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Abstract

This paper develops and tests a simple model of the simultaneous determination of gross fixed capital formation by multinational Japanese firms in home and host countries. We treat multinational firms as multi-product firms, choosing optimal investment locations and production scale for each product. We test the predictions of the model on a unique dataset covering 1707 fixed capital investment decisions by (affiliates of) Japanese multinational firms in the manufacturing sector based on research conducted in 1996 and 1997. We find that the rate of investment is not only determined by factors affecting the return on investment levels in a country (e.g. effective demand and wages), but also by wage levels in other countries in which the firm operates manufacturing affiliates. Firms facing global liquidity constraints show systematically lower investment ratios, suggesting that financing constraints are another source of interaction between investments.

Key words: Multinational Firms; Foreign Direct Investment
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1. Introduction

Investment decisions are the quintessential decisions over which the multinational firm will seek central control and the multinational firm is expected to coordinate and decide centrally on worldwide investment allocation. Although there is an expanding literature on the role of multinational firms on global trade and international investment flows, very few studies have analyzed multinational firms' fixed capital investment decisions (Desai et al. 2005a).[2]

There are two main channels for interaction between investments in different countries by the multinational firm (e.g. Stevens and Lipsey 1992). First, on the manufacturing side, locations in different countries may be competing for investment projects as the multinational firm is likely to compare the expected profitability of performing the project in alternative locations. On the other hand, investment decisions may also be complementary through their (local) demand enhancing effects and expansion of vertical intra-firm trade. Second, on the financing side, different investment projects may also be in competition if the firm faces financing constraints resulting in an upward sloping capital cost function: projects in one country may reduce investments in marginal projects in other countries. A counteracting force may be that multinational firms have more options to utilize internal or external local

[2] The behaviour of multinational firms and the consequences of multinational firm activity for the local economies of host and home countries have received considerable attention in economic research. Attention has focused on the firm and host country determinants of foreign direct investment (e.g. Wheeler and Mody 1992, Belderbos and Sleuwaegen 1996, Chen and Moore 2009, Yeaple 2009, Aw and Lee 2008, Blonigen et al. 2005) the effects of FDI on trade (e.g. Blomström et al. 1997, Lipsey and Wise 1984 Belderbos and Sleuwaegen 1998, Head and Ries 2001, Hanson et al. 2005), the consequences of multinational activity for domestic wages and employment (e.g. Budd et al. 2005, Slaughter 2000, Feenstra and Hanson 1996, Brainard and Riker 1997, Head and Ries 2002, Ito and Fukao, 2005; Konings and Murphy 2006), and (technology) spillovers from foreign direct investments (e.g. Haskell et al. 2007, Aitken et al. 1997).

and international sources of finance, reducing their overall financial constraints (Desai et al. 2004; Harrison et al. 2003).

This paper is the first to examine such potential interactions between global investment projects by multinational firms at the micro level. Since coordinated global fixed capital investments decisions are a potential channel for the international transmission of financial and real shocks across economies, it is of interest to empirically investigate the magnitude and nature of interactions in fixed capital investments. Studies to date have however analyzed relationships at the aggregate industry or macro level, have substituted balance of payments data on the financing of FDI for actual capital expenditure data, or have narrowed attention to the relationship between foreign direct investment and the domestic capital stock.[3] Only two studies have examined interaction between fixed capital investments at the firm level. Stevens and Lipsey (1992) used panel data on a sample of 7 US multinational firms and focused analysis on the impact of finance constraints. They confirmed a negative interaction effect between foreign and domestic investments stemming from a rise in marginal capital cost. Desai et al. (2005a) examined the impact of various measures of foreign activities on domestic (US) activities by multinational firms in a panel of US multinational firms. Instrumenting aggregate foreign activity of the firms by differences in host country economic growth, they find a positive relation between FDI and domestic capital expenditures.

[3] Findings in Belderbos (1992) suggest substitution between FDI stocks and domestic assets for Dutch multinational firms, but the study relied on aggregated industry level balance sheet data. Feldstein (1995) and Desai et al (2005b) similarly find a negative impact of FDI on the aggregate capital stock across OECD countries although Desai et al. (2005a) obtain a complementary relationship if the analysis is restricted to domestic capital of multinational firms. Herzer and Schroten (2006), in contrast, find a positive relationship between outward FDI flows from the US and domestic aggregate capital formation, but a negative relationship for Germany.

