in the previous section assumed identical production functions for all companies, the electric machinery industry in reality produces a wide range of products, from computers to heavy electric machinery. Thus technology may differ widely from industry to industry. The set-up cost in direct investment also may differ greatly across industries. In empirical analysis, these differences in technology need to be controlled.

The second purpose of using industry dummies is to control for the differences in trade barriers that industries face. Depending on the type and composition of goods produced, the level of trade barriers should differ across exporting companies. The model of the previous section showed that companies producing goods for which trade barriers are high have a higher proportion of overseas production even if the stock of technological knowledge is identical. A spurious correlation may therefore be created

[29]Furthermore, a parent company will sometimes own R&D subsidiaries in foreign countries. The Basic Survey reports about 20 overseas R&D subsidiaries in the electric machinery industry; the number is not high. Published by the Research Department of the Japan Association of Electronic Machinery Manufacturers, the *Directory of Overseas Subsidiaries* (1991) reports that 33 of the 467 member companies owned 71 overseas R&D subsidiaries in 1991, 49 of them established after 1985. Thus their exclusion from our sample cannot be a serious problem for 1986.

between "R&D stock intensity" and the "proportion of overseas production" through the following mechanism. Assume that each government tends to protect industries producing goods that are intensive in technological knowledge because they generate significant positive externalities.[30] In these industries, direct investment takes place in countries with protective policies in order to circumvent trade barriers. Hence we observe a positive correlation between R&D stock intensity and the proportion of overseas production.

Industry dummies are important in controlling for the spurious correlation created through this type of mechanism, which is different from that assumed in our model.

In the Basic Survey, the identification of an industry classification is based on the self-declaration of each company, but it did not necessarily reflect the company's main product line at the time of the survey. The same problem also exists for other types of industry classifications (for example, the Tokyo Stock Exchange) because of a tendency to identify the industry classification of a company on the basis of its main product line at the time of initial listing. Thus we made our own classification of sample companies as specified by the three-digit Japan Standard Industry Classification (JSIC) numbers on the basis of main product line (that is, the product generating the largest sales) as reported in the annual securities reports. We created the following dummy variables.

Dummy for heavy electric machinery:
: electric machinery for industrial uses (e.g., electric generators, switchboards, control instruments; JSIC 301).

Dummy for communication devices:
: communication devices for both personal and industrial use (e.g., radios, television sets, and audio equipment; JSIC 304).

Dummy for information devices:
: computers and related products (JSIC 305).

Dummy for applied electronic equipment:
: electronic application devices (video equipment and others; JSIC 306).

In the three-digit JSIC, electric machinery for personal use is sometimes classified with machinery for industrial use. As another drawback, such home appliances as visual devices or video cassette recorders (VCRs) and such electronics machinery as computers and semiconductors are spread across several industry classifications. These products have often been targeted for import restrictions and antidumping charges by the United States and the EC. For these reasons, we have also created the following two industry dummies for our regression analysis by rearranging the JSIC system.[31]

[30]This type of policy is called a strategic trade policy. For details, *see* Helpman and Krugman (1989) and Krugman (1990).

[31]The electric machinery products at which antidumping charges were leveled under the EC Anti-Dumping Law before 1986 were concentrated in electronic application devices, such as magnetic heads (1979), VCRs (1982), electronic measuring instruments (1983), and electronic typewriters (1984). The products that were the object of antidumping charges in the United States include transceivers (1983), car telephones (1984), and

Dummy for home appliances:
home electric appliances (e.g., radios, television sets, electric audio equipment, video equipment)
Dummy for electronics devices:
electronics devices and semiconductors (computers and related equipment, semiconductors, and integrated circuits).

Another control variable is the subsidiary's average number of "years of experience with overseas production." The length of experience in foreign countries varies widely across subsidiaries; thus the difference between the oldest and the newest was about 30 years. Although our model does not explicitly consider this, the adaptation of subsidiaries to the different legal and economic systems, customs, and languages of the host countries should be gradually facilitated by the accumulation of experience with production activity.[32] If there is this kind of learning, companies that for some reason or other began foreign production a long time ago may have a lower cost of overseas production, hence a higher proportion of overseas production. To take account of this difference, we created the variable "years of experience with overseas production." To derive this variable for each parent company, the weighted sum was calculated by multiplying the "years of experience with production" of each of its subsidiaries by the respective value-added proportion.

Next we explain the variable chosen to test the validity of past studies on direct investment. The first is "company size," which is meant to test the theory of monopolistic multinationals known as the Hymer (1960)-Kindleberger (1969) hypothesis.[33] Under this hypothesis, large companies with a monopolistic position in the markets for production factors and products can hire the necessary factors of production at a lower cost and take advantage of economies of scale through large-scale advertising and large-scale production. Consequently, they argue that such companies have advantages not only in domestic production, but also in overseas production; therefore they have a greater tendency to

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semiconductors (1985). These charges indicate to Japanese companies that import-restraining measures will soon be impending and thus have the effect of a threat. Japanese companies producing these products will therefore have an incentive to make "tariff-jumping" direct investment. For a more complete list of products to which antidumping charges have been applied, *see* Ikeda (1989) for the EC and the Study Group on Trade Friction Problems (1989) for the United States.

[32]In general, it is known that the profitability of overseas affiliates starts out low and rises with time. Lupo, Gilbert, and Liliestedt (1978) made an empirical analysis of U.S. overseas subsidiaries concerning this. *See* also Landefeld, Lawson, and Weinberg (1992).

[33]This hypothesis has been supported by Horst (1972), Bromstrom and Lipsey (1986), and Grubaugh (1987) for foreign companies, and by Kimura (1989), Belderbos and Sleuwaegen (1993), and Horaguchi (1992) for Japanese companies. In Kimura and Doguchi's regression analyses, though, the dependent variable was not standardized by company size. It is a natural result that the absolute size of direct investment is positively correlated with the absolute scale of the parent. Thus we cannot conclude from this result that a larger company has a greater preference for overseas production. A representative argument against the view that direct investment is specific to larger companies is on page 189 of Komiya (1972).

engage in overseas production. To test this hypothesis, we include "company size" as an explanatory variable.

As pointed out in the previous section, when the stock of technological knowledge is not specific to the manufacture of a product, the stock of technological knowledge per product becomes greater than the observed value of R&D stock intensity. Thus "company size" may have a positive influence on the proportion of overseas production when direct investment is made in developed countries (with a higher wage); and may have a negative influence in developing countries (with a lower wage). As a variable to measure company size, we used the real stock of capital obtained from the time series of past investment expenses (in millions of yen) in plant and equipment by the perpetual inventory method.[34] For details, refer to Appendix 3.

"Advertising intensity" is used to see the correlation between direct investment and the amount of marketing know-how or the ability to effect product differentiation, both of which are another form of intangible asset. This variable has often been used in past studies. Companies with a greater accumulation of marketing know-how and with greater skills in advertising have greater ability to realize an upward shift in the market demand curve for their products. They can also employ a more tactful sales strategy in the foreign market because of the accumulation of know-how. Moreover, companies with a greater focus on advertising expenses should tend to have a greater degree of product differentiation; thus they have greater monopolistic power over the purchasers of their products. For this reason advertising intensity has been considered as a measure of the monopolistic power of companies in product markets.

However, this variable poses the following problems. First, for it to have a positive correlation with direct investment, know-how or brand appeal in the home market must be directly applicable in the host market. This assumption cannot be realistic. Second, even if we accept this assumption, it is still an insufficient reason to take the trouble to establish a production site in a foreign country. Companies with marketing know-how or established brand appeal should just as easily be able to export their products to the foreign market.[35]

To obtain numerical values for "advertising intensity" for each company, we did not derive stock figures because of the lack of data regarding the rate of depreciation on the

[34]We explain in Appendix 3 that we used two types of depreciation rate to get two sets of data on capital. The results of regression analysis did not change materially regardless of which data set was used. We also used "gross value added" of the parent as a variable to measure company size. Here too the results were basically the same as those when the stock of capital was used. For simplicity of presentation, we simply report the results from using the stock of capital calculated with a depreciation rate of 8.1%.

[35]Even within the same electric machinery industry, the size of advertising expenses differs widely, depending on whether the parent company manufactures products for industrial use or for personal use. Compared with producers of heavy electric machinery, producers of home appliances have a greater propensity to advertise their products widely to consumers. If no control is made for these differences in the nature of electric products, the inclusion of advertising intensity as an explanatory variable can create a false impression of its explanatory power.

accumulation of marketing know-how. Instead, we took the average of advertising expenses and sales promotion expenses during the three years from 1984 to 1986 and divided them for each company by the gross value added of its parent (the deflator was the index of general consumer prices, exclusive of the prices of perishable foods) to obtain the variable for "advertising intensity." The data on each item of expenses were obtained from annual securities reports.

A *keiretsu* dummy is used to test the conjecture of Hoshi, Kashyap, and Scharfstein (1989) about the difference in direct investment behavior between Japanese companies that belong to a horizontal *keiretsu* and those that are independent. In an empirical analysis of the domestic investment of Japanese companies (Hoshi, Kashyap, and Scharfstein [1991]), they found that those belonging to a *keiretsu* or a corporate group were less subject to the liquidity constraint in the financing of plant and equipment. On this basis they surmise that the active direct investment of Japanese companies is also attributable to corporate groups or to the main bank system.[36] If it is more difficult for domestic lenders to monitor overseas investment than domestic investment, and if a corporate group or the main bank system is effective as a means of economizing the cost of gathering information, there is a possibility that companies with a stable main bank relationship may be less subject to the liquidity constraint and have a greater proportion of overseas production. Six corporate groups (Mitsubishi, Mitsui, Sumitomo, Fuyo, Sanwa, and Daiichi Kangyo) are well-known horizontal *keiretsu* in Japan. However, because horizontal *keiretsu* has no established definition,[37] we created a *keiretsu* dummy on the basis of the following three definitions.

