PROFITABILITY OF INDUSTRY AND OUTWARD DIRECT FOREIGN INVESTMENT

by

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ABSTRACT

The paper develops a model of firm that operates with a putty-clay type of technology in order to show a relationship between changing comparative advantage of a country and its outward direct foreign investment. It is argued that firms in declining industries have an incentive to invest abroad their vintage capital which has become unprofitable at home. Patterns of profitability for six Japanese manufacturing industries were estimated for the years of 1960 through 1988, and it is shown that there is in general a linkage between the loss of profitability at home and outward direct foreign investment.
I. Introduction

In recent years there has been an increasing flow of direct foreign investment (DFI) from the newly industrializing economies (NIEs)--Hong Kong, Korea, Singapore, and Taiwan--to the other developing countries of the Asia-Pacific region (Chen 1990, Ramstetter 1991). What is noteworthy about this DFI is that it is by and large out of labor-intensive industries in which the NIEs have been losing their comparative advantage and is thus related to the structural changes taking place therein. It in fact resembles the investment that Japan was making in developing Asia in the 1960s and 1970s, which was out of labor-intensive industries in which the country was losing its comparative advantage (Kojima 1973 and 1978).

Outward DFI from industries in which a country is losing its comparative advantage poses several interesting questions: What are the factors motivating such DFI? Does outward DFI facilitate structural changes by reducing the cost of structural adjustment? What are the appropriate policies on DFI for the country going through a structural change?

Much of the literature on DFI is, however, silent on these questions as its focus is on microeconomic issues relating to DFI and the behavior of the multinational enterprise. In fact the "modern" theory of DFI is called the theory of internalization and regards DFI as a way of economizing the transactions cost for exploiting firm-specific "ownership advantages" in the presence of market imperfections (Rugman 1980). It is microeconomic in its focus and is consequently incapable of explaining the relationship between a country's structural change and its outward DFI.

Even in the "eclectic theory of international production" largely associated with Dunning (1981 and 1988) such a relationship is not fully explored. In this theory a firm must possess some ownership advantages in order to invest in a foreign country and compete successfully with indigenous firms which have obvious home-town advantages. Such a firm is considered to be from an industry which is active in research and development and thus not from a declining industry.

An exception to this general trend in the literature on DFI is the contribution made by Kojima whose theory on Japanese DFI deals explicitly with the relationship between comparative advantage and DFI. According to this theory, a country's "comparative
profitability" (or the ratio of profit rates in two industries) is high in an industry, relative to its counterpart in the other country, in which the country has a comparative advantage. As capital is then said to move out of the industry with a low relative profit rate in one country to the industry with a high relative profit rate in the other, international capital movement is from the industry in which one country has a comparative disadvantage to the industry in which the other country has a comparative advantage. Lee (1990a and 1990b) has pointed, however, that it is the difference in the absolute profit rates that motivates capital movement and that capital outflow is from industries in which a country is losing its comparative advantage.

The purpose of this paper is to provide empirical support for the relationship between changing comparative advantage and DFI. More specifically, it will examine the relationship between the profitability of industries in which a country is losing its comparative advantage and DFI out of these industries. Section II presents a model of a firm with a putty-clay type of technology and analyzes its profitability over time. Section III then reports the patterns of profitability estimated for six Japanese industries over a twenty-nine year period of 1960 through 1988. Although the availability of data dictated the choice of Japan the model proposed here should apply to any economy undergoing a change in comparative advantage. Section IV compares changes in the profitability of vintage capital and the pattern of DFI out of these industries. Section V concludes the paper.

Implicit in the model is the assumption that a firm in a declining industry can either branch out into another industry at home or invest abroad in the same industry. With the first option the firm would find its net worth declining as its industry-specific capital is less productive in the new industry whereas with the second option the firm would incur the cost of transferring capital abroad and operating a foreign subsidiary although the transferred capital may be technically as productive abroad as at home. In principle the firm will choose the option that will minimize the loss in its net worth, but this decision process is not explicitly modelled in this paper.
II. The Model

The model assumes that a price-taking firm has a putty-clay type of production technology. Thus, although substitution is possible ex ante among the inputs for production it is not possible once the firm has chosen a given input combination. A firm with such a technology thus faces two separate decisions. Firstly, it decides on the current level of total output to be produced. Under a putty-clay type of production technology, the firm will operate the capital installed currently and in the past as long as it yields positive profits.\(^1\) Since capital is used with other inputs in a fixed combination, the demand for other inputs is determined simultaneously with the decision on total output.