In this paper we attempt to uncover the interactions between investments by multinational firms in different locations through a systematic study of simultaneous fixed capital investment decisions. We broaden the focus of analysis by examining investment decisions in all locations in which the multinational firms are active and we infer interactions between investments in all these locations (including the home country) from their determinants. We examine global fixed capital investment decisions by Japanese multinational firms, drawing on unpublished affiliate level fixed capital investment data contained in the Survey of Trends in Business Activities of Foreign Affiliates conducted by the Ministry of Economy, Trade and Industry (METI). Our analysis is informed by a model of the simultaneous gross fixed capital formation decision by multinational firms. Starting point is the notion of optimal dynamic investment behaviour under nonconvex adjustment costs, following Abel and Eberly (1994), Eberly (1997) and Barnett and Sakellaris (1998). We treat multinational firms as multi-product firms choosing optimal locations for each unique product based on effective (host country and export) demand, productivity, and wage costs at the industry level. Our model emphasizes interactions through the manufacturing side and allows for demand as well as cost considerations in FDI decisions, while controlling for financial constraints. Examining 1707 fixed capital investment decisions in 1996, we find qualified support for the predictions of the model. The rate of investment is not only determined by factors affecting the return on investment in a country and industry but also by the wage of other countries in which the firm operates manufacturing affiliates.

2. A Model of Global Fixed Capital Investments by Multinational Firms

We develop a model of fixed capital investments to determine how a multinational firm allocates investment over a number of manufacturing locations in *C* different countries (including the home country). We study the firm's optimal dynamic investment behaviour under non-convex adjustment costs following the investment models developed by Abel and Eberly (1994), Eberly (1997) and Barnett and Sakellaris (1998). Let E_t denote the expectations operator conditional on information available at time *t*. The current gross profit at time *t* is given by $\Pi(K_{1t}, K_{2t}, ..., K_{Ct}, Z)$ where K_{ct} is the beginning of period stock of capital in country *c* and *Z* denotes the number of products made by the firm. A linear quadratic adjustment cost function is given by $\Psi_c(I_{ct}, K_{ct}) = \frac{(I_{ct})^2}{2\alpha K_{ct}} + p_{ct}^{+} I_{ct} d_{ct}$ where I_{ct} is gross investment in country *c* at year *t* and p_{ct}^{+} is the unit cost of capital at time *t* in country *c*. The parameter α measures the size of the quadratic adjustment costs. We allow for zero investment decisions by assuming a non-convexity in the adjustment cost function allowing for irreversibility of investment. To that end, the dummy variable d_{ct} takes the value one if investment is positive, otherwise it equals zero.[4] The value of the firm, accounting for its international activities, can be expressed as:

(1)

$$V_t = \max_{\{I_{1s},..,I_{Cs}\}_{s=t}^{\infty}} E_t\left(\Pi(K_{1t},..,K_{Ct},Z) - \sum_{c=1}^{C} \Psi_c(I_{ct},K_{ct}) + \sum_{s=t+1}^{\infty} \rho^s \left[\Pi(K_{1s},..,K_{Cs},Z) - \sum_{c=1}^{C} \Psi_c(I_{cs},K_{cs}) \right] \right)$$

[4] This implies that the returns of selling capital on the second hand market equal zero.

where ρ is the discount factor. The firm maximizes equation (1) subject to the capital accumulation equations given by: $K_{ct+1} = K_{ct}(1-\delta) + I_{ct}$ for *c=1,..,C*. The first order condition for investment I_{ct} yields

(2) $$\frac{\partial \Psi(I_{ct}, K_{ct})}{\partial I_{ct}} = E_t(\lambda_{ct})$$

where the shadow price of installed capital is given by the expression $\lambda_{cs} = \sum_{i=s+1}^{\infty} \rho^i (1-\delta)^{i-1} \left(\frac{\partial \Pi(K_{1i},..,K_{ci},Z)}{\partial K_{ci}} - \frac{\partial \Psi(I_{ci}, K_{ci})}{\partial K_{ci}} \right)$. Following Abel and Eberly (1994), Eberly (1997) and Barnett and Sakellaris (1998), we can determine the optimal investment rule as:

(3) $$\frac{I_{ct}}{K_{ct}} = \alpha\left(E_t(\lambda_{ct}) - p_{ct}^{+}\right) \qquad \text{if RHS>0;}$$

$$\frac{I_{ct}}{K_{ct}} = 0 \qquad \text{otherwise.}$$

The presence of an investment rate equal to zero in our model stems from the irreversible nature of investment.[5] When investment is assumed to be irreversible, abstaining from adjusting the capital stock is preferred to scrapping, as scrapping yields no proceeds while a zero investment rate provides the option to use the capital assets when economic conditions improve in the future.