Keiretsu dummy (I): One for companies belonging to the presidents' clubs of the above six corporate groups; 0 for others.

Keiretsu dummy (II): One for all companies whose largest creditor banks were the main banks of the above six corporate groups for three consecutive years, as reported in the 1988 edition of *Summary Statistics of Corporate Groups* (*Kigyo Keiretsu Souran*), published by Toyo Keizai Shinposha; 0 for others.

Keiretsu dummy (III): One for companies classified as belonging to the above six corporate groups by the 1989 edition of Keizai Chosa Kyokai's *Study of Keiretsu* (*Keiretsu no Kenkyu*); 0 for others.

C. An Overview of Direct Investment by Japanese Companies

Before proceeding with regression analysis, we will undertake a preliminary investigation of the proportion of overseas production, R&D stock intensity, and other major variables by type of industry classification and by company size. We used the JSIC system, the one used to create industry dummies according to the main product line of the parent companies and not the industry classification reported in the Basic Survey. In

[36] *See* Belderbos and Sleuwaegen (1993) for an empirical study concerning this issue.

[37] *See* Uryu, Sunada, and Nakahashi (1992) for a survey of the types and state of Japanese corporate *keiretsu*.

our theoretical model, intercompany differences in the optimal capital labor ratio were an important determinant of the proportion of overseas production. Thus we have also obtained the "capital labor ratio" (in millions of yen per employee) by dividing the real stock of the parent company's capital by the number of its employees to learn the relationship with other variables. To see the extent of production in the geographical areas excluded from our sample, we also created data on the "proportion of overseas production in the world."

The geographical distribution of the value added of 253 subsidiaries of the 34 parent companies in the sample reveals that the proportion of direct investment in developed counties is high (78.62% of the value added of all subsidiaries) for the electric machinery industry. The proportion of U.S. production is especially high at 57.22%.[38] As seen in the previous section, the sales of U.S. subsidiaries are almost exclusively directed to the U.S. market; thus an important part of direct investment in the electric machinery industry is investment directed at the consumer market. In Asia, as many as 30 of the 34 sample companies have established foreign subsidiaries. The number of subsidiaries in the region is also large, although average size is much smaller than in developed countries. (Asia has 111 subsidiaries, the United States 40.)

Table 2 summarizes the average values of the explanatory and dependent variables by industry classification. Producers of information devices (such as computers) and electronic application devices (such as video equipment) have a high proportion of overseas production in developed countries, far exceeding the proportion of any other industry category. They also have an extremely high proportion of overseas production even when the host countries are worldwide. Because these companies' products have frequently been the subject of trade friction, it may be surmised that the "tariff-jumping" type of direct investment has taken place. In Table 2, however, these companies also have high R&D intensity; they are capital-intensive high-technology industries. On the other hand, those categories with lower R&D intensity (such as heavy electric machinery) have a lower proportion of overseas production, which is centered in developing countries. This is consistent with our conjecture. In the previous section's model, if Allen's partial elasticity of substitution between labor and the stock of technological knowledge is greater than that between capital and the stock of technological knowledge (the standard case), companies with a greater accumulation of technological knowledge tend to have a higher proportion of production in developed countries with a relatively

[38]The shares are 60.2% for North America; 20.45% for Europe (5.42% for the former West Germany; 4.84% for the United Kingdom, and 4.83% for the Netherlands, to cite the main ones); 3.05% for Oceania; 11.42% for Asia (4.53% for Taiwan and 3.15% for Singapore, to cite the main ones); 4.83% for Latin America; and 0.05% for Africa. The simple averages: 0.19 (maximum 1.29) for proportion of overseas production; 0.095 (maximum 1.02) for proportion of production in North America; 0.041 (maximum 0.27) for proportion of production in the EC; and 0.054 (maximum 0.45) for proportion of production in the developing countries. The average value of R&D stock intensity (I) was 0.49 (maximum value 1.85), and for "years of experience with overseas production", 11.3 years (maximum 24.8).

Table 2

The Average Values by Industrial Category

	proportion of production overseas	proportion of production in developing countries	proportion of production in developed countries	proportion of production in North America	proportion of production in EC	Capital to labor ratio (¥ millions)	Company size (¥ millions)	R&D stock intensity (I)	R&D stock intensity (II)	R&D stock intensity (III)	Advertising intensity	years of experience with overseas production
Heavy electric machinery (3)	0.1329	0.1199	0.0130	0.0130	0	7.85	15,676	0.0979	0.5868	0.5521	0.0311	12.61
Communication devices(13)	0.1428	0.0650	0.0732	0.0564	0.0168	9.02	74,124	0.4153	1.1220	1.0356	0.1786	11.54
Information devices(7)	0.2691	0.0234	0.2360	0.1558	0.0802	15.14	505,078	0.9842	1.7839	1.6691	0.2231	12.20
Applied electronic equipment(4)	0.5119	0.0562	0.4557	0.3372	0.1185	12.42	116,142	0.7220	1.6500	1.5974	0.3206	12.82
Others(7)	0.0932	0.0472	0.0461	0.0307	0.0154	10.65	25,658	0.1790	0.6064	0.5240	0.0203	10.19

Industries categories

Heavy electric machinery: electric machinery for industrial use,such as electric generators, switchboads,and electric distribution devices

Communication devices: cable and wireless communication devices,radios, television sets and audio products.

Information devices: computers and related products

Applied electronics equipment: VCRs and other applied electric equipment

Others: all others

Note: Figures in parentheses = no. of parent companies in each eategory.

higher labor cost.

In the correlation matrix (Table 3), "R&D stock intensity" has an especially significant positive correlation with the "proportion of production in developed countries," although it has a negative correlation with the "proportion of production in developing countries." The difference in R&D intensity may be reflected in the difference in the geographical pattern of production. The positive correlation between R&D intensity and the capital labor ratio (i.e., as the stock of technological knowledge increases per product manufactured, the capital labor ratio increases through the substitution of labor) is consistent with the standard case of the theoretical model.

Next, Table 4 reports the average values of each variable classified according to the size (the real stock of capital) of the parent. It is observed here that as company size increases, the proportion of production in a developed country increases and in developing countries it decreases. R&D stock intensity also increases with company size. As far as the correlation matrix is concerned, however, the correlation between company size and the proportion of overseas production (in developing and developed countries) is not high. Our analysis has so far failed to verify the theory of Hymer and others about monopolistic multinationals.

Although Tables 2 and 4 show a large variance in advertising intensity across industry categories, advertising intensity is far higher among producers of electrical home equipment than those of heavy electric machinery; moreover, larger companies are more intensive in terms of advertising expenses. But we find no strong positive correlation with the proportion of overseas production, except for the high positive correlation with production in the EC.

The "years of experience with overseas production" across industry categories varies little. In terms of the correlation matrix, though, it has a high correlation with the proportion of overseas production and with R&D stock intensity.

D. Analysis of Direct Investment by Japanese Companies in Developing and Developed Countries

In what follows, we divide the sample countries into a developing country "region" (with lower labor cost) and a developed country "region" comprised of North America and the EC. Then for each region we regress the proportion of production on R&D intensity and other explanatory variables.

Some problems occur in the treatment of data. First, when using cross-sectional data we often encounter heteroscedasticity. So instead of applying ordinary least squares (OLS) directly, we used White's (1980) heteroskedasticity-consistent covariance matrix estimators.

Second, our sample includes only companies that responded to the "Basic Survey," namely, those engaged in overseas production. Consequently, companies not engaged in overseas production and companies that are so engaged but which failed to respond to

Table 3
Correlation Matrix

	proportion of production overseas	proportion of production in developed countries	proportion of production in North America	proportion of production in EC	proportion of production in developing countries	Company size (capital stock) (¥ millions)	Capital to labor ratio (¥ millions)	R&D stock intensity (I)	R&D stock intensity (II)	R&D stock intensity (III)	Advertising intensity	Years of experience with overseas production
proportion of production overseas	1.00000											
proportion of production in developed countries	0.93064	1.00000										
proportion of production in North America	0.92047	0.97834	1.00000									
proportion of production in EC	0.75713	0.84153	0.71149	1.00000								
proportion of production in developing countries	0.32472	-0.04093	-0.01592	-0.09741	1.00000							
Company size(capital stock)	-0.05805	0.00544	-0.00115	0.02148	-0.22727	1.00000						
Capital to labor ratio	0.19646	0.21960	0.22623	0.15508	-0.04928	0.44780	1.00000					
R&D stock intensity (I)	0.39900	0.54782	0.55832	0.40266	-0.36571	0.45909	0.31949	1.00000				
R&D stock intensity (II)	0.44089	0.54041	0.57718	0.32826	-0.22598	0.47010	0.35968	0.81773	1.00000			
R&D stock intensity (III)	0.42667	0.50358	0.53762	0.30648	-0.18656	0.49134	0.35437	0.84027	0.94488	1.00000		
Advertising intensity	0.12030	0.22345	0.15052	0.36575	-0.25664	0.11398	0.22997	0.29241	0.34641	0.35901	1.00000	
Years of experience with overseas production	0.49668	0.41790	0.42784	0.30213	0.23213	0.28267	0.14130	0.34106	0.43771	0.48641	-0.01957	1.00000