Secondly, the firm determines the level of current investment which will maximize the present value of the expected future profits from the investment. This decision is equivalent to that of maximizing the total net cash flow from all vintages if it maximizes the net cash flow from each of the vintages (Virmani 1976 and Adachi 1989).

Formally, the firm's expected future profits earned from the current investment, \(\pi_t\), is expressed as

\[
\pi_t = E_t \left[ \sum_{i=0}^{\infty} \left\{ P_{t+i} O_{t+i} / (1+R_t)^i - W_{t+i} L_{t+i} / (1+R_t)^i - P^M_{t+i} M_{t+i} / (1+R_t)^i - P^E_{t+i} E_{t+i} / (1+R_t)^i - q_i C(I_i) \right\} \right]
\]

where \(E_t\): expectational operator conditional upon the information available to the firm at time \(t\)

- \(P_{t+i}\): output price at time \(t+i\)
- \(W_{t+i}\): wage rate at time \(t+i\)
- \(P^M_{t+i}\): material price at time \(t+i\)
- \(P^E_{t+i}\): energy price at time \(t+i\)
- \(O_{t+i}\): output level at time \(t+i\) produced with the capital installed at time \(t\) together with the current inputs used with the equipment
- \(L_{t+i}\): labor input at time \(t+i\), which is allocated to the equipment installed at time \(t\)
$M_{t+t+i}$: material input at time $t+i$, which is allocated to the equipment installed at time $t$

$E_{t+t+i}$: energy input at time $t+i$, which is allocated to the equipment installed at time $t$

$q_t$: investment goods price at time $t$

$I_t$: investment level at time $t$

$C(I_t)$: adjustment cost function of investment

$C(0) = 0, C'(I_t) > 0, C''(I_t) > 0$

$R_t$: discount rate at time $t$

The ex-ante production function, which is assumed to be homogeneous of degree one, is given by

\begin{equation}
Q^N_t = F(I_t, L^N_t, E^N_t, M^N_t)
\end{equation}

where $Q^N_t$, which is $Q_{t,t}$ in our notation above, is the output level produced at time $t$ with the capital installed at time $t$, while $I_t, L^N_t, E^N_t, M^N_t$ are the levels of investment, labor, energy, and material chosen at time $t$, respectively. $N$ denotes newly installed capital.\(^2\)

It is assumed that the capital installed at time $t$ depreciates at the constant rate of $\delta$. Since substitution among the inputs in the subsequent periods is not possible once the combination of inputs is determined at time $t$, the following relationships holds.

\begin{align}
(3) & \quad K_{t+t+i} = (1-\delta)^i I_t \\
(4) & \quad L_{t+t+i} = (1-\delta)^i L^N_t \\
(5) & \quad E_{t+t+i} = (1-\delta)^i E^N_t \\
(6) & \quad M_{t+t+i} = (1-\delta)^i M^N_t
\end{align}

where $K_{t+t+i}$ is the value of the capital installed at time $t$ which still remains at time $t+i$, while $L_{t+t+i}, E_{t+t+i}$ and $M_{t+t+i}$ are the labor, energy, and material input used at time $t+i$ in combination with the capital installed at time $t$, respectively.

Since the ex-post production technology is of the Leontief-type and its input ratios do not vary over time the output level produced at time $t+i$ with the capital installed at time $t$ is given by

\begin{equation}
Q_{t+t+i} = (1-\delta)^i Q^N_t = (1-\delta)^i F(I_t, L^N_t, E^N_t, M^N_t)
\end{equation}
Combining equations (3) to (6) and (7) we may rewrite the firm's objective function as

\[ \pi_t = E_t \left[ \sum_{i=0}^{\infty} \left\{ P_{t+i}^N Q_t^N (1-\delta)^i / (1+R_t)^i - W_{t+i} L_t^N (1-\delta)^i / (1+R_t)^i \right\} - P_{t+i}^M M_t^N (1-\delta)^i / (1+R_t)^i - P_{t+i}^E E_t^N (1-\delta)^i / (1+R_t)^i \right] - q_t C(I_t) \]

Then, the first order conditions for investment and other inputs are\(^3\)

\[ \Pi_t \frac{\partial Q_t^N}{\partial I_t} = q_tC'(I_t) \]
\[ \Pi_t \frac{\partial Q_t^N}{\partial L_t^N} = \omega_t \]
\[ \Pi_t \frac{\partial Q_t^N}{\partial M_t^N} = \theta_t \]
\[ \Pi_t \frac{\partial Q_t^N}{\partial E_t^N} = \psi_t \]

where

\[ \Pi_t = E_t \left[ P_{t+i} / (1+\delta+R_t)^i \right] \]
\[ \omega_t = E_t \left[ W_{t+i} / (1+\delta+R_t)^i \right] \]
\[ \theta_t = E_t \left[ P_{t+i}^M / (1+\delta+R_t)^i \right] \]
\[ \psi_t = E_t \left[ P_{t+i}^E / (1+\delta+R_t)^i \right] \]