[5] An alternative way to model non-convexity that allows explaining zero investment observations is to assume fixed capital adjustment costs that are independent of the investment size (Abel and Eberly, 1994).

Following Abel and Blanchard (1986) and Nilsen and Schiantarelli (2003) we assume that $\frac{\partial \Psi(I_{ci} K_{ci})}{\partial K_{ci}} = -\frac{1}{2\alpha}\left(\frac{I_{ci}}{K_{ci}}\right)^2$ is small relative to the marginal profit of capital and therefore negligible in the expression for λ_{cs}. If we assume that the marginal profit of capital $\frac{\partial \Pi(.)}{\partial K_{ci}} = \frac{\partial \Pi(K_{1i},..,K_{ci},Z)}{\partial K_{ci}}$ follows an autoregressive process of order 2 (AR(2)), substituting an AR(2) process into the expression for the marginal profit of capital leads to the following investment equation (c.f. Abel and Blanchard, 1986, pp. 253-254):[6]

(4) $$\frac{I_{ct}}{K_{ct}} = \alpha_1^* \cdot \frac{\partial \Pi(.)}{\partial K_{ct-1}} + \alpha_2^*\left(\frac{\partial \Pi(.)}{\partial K_{ct-1}} - \frac{\partial \Pi(.)}{\partial K_{ct-2}}\right) - \alpha p_{ct}^+ \qquad \text{if RHS>0}$$

$$\frac{I_{ct}}{K_{ct}} = 0 \qquad \text{otherwise}$$

The parameters α_1^* and α_2^* are a function of the parameters governing the AR(2) process just mentioned. Investment is determined by the marginal profit of capital in period t-1 and t-2.[7] Alternatively, if we assume that the marginal profit of capital follows an AR(1) process, α_2^* is zero and investment depends on marginal profitability of capital in t-1 only. In the empirical analysis, we will examine both specifications.

[6] This approach disregards the fact that due to non convex adjustment costs the marginal value of capital depends on the notion that additional capital at date *t* affects the future probability of investment (cf. Bontempi et al., 2004). The approach taken here is not likely to lead to omitted variables since variables that affect the current decision to invest also influence the future probability to adjust capital (cf. Nilsen and Schiantarelli, 2003; Letterie and Pfann, 2007).

[7] Previous studies have suggested that $\alpha_1^* + \alpha_2^*$ are positive (Nilsen and Schiantarelli, 2003; and Letterie and Pfann, 2007).

The marginal profit of capital

We turn to the firm's profit maximization behaviour in the short run to determine the fundamentals of the marginal profit of capital. For notational convenience we drop time subscripts. The firm produces Z differentiated products. The firm needs specific knowledge in order to produce each product, and the number of products depends on the firm's past R&D activities. The term z_c denotes the number of products produced by the firm in country c. The total number of products is given by

(5) $$\sum_{c=1}^{C} z_c = Z$$

where C denotes the total number of countries. We assume that firms produce one type of product in one single location depending on effective demand, wage costs, and productivity. The time path of Z is exogenously determined and we treat the number of products Z and the capital stocks located around the world, (K_1, K_2, …., K_C) as given. The firm manufactures a product in country c using L_c units of labour. Total factor productivity in the country for the manufacture of the product is denoted by Ω_c. Total production in country c by the firm is equal to $z_c Q_c$ where Q_c is the volume of production of a single product. Let the firm's production function for each product in country c take the form of a Cobb-Douglas function with constant returns to scale:

(6) $$Q_c = \Omega_c \left(\frac{K_c}{z_c} \right)^{\beta} \left(\frac{L_c}{z_c} \right)^{1-\beta}$$

with $0<\beta<1$. Capital stock and labour input are equally distributed across the number of variants of the product z_c.

We consider multiproduct firms under monopolistic competition. Following Helpman et al. (2004), Yeaple (2009) and Chen and Moore (2010) we assume that preferences across product varieties have the standard CES form, such that demand of country *c*' for the firm's output produced in country *c* can be expressed by:

$$(7) \qquad D_{c,c'} = \left(\frac{p_{c,c'}}{P_{c'}} \right)^{-\frac{1}{1-\sigma}} \frac{E_{c'}}{P_{c'}}$$

where $0<\sigma<1$ is the elasticity of substitution between products. $E_{c'}$ denotes nominal expenditure on all products in country *c*', $p_{c,c'}$ is the market price of a product manufactured in country *c* exported to country *c*' and $P_{c'}$ is the price index of all products sold in country c'. Following Yeaple (2009) and Chen and Moore (2010) we do not close the model through entry. We furthermore consider the model in partial equilibrium and take the price index $P_{c'}$ faced by the firm as exogenous.[8]