Table 4

The Average Values by Company Size (measured by the real capital stock: in millions of yen)

	proportion of world production	proportion of production in developing countries	proportion of production in developed countries	proportion of production in North America	proportion of production in EC	Capital to labor ratio (¥ millions)	R&D stock intensity (I)	R&D stock intensity (II)	R&D stock intensity (III)	Advertising intensity	Years of experience with overseas production
Less than 10,000(8)	0.1260	0.0875	0.0385	0.0382	0.0003	5.49	0.1711	0.5171	0.5305	0.0270	10.39
10,000~100,000(17)	0.2013	0.0597	0.1416	0.0862	0.0554	11.79	0.4024	0.9418	0.8506	0.1741	10.70
100,000 and more(9)	0.2675	0.0231	0.2303	0.1839	0.0463	14.06	0.8999	2.1701	2.0173	0.2475	14.54

Note: Capital stock in real terms (Appendix 3). Figures in parentheses = no. of parent companies in each category.

the "Basic Survey" are excluded, with the possibility of creating a sample selection bias.[39] Because R&D intensity (I) cannot be obtained for one of the 34 sample parent companies, the sample includes only 33 companies for regression tests. Twenty-nine or 30 of them have production in developing countries and 24 in developed countries (20 in North America and 18 in the EC).

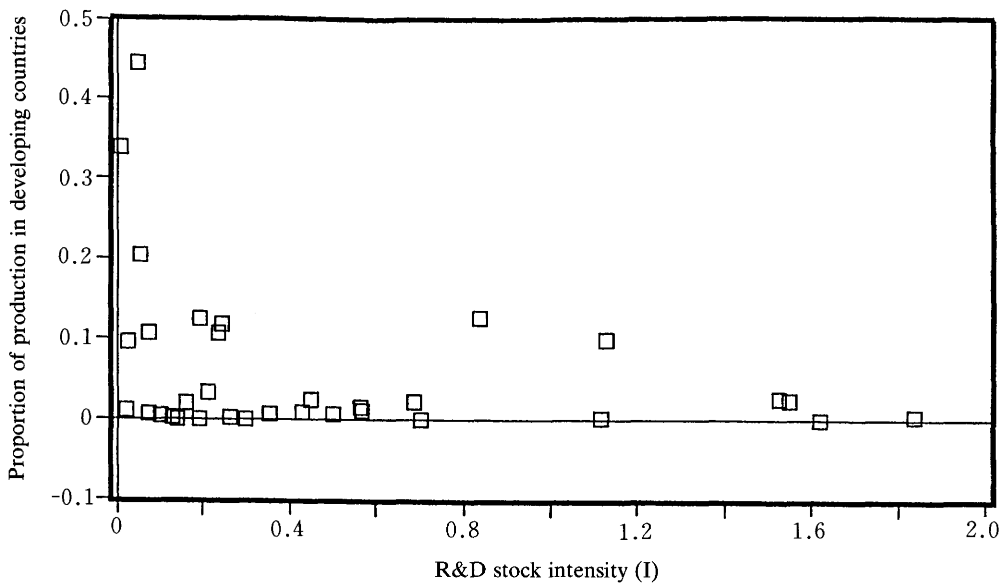
In the regression analysis of the proportion of overseas production in each region, we have excluded companies that have no production in that region. To exploit the information in the excluded companies, however, we have also performed estimations based on the Tobit model by including them.[40] Thus it should be noted that companies with no production in developing countries means those with overseas production, but not in developing countries.

1. *Direct investment in developing countries (Case A)*

In Section II we showed that if Allen's partial elasticity of substitution between labor and the stock of technological knowledge is greater than that between capital and the stock of technological knowledge, the proportion of production in a low labor cost region becomes smaller.

In Figure 1, the relationship between "proportion of production in developing

Figure 1



[39]If only those companies with no overseas production are excluded, the bias would be to reduce the absolute value of regression coefficients when R&D stock intensity is a unique explanatory variable in an OLS estimation. For details, *see* Maddala (1983).

[40]For the Tobit model, *see* Greene (1993) and Maddala (1983).

countries" and "R&D stock intensity (I)" is plotted (including companies for which the value of the dependent variable is zero). From this figure we can see a negative correlation between the two. Table 5 reports the results of running linear regression by the White method. Twenty-nine or 30 sample companies (of the 34) have production in developing countries. Simple regression shows that the coefficients of R&D intensity (I) and R&D intensity (III) are negative and significant at the 5% level. On the other hand, although the coefficient of R&D intensity (II) is negative, it has a low *t* value; thus the theory is not supported. As pointed out already, however, of the three measures of R&D intensity, R&D intensity (I) is presumably the most reliable. When we use R&D intensity (I) as an explanatory variable, the coefficient always remains negative and significant and the estimates are stable, even when other explanatory variables (such as industry dummies) are included in regression equations. These results are consistent with our theoretical analysis.

As stated in the theoretical section, our theory still holds true when in our model capital is replaced by skilled labor (labor with a high human capital component) and labor by unskilled labor (labor with a small human capital component). The production of technology intensive goods should require highly skilled labor. In this context, developing countries have a relatively low accumulation of human capital; this means that the relative wage of skilled labor should be higher than in developed countries. The third issue of *Summary Statistics of Overseas Investment* distinguishes the "difficulty of securing a sufficient amount and a sufficient quality of labor" as the problem of the host country by a high proportion (44%) of subsidiaries in developing countries (Asia and Latin America) in the electric machinery industry. In contrast, the same difficulty is pointed out by 35% of subsidiaries in North America and 30.3% of subsidiaries in the EC. It may reflect the shortage of skilled labor in developing countries.

Even if we include industry dummies, the coefficient of R&D intensity (I) is consistently negative and the estimates and *t* values are stable. None of the industry dummies is statistically significant. This result contrasts with results of the regression analysis of the "proportion of production in developed countries" (discussed below), in which some industry dummies are found significant. The difference may be attributable to no serious trade friction having been experienced with developing countries in regard to electric machinery products; "tariff-jumping" investment there has only been slight.

The other statistically significant variables are "years of experience with overseas production" (with a positive sign) and "company size" (with a negative sign). The former result may reflect, as mentioned earlier, that the adaptation to a host country takes time; companies that began foreign production a long time ago have an advantage over latecomers.

In Section II, we pointed out that "company size" may be negatively correlated with the proportion of production in developing countries. The coefficient had the right sign and significance. To put it differently, this result does not support the Hymer-

Table 5

Regression Analysis on Determinants of Direct Foreign Investment in Developing Countries

Dependent Variable: Proportion of production in developing countries

Method: OLS (variances are heteroskedastic-consistent estimates)

constant	0.101	0.080	0.081	0.081	-0.009	0.092	0.092
	(3.21)[c]	(3.69)[c]	(3.76)[c]	(3.68)[c]	(-0.21)	(2.71)[b]	(3.33)[c]
R&D stock intensity (I)	-0.083	-0.094	-0.088	-0.085	-0.138		
	(-2.56)[b]	(-2.60)[b]	(-2.53)[b]	(-2.79)[b]	(-2.85)[c]		
R&D stock intensity (II)						-0.024	
						(-1.53)	
R&D stock intensity (III)							-0.025
							(-2.09)[b]
Heavy electric machinery		0.049	0.048	0.050	0.035		
(dummy)		(0.55)	(0.54)	(0.56)	(0.42)		
Communication devices		0.019	0.019	0.029	0.029		
(dummy)		(0.40)	(0.41)	(0.57)	(0.67)		
Information devices		0.035	0.059	0.045	0.064		
(dummy)		(0.90)	(1.51)	(1.09)	(1.51)		
Applied electronic equipment		0.044	0.046	0.064	0.055		
(dummy)		(0.90)	(0.97)	(1.27)	(1.31)		
Company size			-0.60×10^{-7}				
			(-2.41)[b]				
Advertising intensity				-0.086			
				(-1.48)			
Years of experiences with overseas production					0.009		
					(2.04)[a]		
Sample	29	29	29	29	29	30	30
Adj.R^2	0.129	0.180	0.193	0.208	0.123	0.045	0.040

Note: Figures in parentheses are *t*-statistics (in two-tail tests).

a: significant at the 10% level b: significant at the 5% level c: significant at the 1% level

Kindleberger hypothesis. But in the analysis of "company size," we cannot ignore sample selection bias. Suppose that the optimal scale of production is sufficiently large. Small companies may then not initiate foreign production or tend to have a high proportion of it if they do decide to begin operations abroad. On the other hand, assume that large companies are like a composite of many small ones, they will then have a positive but small proportion of overseas production because of the law of large numbers. Under these circumstances, because companies with no overseas production are excluded from the sample, the small ones (with no overseas production) are excluded. The outcome of the bias then may be to increase the proportion of overseas production of the smaller companies.

"Advertising intensity" is not significant and has the wrong sign. We have pointed out earlier the theoretical link between advertising intensity and proportion of overseas production is weak. This conjecture is empirically supported.

Finally, we examine the estimation results, using the Tobit model, which included those companies for which the value of the dependent variable was zero (Table 6). Here, too, R&D intensity (I) has a negative and a statistically significant coefficient, as with the results of linear regression.