Since the ex-ante production function is homogeneous of first degree it can be rewritten as

\[ q_t^N = f(l_t^N, e_t^N, m_t^N) \]

where \( q_t^N = Q_t^N / I_t, l_t^N = L_t^N / I_t, e_t^N = E_t^N / I_t, m_t^N = M_t^N / I_t \)

Then, equations (9) to (12) are simplified as

\[ \Pi_t (f - l_t^N f_1 - e_t^N f_2 - m_t^N f_3) = q_t C'(I_t) \]
\[ \Pi_t f_1 = \omega_t \]
\[ \Pi_t f_2 = \psi_t \]
\[ \Pi_t f_3 = \vartheta_t \]
where $f_i$ is the partial derivative of $f(l_i^N, e_i^N, m_i^N)$ with respect to $i$-th component.

From equations (15) to (17), the labor-investment, energy-investment, and material-investment ratios are determined as a function of relative prices $\alpha_i/\Pi_i$, $\psi_i/\Pi_i$, and $\theta_i/\Pi_i$ alone as in the following:

$$l_i^N = g((\alpha/\Pi)_i, (\psi/\Pi)_i, (\theta/\Pi)_i)$$
$$e_i^N = h((\alpha/\Pi)_i, (\psi/\Pi)_i, (\theta/\Pi)_i)$$
$$m_i^N = k((\alpha/\Pi)_i, (\psi/\Pi)_i, (\theta/\Pi)_i)$$

Under the standard putty-putty type production technology, variable input-capital ratios are functions of relative prices currently prevailing, while under the putty-clay type production technology the relevant relative prices are measured in terms of the present value of future prices. This implies that all the expected future output and input prices play a vital role in determining the variable input-capital ratios of the new vintage. Note that the investment goods price does not exert any influence on the variable input-capital ratios.$^4$

To see the determinants of the investment level more clearly, we substitute equations (15) to (17) into equation (14) and obtain

$$\frac{(\Pi f - \alpha_i l_i^N - \psi_i e_i^N - \theta_i m_i^N)}{q_t} = C(I)$$

The numerator of equation (18) is the present value of the expected future profit rates, whereas the denominator is the current investment goods price. The left-hand-side variable in equation (18) can be thus interpreted as the well-known Tobin's marginal $q$, which is specific to the new vintage installed at time $t$. It follows that investment level is an increasing function of the vintage-specific Tobin's marginal $q$.

To sum up, the optimal investment level and the demand for variable inputs associated with it are expressed as a function of relative prices:

$$I_t = H_1 ((q/\Pi)_t, (\alpha/\Pi)_t, (\psi/\Pi)_t, (\theta/\Pi)_t)$$
$$L_t^N = H_2 ((q/\Pi)_t, (\alpha/\Pi)_t, (\psi/\Pi)_t, (\theta/\Pi)_t)$$
$$E_t^N = H_3 ((q/\Pi)_t, (\alpha/\Pi)_t, (\psi/\Pi)_t, (\theta/\Pi)_t)$$
$$M_t^N = H_4 ((q/\Pi)_t, (\alpha/\Pi)_t, (\psi/\Pi)_t, (\theta/\Pi)_t)$$
In specifying the time when the capital installed in a given year gets unprofitable it is necessary to examine how the future profit earned from each vintage capital evolves over time. The profit earned at time \( t+n \) from the capital installed at time \( t \) is given by:

\[
(23) \quad P_{t+n} Q_{t+n} - W_{t+n} L_{t+n} - P_{t+n}^M M_{t+n} - P_{t+n}^E E_{t+n}
\]

\[
= (1-\delta)^n \left\{ P_{t+n} Q_t^N - W_{t+n} L_t^N - P_{t+n}^M M_t^N - P_{t+n}^E E_t^N \right\}
\]

\[
= (1-\delta)^n P_{t+n} \left\{ Q_t^N - (W/P)_{t+n} L_t^N - (P^M/P)_{t+n} M_t^N - (P^E/P)_{t+n} E_t^N \right\}
\]

\[
= (1-\delta)^n P_{t+n} G((W/P)_{t+n}, (P^M/P)_{t+n}, (P^E/P)_{t+n}, (q/\Pi)_t, \\
(n/\Pi)_t, (\psi/\Pi)_t, (\theta/\Pi)_t)
\]