The firm can export from country *c* to all other countries but faces an iceberg type trade cost: if the firm exports its products from country *c* to country *c*', only $100/(1+\mu_{c,c'})$ percent of exported products arrives at the destination, with $\mu_{c,c}=0$ and $\mu_{c,c'}>0$ for all $c \neq c'$. Therefore, the firm faces the following constraint on output of each product:

$$(8) \qquad \sum_{c'=1}^{C} \left(1+\mu_{c,c'}\right) D_{c,c'} = Q_c$$

[8] We also assume that the firm produces goods that are sufficiently differentiated in order to abstract from substitution within the firm's portfolio or products.

The firm maximizes its current gross profit in the short run under a given set of capital stocks located in each country, {K_c: c=1, 2, .., C}, the variety of products, Z, and the wage cost per unit of labour in country c, w_c.

$$(9)\quad \Pi(K_1, K_2, ..., K_C, Z) = \max \sum_{c=1}^{C} z_c \left\{ \left(\sum_{c'=1}^{C} p_{c,c'} D_{c,c'} \right) - VC_c \right\}$$

where the expression $VC_c = w_c \cdot \frac{L_c}{z_c}$ denotes the variable cost of labour of a single product. The firm makes a number of choices in the following order. It first determines the number of products it produces in each country {z_c: c=1, 2, .., C}, with the total number of products, Z, given. Next, it selects the optimal prices for its products {$p_{c,c'}$: c=1, 2, .., C and c'=1, 2, .., C }, the optimal level of production {Q_c: c=1, 2, .., C} and demand for labour {L_c: c=1, 2, .., C} simultaneously. In the appendix we show that the optimal number of products to be manufactured in country c, z_c, is given by:

$$(10)\qquad z_c = \frac{\Lambda_c s_c}{\Lambda_c s_c + \overline{\Lambda}_c} Z$$

where $\Lambda_c = \Omega_c^{\frac{1}{\beta}} \Gamma_c^{\frac{1-\sigma}{\sigma\beta}} \left(w_c\right)^{-\frac{1-\beta}{\beta}}$ captures information concerning the attractiveness of country c, the expression $s_c = \frac{K_c}{\sum_{c=1}^{C} K_c}$ is the share of the firm's total capital stock located in country c and $\overline{\Lambda}_c = \sum_{c' \neq c} \Lambda_{c'} s_{c'}$ denotes the attractiveness of the other countries, weighted by their share of the existing capital stock. Λ_c increases if total factor productivity in country c, (Ω_c)

increases, if the unit wage cost w_c decreases, and if attractiveness of the country in terms of effective demand (Γ_c.) increases. The latter is defined as $\Gamma_c = \sum_{c'=1}^{C} \left\{ \sigma^{\frac{1}{1-\sigma}} \left(\frac{P_{c'}}{1+\mu_{c,c'}} \right)^{\frac{\sigma}{1-\sigma}} E_{c'} \right\}$ and captures a positive effect of real expenditures on the product in the country ($E_{c'}$), and a positive effect of the opportunity to export at lower cost ($\mu_{c,c'}$). Equation (10) indicates that it is not only a country's own attractiveness that determines product allocation decisions, but also the relative attractiveness of other countries in which the multinational firms is established, in particular those countries in which there are large existing investments in capital. The same pattern can be observed in the expression for the marginal product of capital in country c (derived in the appendix):

$$(11) \qquad \frac{\partial \Pi(.)}{\partial K_c} \propto \frac{\Lambda_c}{\left(\Lambda_c s_c + \overline{\Lambda}_c\right)^{1-\sigma\beta\theta}} \left(\frac{Z}{\sum_{c=1}^{C} K_c} \right)^{1-\sigma\beta\theta}$$

The firm's marginal product of capital in country c depends on the expression for the three factors. First, it is affected by the country's own attractiveness given by Λ_c. It is straightforward to derive that the marginal product of capital increases in Λ_c. Second, the marginal productivity of capital decreases as other countries' attractiveness (the index $\overline{\Lambda}_c$) increases.[9] Third, marginal productivity improves if the firm's number of product varieties relative to the capital stock ratio $\frac{Z}{\sum_{c=1}^{C} K_c}$ increases. Substituting (11) in (4) we see that fixed

[9] As $\sigma\beta\theta<1$. We refer to the appendix, where θ is defined.

capital investments in country c depend on these three factors, as the investment path is determined by the marginal product of capital in t-1 and t-2.