From these two types of estimation results, we have found an empirical support to our assertion that companies with a smaller R&D stock intensity have a higher proportion of overseas production in developing countries.

2. *Direct investment in developed countries (Case B)*

"Developed countries" refer to those countries in which unit labor cost was higher than in Japan when the data were collected. Specifically, we performed estimation with North America and the EC as developed regions.

These areas have harbored an increasing protectionist tendency since the 1980s. In particular antidumping charges have been leveled and import restrictions introduced against the industrial products of Japanese companies. Consequently, despite the higher labor cost, Japanese companies have been increasing production in these areas to circumvent trade barriers. Under these circumstances, as shown in the previous section, companies with a greater accumulated stock of technological knowledge have a higher proportion of overseas production if the elasticity of substitution between labor and the stock of technological knowledge is sufficiently greater than it is between capital and the stock of technological knowledge.

Figure 2 plots "R&D intensity (I)" and the "proportion of production in developed countries," including companies for which the value of the dependent variable is zero. As in the analysis of developing countries, Table 7 reports the estimation results from linear regression, using the White method. The sample includes 24 companies that had production in developed countries. Although the coefficients of "R&D intensity (I)" and "R&D intensity (II)" have a positive sign and are sometimes significant, the results are not

Table 6

Regression Analysis on Determinants of Direct Foreign Investment in Developing and Developed Countries

Method: Tobit analysis

	Dependent variable: Proportion of production in developing countries			Dependent variable: Proportion of production in developed countries		
Constant	0.045	0.052	0.046	-0.054	-0.195	-0.041
	(1.15)	(1.76)[a]	(1.18)	(-0.59)	(-2.22)[b]	(-0.49)
R&D stock intensity (I)	-0.103	-0.090	-0.099	0.269	0.309	0.292
	(-2.30)[b]	(-2.54)[b]	(-2.20)[b]	(2.77)[c]	(3.34)[c]	(3.30)[c]
Heavy electric machinery	0.085		0.084	-0.117		-0.109
(dummy)	(1.24)		(1.24)	(-0.64)		(-0.66)
Communication devices	0.041		0.041	-0.091		-0.084
(dummy)	(0.84)		(0.84)	(-0.77)		(-0.79)
Information devices	0.080		0.100	0.025		0.210
(dummy)	(1.23)		(1.34)	(0.17)		(1.35)
Applied electronic equipment	0.085		0.088	0.315		0.336
(dummy)	(1.27)		(1.31)	(2.06)[b]		(2.43)[b]
Home appliances		0.071			0.237	
(dummy)		(1.67)			(2.09)[b]	
Electronics devices		0.062			0.141	
(dummy)		(1.33)			(1.17)	
Company size		-0.50×10^{-7}			-0.44×10^{-6}	
			(-0.54)			(-2.25)[b]
Sigma	0.097	0.096	0.097	0.224	0.245	0.202
	(7.55)	(7.54)	(7.54)	(6.86)	(6.86)	(6.84)
Sample	33	33	33	33	33	33

Note: Figures in parentheses are *t*-statistics (in two-tail tests). a: significant at the 10% level b: significant at the 5% level c: significant at the 1% level

Table 7

Regression Analysis on Determinants of Direct Foreign Investment in Developed Countries

Dependent Variable: Proportion of production in developed countries

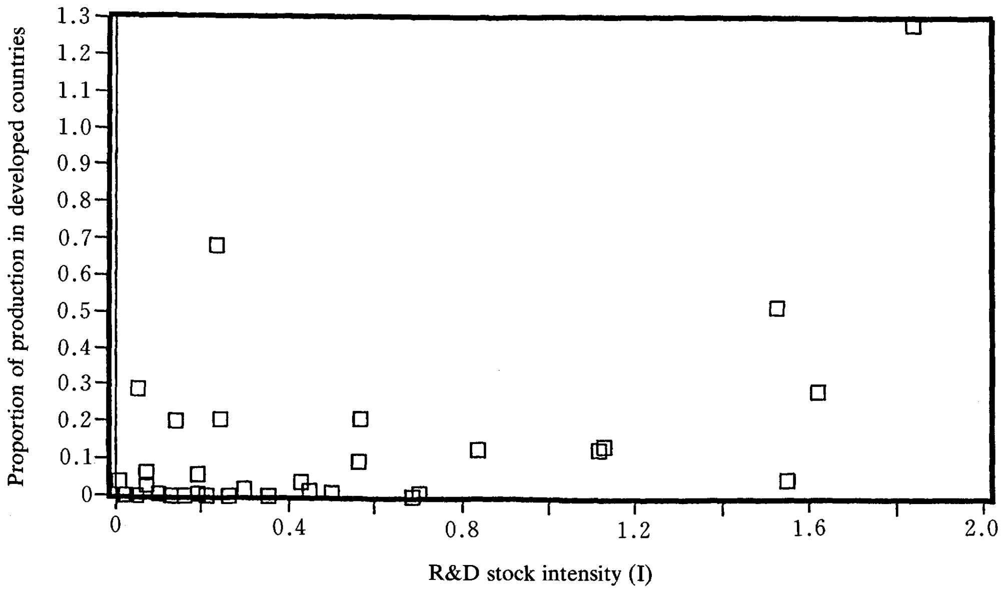
Method: OLS (variances are heteroskedastic-consistent estimates)

Cconstant	0.034	0.021	0.031	0.022	-0.136	0.002	0.005
	(0.48)	(0.50)	(0.71)	(0.51)	(-1.25)	(-0.05)	(0.10)
R&D stock intensity (I)	0.256	0.247	0.273	0.248	0.154		
	(1.73)[a]	(1.50)	(1.88)[a]	(1.51)	(1.24)		
R&D stock intensity (II)						0.113	
						(1.74)[a]	
R&D stock intensity (III)							0.113
							(1.28)
Heavy electric machinery		0.015	0.011	0.016	-0.051	-0.049	-0.040
(dummy)		(0.38)	(0.27)	(0.39)	(-1.53)	(-1.94)[a]	(-1.37)
Communication devices		-0.058	-0.051	-0.048	-0.028	-0.042	-0.028
(dummy)		(-0.74)	(-0.69)	(-0.52)	(-0.42)	(-0.57)	(-0.34)
Information devices		-0.029	0.172	-0.021	0.015	0.037	0.042
(dummy)		(-0.14)	(0.74)	(-0.10)	(0.08)	(0.25)	(0.25)
Applied electronic equipment		0.256	0.282	0.267	0.265	0.272	0.269
(dummy)		(1.73)[a]	(2.01)[a]	(1.87)[a]	(2.15)[b]	(1.89)[a]	(1.90)[a]
Company size			-0.47×10^{-6}				
			(-2.04)[a]				
Advertising intensity				-0.040			
				(-0.18)			
Years of experiences with overseas production					0.017		
					(1.74)[a]		
Sample	24	24	24	24	24	25	25
Adj.R^2	0.219	0.236	0.360	0.192	0.264	0.230	0.164

Note: Figures in parentheses are *t*-statistics (in two-tail tests).

a: significant at the 10% level b: significant at the 5% level c: significant at the 1% level

Figure 2



robust. However, both in simple regression and in multiple regression with other variables included, the coefficient estimates are stable.[41]

Almost always the coefficient of the dummy variable for applied electronic equipment was positive and significant, which is consistent with the trade friction concerning such products. This gives substance to the observation that tariff-jumping direct investment has occurred. Even when the industry dummies were included, the coefficient of R&D intensity remained positive and significant. Thus the tendency of companies that are more intensive in technological knowledge to produce in developed countries is probably not a spurious one, nor does it result from strategic trade policy being concentrated in the production of goods that are technology intensive. Most likely, this tendency is attributable to the mechanism suggested in our model.

Even in the results of estimation based on the Tobit model (Table 6) the coefficients of R&D intensity and the dummy variable for applied electronics equipment, also for home appliances, were positive and significant. The inclusion of manufacturers producing such applied electronics equipment as VCRs with those producing home appliances must have affected the results.

In order to see that a difference may exist between the EC and North America concerning the influence of trade barriers or wage levels, regression analysis was per-

[41]We find one company in Figure 2 whose "R&D stock intensity" and "proportion of production in developed countries" are both far greater than those of other companies. Because the estimation results may have been influenced by this single observation, we have also performed regression analysis by excluding this company. The coefficient of R&D stock intensity remained positive and significant.

formed by breaking down the sample of developed countries into those two regions. The results are reported in Table 8 (for linear regression) and in Table 9 (for the Tobit model). The sample included 20 for North America and 18 for the EC.

The results show that in both areas the coefficient of R&D intensity was positive. But the coefficient estimate was much higher for regression for the United States, and the *t* values were also higher. As for industry dummies, the coefficient of the dummy variable for applied electronics equipment was often positive and significant for both areas. Furthermore, in the regression analysis of the EC, the dummies for home appliances and electronics devices (obtained by rearranging the three-digit JSIC code) were both positive and significant (Tobit model). Several reasons can be given for this difference. First, the wage level in North America, especially in the United States, was very high by international standards in 1986; North America was therefore probably the area most applicable to Case B of the theoretical analysis. In contrast, the wage level in the EC was not necessarily high (i.e., as early as 1982, the wage levels in Ireland and the United Kingdom were lower than the level in Japan, as Table 1 shows). Consequently, the coefficient of R&D intensity may be very significant concerning direct investment in the United States, but not so significant in the EC. Second, the EC has maintained higher trade barriers against electric machinery, compared with the United States. This has resulted in a strong motive for tariff-jumping direct investment in the EC. This difference in the degree of foreign production across companies may have been captured by industry dummies.