The last equality holds since \( Q_t^N, L_t^N, M_t^N, \) and \( E_t^N \) are all expressed as a function of \( (q/\Pi)_t, (n/\Pi)_t, (\psi/\Pi)_t, \) and \( (\theta/\Pi)_t \). That is, the future profitability of the capital installed at time \( t \) depends critically on the difference between the ratios of the current actual factor to output prices and the ratios of the factor to output prices expected by the firm at the time of installation. For example, consider the case where the wage rates have grown more rapidly than expected by the firm when the capital was installed at time \( t \). Then the profit at time \( t+n \) will be less than expected initially and the firm would have an incentive either to scrap the capital or to transfer it to a location where the wage rate is not as high. This effect is captured in equation (23) with the inclusion of the terms of \( (W/P)_{t+n} \) and \( (n/\Pi)_t \).

III. Estimation of Profitability

In the preceding section we analyzed the determinants of the profitability of vintage capital. Here we focus specifically on the labor input for two reasons. First, it is frequently argued that rapid increases in wage rates in Japan have forced Japanese firms to invest abroad in search of cheap labor. Empirical examination of the effect of wage-rate increases on the profitability of vintage capital will enable us to test whether there was any incentive on the part of Japanese firms to move abroad in search of cheap labor and if so when.

Secondly, data on all the current inputs used in combination with capital are needed to obtain full information about the effects of the movement of factor prices on the profitability of vintage capital. It is quite difficult to construct the data for inputs other
than labor, but we are able to retrieve information about the elasticity of substitution of the ex-ante production function from of the first order condition for the labor input.

**Specification of the Ex-ante Production Function**

For further simplification we assume the the following CES production function:

\[(24) \quad Q_t^N = A[\alpha_1 L_t^{N,p} + \alpha_2 I_t^{p} + \alpha_3 M_t^{N,p} + \alpha_4 E_t^{N,p}]^{1/p}\]

Then the first order condition for the labor input is simplified as

\[(25) \quad (L^N/Q^N)_t = (A^p \alpha_1^{-1} \pi_t / \pi_t)^{1/(1+p)}\]

Taking the logarithm of equation (25), we derive the following:

\[(26) \quad \log(L^N/Q^N)_t = (\sigma-1)\log(A) + \sigma \log(\alpha_1) - \sigma \log(\alpha/\pi)_t\]

where \(\sigma\) is the elasticity of substitution \([=1/(1+\rho)]\). By estimating the parameters of this equation we can now calculate the profitability of vintage capital.

The profit earned at time \(t+n\) by utilizing capital installed at time \(t\), which is given by equation (23), is further simplified as:

\[(27) \quad P_{t+n} Q_{t+n} - W_{t+n} L_{t+n} - P_{t+n}^M M_{t+n} - P_{t+n}^E E_{t+n}
= (1-\delta) P_{t+n} Q_t^N \{1 - (W/P)_{t+n} (L^N/Q^N)_t - (P^M/P)_{t+n} (M^N/Q^N)_t
- (P^E/P)_{t+n} (E^N/Q^N)_t\}.\]

The profitability of vintage capital depends then on the magnitude of the term in the parenthesis in the RHS, which measures the capital share of output.

The \((L^N/Q^N)_t\) term in equation (27) is computed from equation (25) based on the parameter estimates of equation (26). Specifically,

\[(L^N/Q^N)_t = \exp(\text{constant term in equation (26)}) \ (\Pi/\alpha)_t^s\]

where \(s\) is the coefficient estimate of \(\log(\alpha/\Pi)_t\).

For \((M^N/Q^N)_t\) and \((E^N/Q^N)_t\) we use the average material-output and energy-output ratios prevailing at the time of installation, respectively.\(^5\) That is,

\[(28) \quad (M^N/Q^N)_t = (M/Q)_t \quad \text{and} \quad (E^N/Q^N)_t = (E/Q)_t\]

where \(M_t\): total material input used with all the vintages existing at time \(t\)

\(E_t\): total energy input used with all the vintages existing at time \(t\)

\(Q_t\): total output produced with all the vintages existing at time \(t\)
Generation of Future Expected Prices and Wage Rates

As discussed in the preceding section, the expectations of future output prices and wage rates formed at the time when capital was installed affect its future profitability. We assume that the firm forms expectations for the future output price and the wage rate rationally on the basis of their own past history. Specifically, the firm’s forecasting equations of the output price and the wage rate are of the following type:

\[ \Delta P_t = a_{t0} + a_{t1} \Delta P_{t-1} + u_{pt} \]
\[ \Delta W_t = a_{w0} + a_{w1} \Delta W_{t-1} + u_{wt} \]

where \( u_{pt} \) and \( u_{wt} \) are, respectively, disturbance terms in the output price and the wage rate equations and assumed to be serially uncorrelated.