Table 7 shows that the coefficient of R&D intensity remained significant even when we included "company size" as an explanatory variable in the regression equation of the proportion of production in developed countries. Although we had predicted the sign of company size to be positive, because of the applicability of technological knowledge to the production of many goods, the coefficients were always negative and significant (both for linear regression and the Tobit model). In this regard, we need to explore the possibility of sample selection bias, as discussed earlier. For now we can say that the Hymer-Kindleberger hypothesis is not supported.

"Advertising intensity" is again negative and insignificant. We did not obtain any results suggesting that this variable was an important determinant of direct investment.

The coefficient of "years of experience with overseas production" has a lower *t* value compared with the case of developing countries, but it is positive and significant. Although less significant than in developing countries, the adaptation of companies to different systems and languages may be accomplished by the accumulation of experience with overseas production.

To summarize, as predicted by the theoretical model, companies with greater R&D intensity have a higher proportion of production in developed countries (especially the United States). Moreover, the coefficient estimates of industry dummies have suggested the possibility that tariff-jumping direct investment is occurring (especially in the EC).

Table 8

Regression Analysis on Determinants of Direct Foreign Investment in North-America and EC

Method: OLS (variances are heteroskedastic-consistent estimates)

	Dependent variable: Proportion of production in North-America			Dependent variable: Proportion of production in EC		
Constant	0.030	-0.038	0.005	0.024	0.008	0.034
	(0.53)	(-0.44)	(0.15)	(1.31)	(0.44)	(1.25)
R&D stock intensity (I)	0.202	0.224	0.218	0.017	0.050	0.068
	(1.72)[a]	(2.08)[a]	(1.66)	(0.26)	(0.85)	(1.55)
Heavy electric machinery			0.033			
(dummy)			(1.03)			
Communication devices			0.004	0.007		
(dummy)			(0.06)	(0.29)		
Information devices			-0.063	0.071		
(dummy)			(-0.41)	(0.93)		
Applied electronic equipment			0.175	0.119		
(dummy)			(1.34)	(1.75)[a]		
Home appliances		0.194			0.030	
(dummy)		(1.89)[a]			(1.14)	
Electronics devices		-0.031			0.060	
(dummy)		(-0.34)			(1.08)	
Sample	20	20	20	18	18	18
Adj.R^2	0.229	0.320	0.193	0.132	0.052	0.120

Note: Figures in parentheses are *t*-statistics (in two-tail tests).
a: significant at the 10% level b: significant at the 5% level c: significant at the 1% level
In our samples, there is no heavy electric machinery firm which operates in EC, therefore we do not use heavy electric machinery dummy in the related regression analysis.

Table 9

Regression Analysis on Determinants of Direct Foreign Investment in North-America and EC

Method: Tobit analysis

	Dependent variable: Proportion of production in North-America			Dependent variable: Proportion of production in EC		
Constant	-0.058	-0.169	-0.047	-0.028	-0.103	-0.101
	(-0.73)	(-2.17)[b]	(-0.66)	(-0.69)	(-2.52)[b]	(-2.65)[b]
R&D stock intensity (I)	0.241	0.265	0.256	0.044	0.061	0.081
	(2.85)[c]	(3.24)[c]	(3.29)[c]	(1.04)	(1.61)	(2.23)[b]
Heavy electric machinery	-0.086		-0.080	-0.554		
(dummy)	(-0.55)		(-0.56)	(-0.001)		
Communication devices	-0.173		-0.162	-0.014		
(dummy)	(-1.55)		(-1.59)	(-0.28)		
Information devices	-0.024		0.119	0.048		
(dummy)	(-0.19)		(0.88)	(0.76)		
Applied electronic equipment	0.221		0.238	0.101		
(dummy)	(1.69)		(1.98)[a]	(1.53)		
Home appliances		0.117			0.114	0.115
(dummy)		(1.15)			(2.34)[b]	(2.56)[b]
Electronics devices		0.071			0.116	0.147
(dummy)		(0.67)			(2.27)[b]	(2.88)[c]
Company size		-0.33×10^{-6}				-0.13×10^{-6}
			(-1.98)[a]			(-1.71)[a]
Sigma	0.191	0.215	0.175	0.093	0.094	0.086
	(6.19)	(6.07)	(6.19)	(5.67)	(5.74)	(5.72)
Sample	33	33	33	33	33	33

Note: Figures in parentheses are *t*-statistics (in two-tail tests).
a: significant at the 10% level b: significant at the 5% level c: significant at the 1% level

E. Horizontal *Keiretsu* and Direct Investment

Let us now examine the relationship between Japanese corporate *keiretsu* and foreign direct investment, which has been receiving attention in recent years. Table 10 compares the average values of the dependent and independent variables between companies that belong to a *keiretsu* group and those that do not, based on the three definitions of *keiretsu*. The proportion of overseas production of *keiretsu* companies exceeds that of non-*keiretsu* companies based on all three definitions of horizontal *keiretsu* only in the case of direct investment in North America. Thus *keiretsu* companies do not necessarily have an especially high proportion of overseas production. Interestingly, the capital labor ratio and the R&D stock intensity of *keiretsu* companies do exceed those of non-*keiretsu* companies. As pointed out by Hoshi, Kashyap, and Sharfstein, it may be that these *keiretsu* companies are less subject to the liquidity constraint in the financing of plant and equipment investment and R&D investment because of a stable main bank relationship. As a result, they may have been able to maintain an advantage over non-*keiretsu* companies in the accumulation of capital and the formation of R&D stock.

Table 11 and Table 12 show the results of the regression analysis in which the previously defined dummy variables for horizontal *keiretsu* (that is, *keiretsu* dummy I, *keiretsu* dummy II, and *keiretsu* dummy III) were included. The dependent variables were the proportion of production in developed countries and that in developing countries. The sample companies included only those with production in those regions (24 for developed countries, 29 for developing countries). The results indicate that for the proportion of production in developed countries, only the coefficient of "*keiretsu* dummy (II)" (for financial *keiretsu*) had the right sign. The coefficients were negative and those of "*keiretsu* dummy (III)" were even significant. For the proportion of production in developing countries, the coefficients were also negative and those of "*keiretsu* dummy (I)" were significant. The negative sign of the coefficients of *keiretsu* dummies may be related to the negative sign of the coefficient of "company size." As is clear from Table 10, the average size of *keiretsu* companies is much larger than that of non-*keiretsu* companies. Thus, given the previously observed fact that larger companies have a smaller proportion of overseas production, *keiretsu* companies will have a seemingly smaller proportion of overseas production. In fact, when "company size" was included in the regression, the t values and coefficient estimates of the previously significant *keiretsu* dummies tended to decline. However, on no occasion did the coefficients of the *keiretsu* dummies become positive and significant. Thus no empirical support is evident to support the hypothesis that the proportion of overseas production is greater for companies belonging to a *keiretsu* or a corporate group.

Table 10

Average Values by *Keiretsu* Affiliciation

	Proportion of production overseas	Proportion of production in developing countries	Proportion of production in developed countries	Proportion of production in North America	Proportion of production in EC	Capital to labor ratio (¥ millions)	Company size (¥ millions)	R&D stock intensity (I)	R&D stock intensity (II)	R&D stock intensity (III)	Advertising intensity	Years of experience with overseas production
Keiretsu (I) (7)	0.1493	0.0044	0.1351	0.1070	0.0281	13.59	502,046	0.9844	1.9437	1.7661	0.2003	11.28
others(27)	0.2145	0.0701	0.1423	0.0991	0.0431	10.22	62,076	0.3622	0.9656	0.9073	0.1481	11.73
Keiretsu (II) (19)	0.2104	0.0358	0.1711	0.1250	0.0461	11.96	209,642	0.5970	1.2825	1.2048	0.1124	11.07
others(15)	0.1894	0.0829	0.1025	0.0700	0.0324	9.58	80,477	0.3547	1.0207	0.9313	0.2178	12.37
Keiretsu (III) (20)	0.2065	0.0388	0.1612	0.1184	0.0428	12.02	246,518	0.7138	1.4957	1.3768	0.1657	12.31
others(14)	0.1935	0.0819	0.1116	0.0755	0.0361	9.33	18,572	0.1961	0.6975	0.6661	0.1491	10.69

Note: Figures in parentheses = no. of parent companies in each category.
Keiretsu (I) : Companies belonging to the president's council of 6 major corporate groups
Keiretsu (II) : Companies whose main banks are the city banks of the 6 major corporate groups
Keiretsu (III) : Companies classified as belonging to the 6 major corporate groups in *Keiretsu no kenkyu* (Surveys on *Keiretsu*)

Table 11

Regression Analysis on the Effect of *Keiretsu* upon the Direct Foreign Investment in Developed Countries

Dependent Variable: Proportion of production in developed countries
Method: OLS (variances are heteroskedastic-consistent estimates)