It can be then shown that the present values of the expected future output prices and the wage rates are, respectively,

\[ \Pi_t = (1 + \delta + R_t) (P_t + PVP_t)/(\delta + R_t) \]
\[ \omega_t = (1 + \delta + R_t) (W_t + PWV_t)/(\delta + R_t) \]

where \( PVP_t = \{(1 + \delta + R_t) a_{t0}/(\delta + R_t) + a_{t1} \Delta P_t\}/(1 + \delta + R_t - a_{t1}) \)
\[ PWV_t = \{(1 + \delta + R_t) a_{w0}/(\delta + R_t) + a_{w1} \Delta W_t\}/(1 + \delta + R_t - a_{w1}) \]

Date Construction

For our empirical study we have chosen six industries—textiles, chemicals, basic metal, machinery, electrical machinery, and transport equipment—covering a twenty-nine year period of 1960 through 1988. [We use annual data. The criterion for choosing these industries is the completeness of the data on the export price as well as DFI.]

The labor input associated with the capital installed at year \( t \), \( L^N_t \), is constructed in the following manner:

\[ L^N_t = LR_{t-1} HIRE_t HR_t \]

where \( L^N_t \) is the labor input currently used for new vintage and is measured in terms of man-hour. This term is constructed by multiplying the total number of employees at time \( t-1 \), \( LR_{t-1} \), and the rate of new hire at time \( t \), \( HIRE_t \) (a ratio of new hires at time \( t \) to total employment at time \( t-1 \)) to the number of hours worked per person at time \( t \), \( HR_t \). Although the above implies that the employees hired at time \( t \) is all assigned to new
vintage this may not be necessarily the case. In fact employees working with an old vintage may be assigned to the new vintage while the newly hired are assigned to the old vintage.

The procedure for computing the output produced with the capital installed at time \( t \), \( Q^N_{t} \), is as follows:

The ex-post average productivity at time \( t-1 \) of the labor associated with all but the new vintage is written as

\[
\phi_{t-1} = \frac{Q_{t-1}}{(HR_{t-1} LR_{t-1})}
\]

where \( Q_{t-1} \) is real gross output at time \( t-1 \). We assume that this productivity is held constant for the portion of the capital still remaining for time \( t \). Then the output produced with all but the new vintage at time \( t \) is calculated as

\[
\phi_{t-1} HR_t (LR_t - LR_{t-1} HIRE_t).
\]

Thus, the value in the parenthesis is the labor associated with all but the new vintage capital. The contribution of the new vintage to the total output produced at time \( t \) is obtained by subtracting equation (35) from the total output at time \( t \). That is,

\[
Q^N_t = Q_t - \phi_{t-1} HR_t (LR_t - LR_{t-1} HIRE_t)
\]

\[
= Q_t - Q_{t-1} HR_t (LR_t - LR_{t-1} HIRE_t)/(HR_{t-1} LR_{t-1})
\]

IV. Profitability of Vintage Capital

With the estimates of the ex-ante production function (see Appendix D for estimating procedures) and with equation (27) we can now compute the labor-output ratio for the new vintage capital and hence trace its profitability subsequent to its installation.

Profitability is measured as the capital share of output. Its estimates at producer prices are reported in Figures 1 to 6 and those at export prices, which thus take into account the effect of exchange-rate changes, in Figures 7 to 12. These figures show the time paths of the profitability of vintage capital installed in 1960 through 1987 for the six sample industries. For example, the line in Figure 1 labeled 60 traces the profitability of the capital installed in 1960 for the textile industry until it turns negative. The calculation
based on export prices is especially relevant to our study as these Japanese manufacturing industries have exported a large proportion of their output.

The results of our calculation show that although in the chemical and basic metal industries the vintages installed in 1986 and 1987 have remained profitable in the international as well as domestic markets most of the vintages installed after the early 1970s have remained profitable only in the domestic market. For transport equipment the vintages of the late 1970s and the 1980s have remained profitable in both domestic and international markets. But, for machinery and electrical machinery only those of the 1980s have remained profitable in both markets. For textiles the vintages installed after 1983 are still profitable only in the domestic market.

The patterns of the profitability of vintage capital for the six Japanese industries during the sample period have been affected basically by three factors: the oil crises, yen appreciation, and technological changes. The profitability of textiles, basic metal, electrical machinery and transport equipment turned negative at producer prices as a result of the oil shocks of 1974-75 and 1979-81.

The profitability of all the six industries turned negative at export prices around 1977-78 and 1986. These are the periods during which the yen underwent major appreciation. In the machinery and electrical machinery industries all the vintages have become unprofitable at a more or less uniform rate. This can be explained as due to a continuous and high rate of technological improvement taking place in these industries, thus rendering old vintages less efficient and thus less profitable at a constant rate over time (See Appendix B).

V. Profitability of Capital and Direct Foreign Investment

In the preceding section we traced out the time-profile of the profitability of various vintages for the six industries. Now we can examine whether the outflow of DFI is related to the loss of profitability by checking the relation between the years when DFI increases and those when capital became unprofitable. It should be noted, however, that the loss of profitability is neither a necessary nor a sufficient condition for DFI. The firm could transfer abroad vintage capital still profitable at home if it could earn a larger
profit abroad. It might even utilize the capital in another industry if the DFI-related transactions cost is sufficiently high to offset the gains from preserving the implicit value of capital. Furthermore, even if the firm decides to invest abroad the timing of DFI may not exactly coincide with the loss of profitability at home. Searching for a suitable host country takes time and, consequently, DFI would in general take place sometime after a particular vintage becomes unprofitable. This time lag would vary from industry to industry as it would depend on factors such as the size and longevity of capital. Predicting the exact timing of DFI would require more detailed information on the factors.

Our investigation shows that in general there is a close relationship between the time when capital becomes unprofitable and the movement of DFI when the profitability is evaluated at export prices. We were unable to find a close tie between the profitability evaluated at the producer price and the movement of DFI. This relationship is shown for the individual industries in Figures 13 through 18. Since a particular vintage can be temporarily unprofitable, we regarded it unprofitable only if it earns negative profits for two or more consecutive years. The height of the bar in the histogram denotes the number of vintage years that have become unprofitable. Thus, for example, the height of a bar equal to 2 means that in that particular year two vintage years have become unprofitable. Figures 13 through 18 also show the time series path of the amount of DFI for the six industries, and we can thus compare the histogram of profitability and the time series pattern of DFI.

What is noteworthy in all the figures is that the two oil shocks do not seem to have affected the flow of DFI although they had had an adverse effect on their profitability at producer prices. This can be explained by the fact that the effect of the oil shocks was global, thus affecting adversely prospective host countries for Japanese DFI as well as Japan itself. It would thus follow that vintages that turned unprofitable in Japan would be likewise unprofitable abroad.

As noted in the preceding section, the textiles, chemicals, basic metal, machinery, and electrical machinery industries were adversely affected at export prices by the yen appreciations that took place during the sample period. Our figures clearly show that
DFI from these industries increased soon after the yen appreciated. Clearly, old vintages in these industries became less competitive in the world market at a higher yen value but were profitable in other countries whose currency depreciated vis-a-vis the yen. Thus, unlike the two oil shocks the yen appreciation would have provided an incentive for outward DFI from Japan.

In the transport equipment industry we do not find any strong relationship between the loss of profitability and DFI. The year when there begins a large outflow of DFI from this industry is 1981. This is the year when the voluntary export restriction was introduced by the United States and this effect seems to have dominated whatever effect the loss of profitability of vinatage capital may have had on DFI from this industry.

VI. Conclusion

One thing that has been made clear by the "eclectic theory of international production" is that DFI from a given industry depends on a variety of factors existing in both the investing and host countries. It is not, therefore, something that can be explained with one variable such as the loss of profitability of vintage capital. Our objective here is thus quite modest: to show that a particular vintage capital will become unprofitable as input and output prices diverge from those expected and the resulting loss of profitability will be an incentive for investing abroad. Our empirical analysis based on Japanese data has shown that there is in general a close relationship between the time when capital becomes unprofitable and outward DFI. It is, however, obvious that a more exact analysis of the timing of outflow DFI requires a more fully specified model of the firm's decision that takes into account various options on the use of vintage capital.