Constant	0.013	-0.003	0.171	0.140
	(0.34)	(-0.05)	(1.62)	(1.62)
R&D stock intensity (I)	0.290	0.238	0.392	0.374
	(1.97)[a]	(1.49)	(2.58)[b]	(2.37)[b]
Heavy electric machinery	0.023	-0.024	0.157	0.118
(dummy)	(0.58)	(-0.35)	(1.91)[a]	(1.53)
Communication devices	-0.006	-0.057	-0.203	-0.161
(dummy)	(-0.06)	(-0.74)	(-1.70)	(-1.35)
Information devices	0.108	-0.051	-0.071	0.084
(dummy)	(0.51)	(-0.25)	(-0.41)	(0.38)
Applied electronic equipment	0.232	0.254	0.220	0.248
(dummy)	(1.70)	(1.74)[a]	(1.69)	(1.93)[a]
Keiretsu (I)	-0.240			
(dummy)	(-1.46)			
Keiretsu (II)		0.064		
(dummy)		(0.76)		
Keiretsu (III)			-0.291	-0.218
(dummy)			(-2.38)[b]	(-1.97)[a]
Company size				-0.33×10^{-6}
				(-1.58)
Sample	24	24	24	24
Adj.R^2	0.301	0.205	0.372	0.413

Note: Figures in parentheses are *t*-statistics (in two-tail tests).
a: significant at the 10% level b: significant at the 5% level c: significant at the 1% level

Table 12

Regression Analysis on the Effect of *Keiretsu* upon the Direct Foreign Investment in Developing countries

Dependent Variable: Proportion of production in developing countries
Method: OLS (variances are heteroskedastic-consistent estimates)

Constant	0.080	0.097	0.096	0.081
	(3.67)[c]	(5.22)[c]	(3.83)[c]	(3.72)[c]
R&D stock intensity (I)	-0.091	-0.088	-0.078	-0.089
	(-2.57)[b]	(-2.57)[b]	(-2.17)[b]	(-2.58)[b]
Heavy electric machinery	0.049	0.076	0.052	0.048
(dummy)	(0.55)	(0.86)	(0.56)	(0.55)
Communication devices	0.019	0.014	0.008	0.019
(dummy)	(0.39)	(0.33)	(0.18)	(0.40)
Information devices	0.067	0.051	0.030	0.065
(dummy)	(1.85)[a]	(1.26)	(0.89)	(1.85)[a]
Applied electronic equipment	0.042	0.045	0.039	0.045
(dummy)	(0.87)	(1.04)	(0.95)	(0.92)
Keiretsu (I)	-0.047			-0.018
(dummy)	(-2.43)[b]			(-0.56)
Keiretsu (II)		-0.045		
(dummy)		(-1.62)		
Keiretsu (III)			-0.030	
(dummy)			(-0.85)	
Company size				-0.44×10^{-7}
				(-1.16)
Sample	29	29	29	29
Adj.R^2	0.191	0.213	0.194	0.194

Note: Figures in parentheses are *t*-statistics (in two-tail tests).
a: significant at the 10% level b: significant at the 5% level c: significant at the 1% level

IV. Conclusion

The most interesting result of our empirical analysis is the tendency of companies that are technology intensive (the R&D stock) to have a smaller proportion of production in developing countries and a bigger proportion in developed countries. This has the following policy implications:

The first is an implication for industrial adjustment and employment. The empirical results show that Japan's electric machinery industry is characterized by asymmetry between developed and developing countries. In developing countries, companies that are not in technology intensive tend to have located in such areas in search of cheaper labor. If a similar motive supports the decision of companies to invest in rural areas in Japan, production in the such areas may be replaced by production in developing countries because the further appreciation of the yen raises domestic wages. As a result, the subsidiaries of companies that are not technology intensive may withdraw from production in rural areas, thus creating unemployment in such areas.

Second, if protectionism in developed countries intensifies because of an increase in trade barriers and antidumping charges against Japanese products, the production of goods that are technology intensive may further move to those countries. As Krugman (1990) pointed out, the production of goods that are technology intensive may have strong positive externalities associated, for example, with "learning by doing." If the externalities are created in the parent's home country, direct investment by Japanese companies in developed countries should not create a serious problem for Japan. But if the externalities mainly benefit the host country by increasing the skill level of workers, direct investment by Japanese companies in developed countries will have a negative effect on Japan. The future holds a greater need for this type of strategic analysis regarding direct investment in developed countries, which are carried away by technology intensive companies.

To test the hypothesis based on the often-discussed theory of monopolistic multinationals, the paper also analyzed whether "company size" or "advertising intensity" was positively correlated with the proportion of overseas production. We have found no such positive correlation. We have also found that companies belonging to a horizontal *keiretsu* have no special tendency to initiate overseas production compared with non-*keiretsu* companies.

Finally, two remaining issues should be considered.

First, our empirical analysis has covered only those companies that have foreign production. This may have created a sample selection bias. To address this problem, regression analysis must be performed by including companies having no foreign production and those that do but which did not respond to the "Basic Survey." To do this, we must obtain data on the stock of technological knowledge for these additional companies from their financial data, after identifying companies with and without foreign production in the electric machinery industry by using Toyo Keizai Shinposha's *General Survey of Companies with Overseas Operations*.

Second, the result that the sign relationship between R&D intensity and direct investment changes depending on the host country may also apply to domestic investment. That is, even within Japan larger cities may have a more plentiful supply of skilled labor with a relatively greater production of goods that are technology intensive. Conversely, rural areas may have a lower cost of unskilled labor with a greater production of goods that are not technology intensive.[42] This possibility is an important consideration when the effect of foreign direct investment on the domestic economy is evaluated.

Appendix 1. The Optimal Production of a Multinational Company

This appendix derives the solution for the profit maximization problem given in Section II. To make sure that we obtain an interior solution, we add the following assumptions to the model.

Assumption (1): For all $i \epsilon N$, the total revenue function $TR_i(s_i)$ is twice continuously differentiable and satisfies the following conditions.

$$TR_i'(0) = +\infty, \quad TR_i''(\cdot) < 0$$

For an arbitrary $\epsilon > 0$, there exists x such that the following condition is satisfied:

$$TR_i'(x) < \epsilon$$

Assumption (2): This equation holds for at least one country (country j).

$$TR_j'(x_j^*) > \tau_j$$

where x_j^* is defined by,

$$TR_j'(x_j^*) = VC_j'(x_j^*)$$

Under assumptions about the production function, it can be shown that for all $i \epsilon N$, the functional $VC_i(x_i)$ is twice continuously differentiable and satisfies the following conditions.

$$VC_i'(0) = 0, \; VC_i'(+\infty) = +\infty, \; VC_i''(\cdot) > 0$$

Let $L(\cdot)$ denote the Lagrangean for the optimization problem of Section II.

[42] Uno (1986) reports that the substitutability relationship of unskilled labor, skilled labor, and real capital differs between the Tokyo/Osaka regions and other regions in Japan. Mizoguchi (1992) uses annual securities reports to analyze recent changes in the number of domestic and overseas subsidiaries of Japanese companies.

$$L(s, x, m, e, \lambda_1, \lambda_2) = \sum_{i \in N} \{TR_i(s_i) - \tau_i m_i - VC_i(x_i)\} + \lambda_1 \left\{ \sum_{i \in N} x_i - \sum_{i \in N} s_i \right\} + \sum_{i \in N} \lambda_{2,i} \{m_i - e_i - s_i - x_i\}$$

where $\lambda_2 = \{\lambda_{2,1}, \lambda_{2,2}, \cdot\cdot, \lambda_{2,n}\}$. From the Kuhn-Tucker theorem, the necessary and sufficient condition for optimum production is that non-negative λ_1 and λ_2 exist, which satisfy equations (6), (7), and (8) and the following equations (*see* Theorem 3 in Chapter 16 of Uzawa 1990).[43]

$$TR_i'(s_i) = VC_i'(x_i) = \lambda_1 + \lambda_{2,i} \tag{A-1}$$
$$\lambda_{2,i} \leq \tau_i \tag{A-2}$$
$$m_i = 0 \text{ or } \lambda_{2,i} = \tau_i \tag{A-3}$$
$$e_i = 0 \text{ or } \lambda_{2,i} = 0 \tag{A-4}$$

In what follows, we study the company's optimization problem in two stages. First, assuming that λ_1 is predetermined at some positive value,[44] we derive s_i, x_i, m_i, e_i, and $\lambda_{2,i}$, which satisfy equations (6), (7), (A-1), (A-2), (A-3), and (A-4) for each i. This is equivalent to thinking about the optimal behavior of subsidiaries in each country. Next, we show that λ_1 can be uniquely determined at some positive value under the constraint given by equation (8).

λ_1 is the imputed price of the product for the subsidiary exporting it. On the other hand, $\lambda_{2,i}$ shows the excess of the imputed price of the product manufactured in country i relative to that of the importable product (given by λ_1). As shown in equations (A-2), (A-3), and (A-4), $\lambda_{2,i}$ is equal to τ_i in the importing country and to zero in the exporting country. The value of $\lambda_{2,i}$ for a country that is self-sufficient in that product lies between zero and τ_i. Given the positive value of λ_1, we think of optimal behavior in country i. The situation there can theoretically be classified into the following three cases.

(Case A) exporting country

If country i is an exporting country ($e_i > 0$), equations (6), (A-1), and (A-4) yield the following equation, which determines the optimal sales volume s_i, production volume x_i, import volume m_i, and export volume e_i.

$$TR_i'(s_i) = VC_i'(x_i) = \lambda_1, \tag{A-5}$$
$$e_i = x_i - s_i, \qquad m_i = 0$$

[43]For a country for which τ_i is zero, we cannot rule out the possibility that it can simultaneously be an exporter and an importer under our specifications. We proceed with our analysis, however, by assuming for such a country that τ_i is positive, although sufficiently close to zero.