One question that needs to be addressed here is why the firm does not sell unprofitable vintages to buyers in a foreign country but transfers them instead to its foreign subsidiary. The reason is that the vintages currently employed are firm- and industry-specific second-hand capital. The market for such capital is, therefore, like that for used cars and deteriorates into a market for "lemons" because of the asymmetry of information (Akerlof 1970). In such a situation the firm would find the market
systematically undervaluing its capital and would thus consider utilizing it internally. When this internal utilization takes place across national boundaries, we observe DFI.
## Appendices

### A. Data Description

<table>
<thead>
<tr>
<th>Description</th>
<th>Source</th>
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<tbody>
<tr>
<td>$P_t$: gross output price 1980 = 1.0</td>
<td>ARNA</td>
</tr>
<tr>
<td>$W_t$: wage rate per manhour (million yen; annual base)</td>
<td>ARNA, YLS</td>
</tr>
<tr>
<td>= (compensation of employees)/(employees)/(hours worked)</td>
<td></td>
</tr>
<tr>
<td>$P_{M_t}^*$: material input price 1980 = 1.0</td>
<td>S &amp; T</td>
</tr>
<tr>
<td>(constructed by the dual approach based on the Cobb-Douglas production technology)</td>
<td></td>
</tr>
<tr>
<td>$P_{E_t}^*$: energy input price 1980 = 1.0</td>
<td>S &amp; T</td>
</tr>
<tr>
<td>(constructed by the dual approach based on the Cobb-Douglas production technology)</td>
<td></td>
</tr>
<tr>
<td>$M_t$: real material input (billion yen; at market prices in 1980)</td>
<td>S &amp; T</td>
</tr>
<tr>
<td>(aggregated inputs based on the Cobb-Douglas production technology)</td>
<td></td>
</tr>
<tr>
<td>$E_t$: real energy input (billion yen; at market prices in 1980)</td>
<td>S &amp; T</td>
</tr>
<tr>
<td>(aggregated inputs based on the Cobb-Douglas production technology)</td>
<td></td>
</tr>
<tr>
<td>$Q_t$: real gross output (producers' values) (billion yen; at market prices in 1980)</td>
<td>ARNA</td>
</tr>
<tr>
<td>$P_{X_t}^*$: export price index (yen base) 1980 = 1.0</td>
<td>PIA</td>
</tr>
<tr>
<td>$R_t$: average contracted interest rates on loans and discounts (all banks)</td>
<td>ESA</td>
</tr>
<tr>
<td>$\delta$: depreciation rate = 0.05 (This rate is assumed to be common to all the industries.)</td>
<td></td>
</tr>
<tr>
<td>$LR_t$: total employed persons (thousand persons)</td>
<td>ARNA</td>
</tr>
<tr>
<td>$HR_t$: total hours worked per person (hours per month)</td>
<td>YLS</td>
</tr>
<tr>
<td>$HIRE_t$: hiring rate of new employees</td>
<td>SET</td>
</tr>
</tbody>
</table>

*where ARNA: Annual Report on National Accounts (Economic Planning Agency)*

*YLS: Yearbook of Labor Statistics (Ministry of Labor)*


*PIA: Price Indexes Annual (The Bank of Japan)*

*ESA: Economic Statistics Annual (The Bank of Japan)*

*SET: Surveys on Employment Trends (Ministry of Labor)*
B. Estimated Series of $L_t^N$ and $Q_t^N$

Our constructed series of $L_t^N$ and $Q_t^N$ shows an upward trend in the labor productivity of new vintage ($Q_t^N/L_t^N$), for all the sample industries but one. The only exception is in the chemical industry for 1975 when the value of $Q_t^N$ takes a negative value.

The following table shows the average growth rate of the labor productivity of the new vintage and that of aggregated vintage. The average growth rate of the new vintage is higher than that of the aggregated vintage for machinery and electrical machinery industries where rapid technological progress has been attained during our sample period. The opposite holds for chemicals and transport equipment, and no significant difference is seen in textiles and basic metal. These are the industries that have not experienced rapid technological changes during the sample period.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Average growth rate of the labor productivity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New vintage</td>
</tr>
<tr>
<td>Textiles</td>
<td>6.70</td>
</tr>
<tr>
<td>Chemicals</td>
<td>7.18</td>
</tr>
<tr>
<td>Basic metal</td>
<td>7.17</td>
</tr>
<tr>
<td>Machinery</td>
<td>10.48</td>
</tr>
<tr>
<td>Electrical machinery</td>
<td>11.96</td>
</tr>
<tr>
<td>Transport equipment</td>
<td>6.94</td>
</tr>
</tbody>
</table>
C. Construction of the Present Value Series of the Output Price and the Wage Rate

We first estimated the forecasting equations for output prices and wage rates, eqs. (29) and (30), and then using the estimates of the coefficients we computed the present value (PV) of the future expected output prices and wage rates. The estimates of these coefficients will be provided by the authors upon request.

It is observed that the average growth rate of the real wage rates on the PV basis is much lower than that of the actual real wage rates for all the industries. The following table summarizes the average growth rate of the real wage rates on PV basis and the actual real wage rates.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Average growth rate of the real wage rates (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual real wage</td>
</tr>
<tr>
<td>Textiles</td>
<td>8.58</td>
</tr>
<tr>
<td>Chemicals</td>
<td>8.76</td>
</tr>
<tr>
<td>Basic metal</td>
<td>9.28</td>
</tr>
<tr>
<td>Machinery</td>
<td>10.02</td>
</tr>
<tr>
<td>Electrical machinery</td>
<td>11.05</td>
</tr>
<tr>
<td>Transport equipment</td>
<td>8.90</td>
</tr>
</tbody>
</table>
D. Estimated Results of the Labor Demand Equation

We estimated the demand for labor demand, eq. (26). The estimates of all the important parameters characterizing the production technology, in particular the elasticity of substitution, are stable. For some industries the dummy variables are introduced in the equation for a few years when the labor-output ratio was notably high. Our estimation of the demand for labor function shows that the ex-ante substitutability among the factors of production is quite high, especially in comparison with the estimates of substitutability reported in a study carried out by Saito and Tokutsu 1989). The difference is due to the fact that their study estimated the elasticity of substitution on the basis of total output and inputs data. Their estimates hence combine the low substitutability between the capital already installed in the past and other inputs and the high substitutability between new capital and other inputs. In contrast, our estimates reflect only the ex-ante substitution between new capital and other inputs. The estimates of the equation will be provided by the authors upon request.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Elasticity of substitution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Our estimates</td>
</tr>
<tr>
<td>Textiles</td>
<td>1.8550</td>
</tr>
<tr>
<td>Chemicals</td>
<td>1.9019</td>
</tr>
<tr>
<td>Basic metal</td>
<td>1.7512</td>
</tr>
<tr>
<td>Machinery</td>
<td>2.2960</td>
</tr>
<tr>
<td>Electrical machinery</td>
<td>1.6837</td>
</tr>
<tr>
<td>Transport equipment</td>
<td>1.5072</td>
</tr>
</tbody>
</table>
References


1. Ando et al, (1974) espiatated an investment function based on a putty-clay type of technology but their investment function is for selecting an optimum combination of capital of various vintages for a given level of output. Our problem differs from theirs as we do not take the output level as a given.

2. The firm's production and investment behavior may be analyzed by formulating the production function in terms of value added instead of gross output. It turns out that our constructed series of the value-added output price exhibits an erratic movement for some industries, influencing (to a large extent) our estimates of ex-ante elasticity of substitution. Accordingly, we have chosen the gross output approach and not the value-added approach.

3. Here we utilize the approximation that \((1-\delta)/(1+R_t) \approx 1/(1+\delta+R_t)\). These first order conditions are different from the usual static conditions in that all the future output and input prices are taken into account in deciding the level of input demand and output. In equations (9) to (12), the future output and input prices are incorporated into \(\Pi_t\), \(\alpha_t\), \(\theta_t\), and \(\psi_t\), which are the present value of future output prices, wage rates, material prices, and energy prices, respectively.

4. This property is demonstrated in Adachi (1989).

5. The average here is an arithmetic mean of the ratios associated with all the vintages.
Figure 1
Profitability of Vintage Capital
Evaluated at Producer Price
(Textiles)
Figure 3
Profitability of Vintage Capital Evaluated at Producer Price (Basic Metal)
Figure 4
Profitability of Vintage Capital Evaluated at Producer Price (Machinery)
Figure 5
Profitability of Vintage Capital Evaluated at Producer Price (Electrical Machinery)
Figure 8
Profitability of Vintage Capital Evaluated at Export Price (Chemicals)
Figure 9
Profitability of Vintage Capital Evaluated at Export Price
(Basic Metal)
Figure 10
Profitability of Vintage Capital Evaluated at Export Price
(Machinery)
Figure 11
Profitability of Vintage Capital Evaluated at Export Price (Electrical Machinery)
Figure 12
Profitability of Vintage Capital
Evaluated at Export Price
(Transport Equipment)
Figure 18

DFI in Transport Equipment & Unprofitable Vintage Capital

Distribution of Years When Vintage Capital Gets Unprofitable (left scale)

DFI in Transport Equipment (right scale)

YEARS


BILLIONS $US

0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6

Producer Prices Export Prices DFI