[44]The following shows that λ_1 cannot be zero. Suppose that $\lambda_1=0$. Then from Assumption (2), equation (A-1), and equation (A-2), country j becomes an importer. Thus, at least one country (country i) must be an exporter. We then have from equations (A-1) and (A-4) that $VC'(x_i)=0$ for some $x_i>0$. This is inconsistent with the properties of the VC function.

Expressing the inverse functions of the marginal revenue function and the marginal cost function by $TR_i'^{-1}(\cdot)$ and $VC_i'^{-1}(\cdot)$, we find that the following inequality holds when country i is an exporting country.

$$TR_i'^{-1}(\lambda_1) < VC_i'^{-1}(\lambda_1) \tag{A-6}$$

(Case B) importing country
If country i is an importing country ($m_i > 0$), we have

$$TR_i'(s_i) = VC_i'(x_i) = \lambda_1 + \tau_i, \tag{A-7}$$
$$m_i = s_i - x_i, \qquad e_i = 0$$

and

$$TRi'^{-1}(\lambda_1 + \tau_i) > VC_i'^{-1}(\lambda_1 + \tau_i) \tag{A-8}$$

(Case C) self-sufficient country
If country i is self-sufficient (e_i=m_i=0), we have

$$TR_i'(s_i) = VC_i'(x_i) = \lambda_1 + \lambda_{2,i}, \tag{A-9}$$
$$s_i = x_i,$$

and

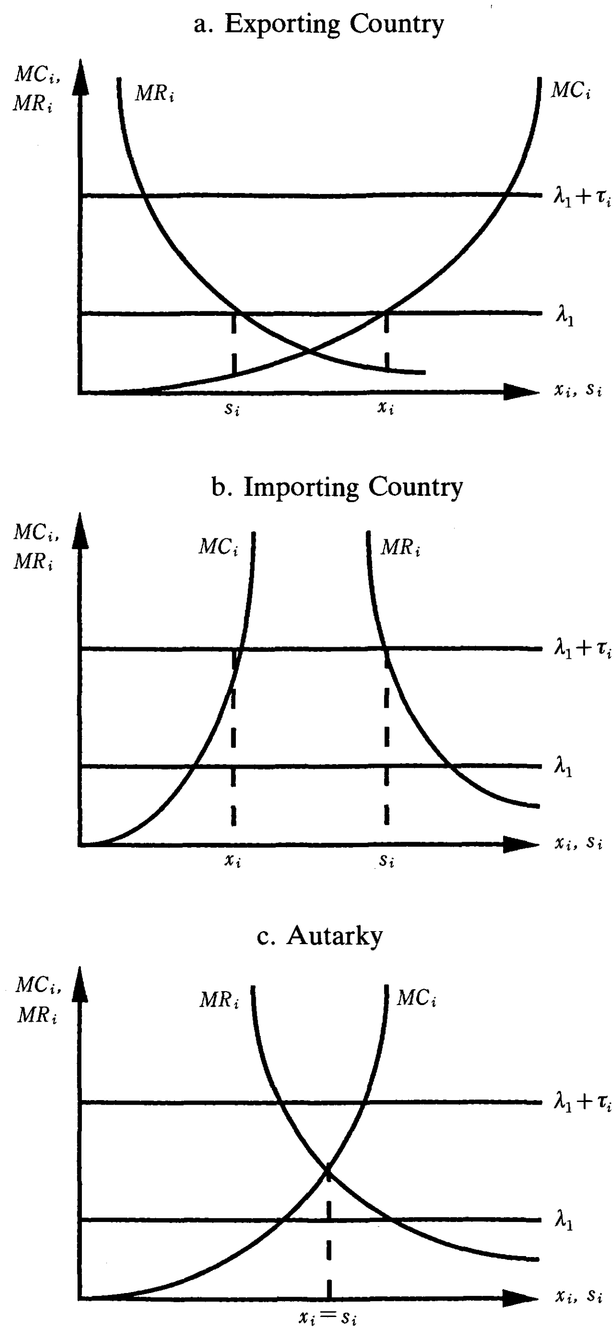
$$TR_i'^{-1}(\lambda_1) \geq VC_i'^{-1}(\lambda_1) \tag{A-10}$$
$$TR_i'^{-1}(\lambda_1 + \tau_i) \leq VC_i'^{-1}(\lambda_1 + \tau_i) \tag{A-11}$$

Under Assumption (1), the set of countries that satisfies equation (A-6), the set that satisfies equation (A-8), and the set that satisfies equations (A-10) and (A-11) have no intersection, and all countries belong to one of the three sets. Consequently, equations (A-6), (A-8), and the pair of equations (A-10) and (A-11) are necessary and sufficient conditions for determining whether a country belongs to Case A, Case B, or Case C respectively.

Figure A shows how sales volume and production volume are determined in the three cases, where *MC* is the marginal cost curve and *MR* is the marginal revenue curve. The figure shows that if the marginal revenue curve lies to the left of the marginal cost curve, the country is an exporting country. If this curve is to the right of the marginal cost curve and the tariff rate is low, the country becomes an importing country. In all other cases, the country becomes self-sufficient.

Next we show that λ_1 is uniquely determined at a positive value. As indicated by equations (A-6), (A-8), (A-10), and (A-11), as λ_1 increases, the country moves from being an importer to being a self-sufficient country, then to an exporting country. Moreover, as indicated by equations (A-5), (A-7), and (A-9), the import volume and export volume of each country are, respectively, a continuous decreasing function and a continuous increasing function of λ_1. Finally, from Assumptions (1) and (2), when λ_1 is sufficiently small, total imports by the parent company and all of subsidiaries exceed total exports; when λ_1 is sufficiently large, total imports fall below total exports. Thus it has

Figure A
Optimal Production and Sales of Firms



been shown that the value of λ_1, which satisfies equation (8), is uniquely determined and that it is positive.

Appendix 2. The Stock of Technological Knowledge and Production in Developing Countries

This appendix analyzes how the stock of technological knowledge influences the ratio of production in developing countries to production in Japan (x_L/x_J) and derives equation (13).

The optimal values of L_i and K_i in the cost minimization problem of Section II are continuously differentiable functions of w_i, r_i, and Z. By making use of the factor demand functions being homogeneous of degree zero with respect to w_i and r_i when output is held constant, the functions can be expressed as follows:

$$L_i = L\left(\frac{w_i}{r_i}, Z\right)$$

$$K_i = K\left(\frac{w_i}{r_i}, Z\right)$$

We also have the following relationship between L_i, K_i, and $g\,(w_i/r_i, Z)$ in equation (4).

$$g\,(w_i/r_i, Z) = K_i + \frac{w_i}{r_i}L_i$$

Because g is a continuously differentiable function, we have

$$\frac{g\left(\frac{w_J}{r_J}, Z\right)}{g\left(\frac{w_L}{r_L}, Z\right)} = \exp\left[\int_{\frac{w_L}{r_L}}^{\frac{w_J}{r_J}} \frac{\dfrac{\partial g\left(\frac{w}{r}, Z\right)}{\partial\frac{w}{r}}}{g\left(\frac{w}{r}, Z\right)}\, d\frac{w}{r}\right] = \exp\left[\int_{\frac{w_L}{r_L}}^{\frac{w_J}{r_J}} \frac{L\left(\frac{w}{r}, Z\right)}{g\left(\frac{w}{r}, Z\right)}\, d\frac{w}{r}\right] \tag{A-12}$$

where the second equality comes from Shepherd's lemma (*see*, for example, Varian [1984]).

We will now examine the effect of a change in Z on L/g. From the definition of g, we have the following equation:

$$\frac{g}{L}\frac{\partial\dfrac{L\left(\frac{w}{r}, Z\right)}{g\left(\frac{w}{r}, Z\right)}}{\partial Z} = \frac{K}{g}\left\{\frac{1}{L}\frac{\partial L\left(\frac{w}{r}, Z\right)}{\partial Z} - \frac{1}{K}\frac{\partial K\left(\frac{w}{r}, Z\right)}{\partial Z}\right\} \tag{A-13}$$

To learn the relationship between the effect of a change in Z on factor demand under constant output ($\partial L/\partial Z$ and $\partial K/\partial Z$) and Allen's partial elasticities of substitution, let us consider the following cost minimization problem. That is, we consider the optimal combination of L, K, and Z to produce one unit of output when not only L and K, but also Z, are variable factors of production. By denoting the price of Z by v and the imputed price of the product by μ, the necessary conditions for the solution of the cost minimization problem are given by

$$\mu f_K(K, L, Z) = r \tag{A-14}$$
$$\mu f_L(K, L, Z) = w \tag{A-15}$$
$$\mu f_Z(K, L, Z) = v \tag{A-16}$$
$$f(K, L, Z) = 1 \tag{A-17}$$

We now find how K, L, Z, and μ change when v changes by taking a linear approximation of equations (A-14)-(A-17),

$$\begin{bmatrix} \mu f_{KK} & \mu f_{KL} & \mu f_{KZ} & f_K \\ \mu f_{KL} & \mu f_{LL} & \mu f_{LZ} & f_L \\ \mu f_{KZ} & \mu f_{LZ} & \mu f_{ZZ} & f_Z \\ f_K & f_L & f_Z & 0 \end{bmatrix} \begin{bmatrix} dK \\ dL \\ dZ \\ d\mu \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ dv \\ 0 \end{bmatrix} \tag{A-18}$$

In equation (A-18), we set dv as

$$dv = \frac{|F|}{F_{ZZ}} dZ_0 \tag{A-19}$$

where $|F|$ is the determinant of the matrix of coefficients on the left-hand side of equation (A-18), i.e., the bordered Hessian for this minimization problem, and F_{ZZ} is a cofactor of the element in the third row and third column. Then dZ, which satisfies equation (A-18), becomes equal to dZ_0. It can now be shown that the values of dK and dL, which are determined by equation (A-18), become equal to the changes in L and K generated when Z changes by dZ_0 in the cost minimization problem of Section II. (It is necessary to derive equation (A-18) in the neighborhood of some appropriate point.)

From the above, $\partial L / \partial Z$ and $\partial K / \partial Z$ in equation (A-13) can be found by using equations (A-18) and (A-19). By substituting these into equation (A-13), we have

$$\frac{g}{L} \frac{\partial \dfrac{L\left(\frac{w}{r}, Z\right)}{g\left(\frac{w}{r}, Z\right)}}{\partial Z} = \frac{K}{g} \frac{Z|F|}{\mu F_{ZZ}} \left(\frac{\mu F_{LZ}}{LZ|F|} - \frac{\mu F_{KZ}}{KZ|F|} \right)$$

where F_{LZ} and F_{KZ} are the cofactors of the element in the second row, third column and the first row, third column, respectively, of the bordered Hessian. The first term and the second term in parentheses on the right-hand side are, respectively, Allen's partial elasticities of substitution between labor and stock of technological knowledge and that between capital and stock of technological knowledge. From our assumptions about the production function, $|F|$ is positive and F_{ZZ} is negative. Equation (13) is obtained from this and equation (A-12).

From the above equation and equation (13), we can see that, given the factor prices, a company with a greater value of Z has a higher ratio of capital to labor (K/L) when $\sigma_{LZ}>\sigma_{KZ}$. Conversely, when $\sigma_{LZ}<\sigma_{KZ}$, a company with a greater value of Z has a lower capital to labor ratio (K/L).

Appendix 3. Methodology for Obtaining Data on the Proportion of Overseas Production, R&D Stock Intensity, and Company Size (Stock of Capital)

Proportion of Overseas Production

The proportion of overseas production was obtained by dividing the total value added of subsidiaries by the gross value added of the parent company. The value added of subsidiaries was obtained by subtracting the total cost of purchases from total sales as reported in the Basic Survey and multiplying it by the parent's ownership proportion (the company with the largest ownership proportion). In calculating ownership proportion, allowance was made for the possibility that the parent company also has equity ownership in investment partner companies, as explained in the text.

We obtained the value added of the parent by taking note of how it is distributed. We added up personnel-related expenditures (labor expenses and bonus payments to managers, for example), corporate profits (operating profit before depreciation), and other items (leasing fees, taxes, and patent royalties), as found in the annual securities report of each company for fiscal 1986.

Company Size (Real Stock of Capital)

The stock of capital of the parent company was obtained by the perpetual inventory method based on the value of fixed capital investment (excluding land). The nominal value of capital investment (excluding land) during a year was obtained by taking the annual increase in the stock of fixed property after adjusting for the suspense account for construction. The real value of capital investment in 1985 prices was then obtained by deflating the nominal value by the private corporate investment deflator found in national income accounts tables.

We used two measures of the rate of retirement of fixed assets: (1) the rate of retirement (8.1%) estimated from data on the electric machinery and equipment industry as reported in the Economic Planning Agency's *Private Capital Stock Statistics*; and (2) the rate of retirement (11.4%) obtained from the average useful life (years) of assets owned by the electric machinery and equipment industry in 1970 as reported in the

Economic Planning Agency's *National Wealth Survey,* by assuming a constant rate of depreciation (*see* Kuninori [1988]). The real value of capital stock in the base year (in 1985 prices) for each company was obtained by adjusting the balance of fixed assets (excluding land) held either at the time of initial listing on the Tokyo Stock Exchange or when the Japan Development Bank began compiling corporate financial data in 1955 by the investment deflator.

R&D Stock Intensity

Data on the R&D expenditures of individual companies come from (1) the time-series data of "R&D expenses" reported in sections on sales and general administrative expenses and "R&D expenses" reported in sections on production costs, both in annual securities reports (securities report data), and (2) the time-series data obtained from the questionnaire surveys of R&D expenses by Toyo Keizai Shinposha's *Quarterly Report of Listed Companies (Kaisha Shiki-hō* ; Toyo Keizai data). "R&D stock intensity" was obtained first by deflating these time series of R&D expenses by an appropriate deflator; second by deriving the 1986 stock of technological knowledge from real R&D expenses by the perpetual inventory method,[45] then by dividing 1986 stock by the gross value added of the parent.

To obtain the deflator on R&D expenses for the entire electric machinery and equipment industry, we followed the procedure of Goto *et al.* (1986). In its *Report of Survey on Science and Technology Research* (*Kagaku Gijutsu Kenkyū Hōkoku*; science and technology report in short), the Statistics Bureau of the Coordination and Management Agency, publishes a breakdown of corporate research expenses by two-digit industry classifications. We reclassified them for the electric machinery industry into (a) personnel expenses; (b) cost of raw materials; (c) land; (d) buildings; (e) machinery, instruments, and equipment; and (f) others. The relative proportion of each category was then obtained by dividing the expenses by the total corporate research expenses. Because land and buildings are classified in the same category in the science and technology report, we obtained the separate expense proportions for land and buildings by using the relative composition calculated from the purchase values of fixed assets of the electric machinery industry reported in MITI's *Statistical Tables of Manufacturing* (*Kogyō Tōkei-hyō*; 1985).

Given these relative expenditure proportions, the Laspeyres formula was then used to obtain the deflator on R&D expenses (with 1985 as the base year) by taking the weighted average of the price indices of the component expenditure items: (a) the wage

[45]According to the Economic Planning Agency's *Survey Research on Corporate Behavior: Corporate Strategy for New Efficient Management and Technical Development*, 1981, a lag of about two years is reported for the electric machinery industry between the time of R&D investment and when it is used at the corporate level. This paper, however, does not explicitly take account of lags in performing estimation because the sample covers only the electric machinery industry and sometimes the sample period is short.

index for the electric machinery industry from the Ministry of Labor's, *Comprehensive Report of Monthly Surveys of Labor Statistics* (*Maitsuki Kinrō Tōgō Chōsa Sōgō Hōkoku*); (b) the wholesale price index of domestic raw materials in the comprehensive wholesale price indices by production stage and use as reported in the Bank of Japan's *Price Indices Annual* (*Bukka-shisū Nenpō*); (c) the industrial land price index for September of each year published in the Japan Real Estate Research Institute's *Urban Land Price Indices of Japan* (*Zenkoku Shigaichi Kakaku Shisū*); (d) the construction cost index for non-residential buildings obtained from the Ministry of Construction's *Construction Statistics Monthly* (*Kensetsu Tōkei Geppō*); (e) the wholesale price index of machinery and equipment in comprehensive wholesale price indices by type as reported in the Bank of Japan's *Price Indices Annual*; and (f) the overall index (excluding perishable food) obtained from the Statistics Bureau of the Management and Coordination Agency, *Consumer Price Indices Annual* (*Shōhisha-bukka-shisū Nenpō*).

The rate of obsolescence of technological knowledge used in applying the perpetual inventory method was based on the average useful life of a patent (about seven years) during which revenues are generated, according to the 1985 issue of the *White Paper on Science and Technology*. The respective R&D expenses in the electric machinery industry were used to obtain the weighted average of the inverse of the average useful life of a patent in the electric machinery industry and also the same with respect to the communications and electronics, and electric measuring instruments industries.

Concerning securities report data, we used as the stock of technological knowledge for the base year the real value of R&D expenses either at the time of initial listing or when they were first reported (R&D stock intensity [I] and [II]). With regard to Toyo Keizai data, the stock of technological knowledge for 1981 was estimated by the perpetual inventory method (R&D stock intensity [II]).[46]

R&D stock intensity (I): obtained by the perpetual inventory method after deflating R&D expenses reported in the section on sales and general administrative expenses of annual securities reports.

R&D stock intensity (II): obtained by the perpetual inventory method after deflating Toyo Keizai data.

R&D stock intensity (III): obtained by the perpetual inventory method by using the

[46]By denoting real R&D expenses during period t by E_t and the constant rate of obsolescence by d, the stock of technical knowledge R_t can be expressed as

$$R_t = E_t + (1-d)\,R_{t-1}$$

By rearranging this expression, we get

$$R_{t-1} = E_t/(g_t+d)$$

where $g_t = (R_t/R_{t-1}) - 1$, which is the rate of growth of the stock of technical knowledge. Thus we get the stock of technical knowledge in period $t-1$. Because the value of g_t cannot be known *a priori*, we use the average annual rate of growth of real R&D expenses in the past as a proxy.

same real R&D expenses data as R&D stock intensity (I). To estimate the R&D expenses that were not specified in the section on production cost in the annual securities reports, however, the time-series data of real R&D expenses for the period before 1981 were multiplied by the simple average of the rate of difference between the Toyo Keizai data and R&D expenses in the section on sales and general administrative expenses of securities reports for the years 1982-86.

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