3. Empirical Model, Data and Variables

If we substitute equation (11) in equation (4) and take a loglinear approximation, we obtain an empirical version of the investment equation. In case $\alpha_2^* = 0$, then:

$$
(12) \qquad \begin{aligned} \frac{I_{ct}}{K_{ct}} &= \gamma_0 + \gamma_1 \Omega_{c,t-1} + \gamma_2 \Gamma_{c,t-1} + \gamma_3 w_{c,t-1} \\ &\quad + \gamma_4 \overline{\Omega}_{c,t-1} + \gamma_5 \overline{\Gamma}_{c,t-1} + \gamma_6 \overline{w}_{c,t-1} + \gamma_7 \frac{Z_{t-1}}{\sum_{c=1}^{C} K_{c,t-1}} - \alpha \cdot p_{c,t} \end{aligned} \qquad \text{if RHS>0}
$$

$$
\frac{I_{ct}}{K_{ct}} = 0 \qquad \text{otherwise}
$$

where the upper bar expressions in the above equation denote that the corresponding variables are calculated as the weighted average of the variable for the other countries. If $\alpha_2^* \neq 0$ then the differenced values of the variables in equation (12) have to be included as well. Estimation of equation (12) implies the use of a tobit model, allowing for censoring of investment ratios at zero.

Data

Our analysis draws on unpublished data on fixed capital investments of Japanese firms from the sixth Basic Survey of Overseas Business Activities held in 1996 (data for fiscal year

1995) and the 27th Trend Survey of Overseas Business Activities held in 1997 (data for fiscal year 1996). The Basic Survey is an extensive survey among Japanese multinational firms conducted every three years and the Trend Survey is a shortened survey conducted in the two years between the Benchmark Surveys. Both surveys are conducted by the Japanese Ministry of Economy, Trade and Industry (METI, former MITI) and ask firms to supply information for the parent firm each of their foreign affiliates. The response rates of the surveys at the parent firm level are 60.4% and 59.1%, respectively, but because non-responding firms are usually small in size, the coverage in terms of global affiliates is substantially higher. Affiliate data on capital stocks are only included in the Basic Survey, but gross fixed capital investment data are included in all surveys. We merged the two datasets at the parent and affiliate level to analyze investments in fiscal year 1996 (the year ending March 1997) as a ratio of the capital stock at the end of fiscal year 1995 (March 1996). Data on capital stocks and gross fixed capital investments in Japan were drawn from the third and the fourth Basic Survey of Japanese Business Structure and Activities held in 1996 and 1997 by METI (data for fiscal 1995 and 1996). This survey is mandatory and has a response rate exceeding 90 percent.

We calculate the relevant capital stocks and fixed capital investment of a multinational firm in all countries in which they operate manufacturing activities by main industry of the affiliate. If a firm operates more manufacturing affiliates in the same industry in a country, capital stock and fixed capital investments were aggregated at the country level. If affiliates operate in different industries, a capital stock and investment variable was derived for each industry in a host country.[10] We selected parent firms active in manufacturing industries and

[10] This occurred infrequently (38 firms). For parent firm operations no such detail on capital expenditures by industry is available. We used the main line of business in Japan to allocate the domestic capital stock and capital investments to an industry, while the capital stock in Japan was used as weight s_c for all foreign fixed capital investment decisions.

responding to two overseas business surveys and the domestic activity survey. Since quite a few firms tend to respond erratically to the foreign activity survey, this reduced our sample substantially. Second, for these firms we needed complete information for manufacturing affiliates worldwide. This required reliable item responses for all relevant variables (capital stocks and fixed capital investments) for all manufacturing affiliates. Finally, the sample was reduced due to the unavailability of some explanatory variables (mainly industry-level output and demand). All this left us with 1707 observations on investments in 29 countries (including Japan) by 502 Japanese firms active in 20 industries. On average each multinational firm has capital allocated to 3.5 countries.

The gross investment ratio is total gross fixed capital investment of the firm in a country in fiscal year 1996 divided by the value of the firm's fixed tangible assets in the country at the end of fiscal year 1995. It is equal to zero for 5.3 percent of the observations.

INSERT Tables 1 and 2

The industry- and regional- distribution of our observations is summarized in Tables 1 and 2. The largest number of investment observations in the sample is in the Motor Vehicle industry (274) followed by Electrical Machinery, Radio TV and Communication Equipment, Chemicals, and Non-Electrical Machinery (Table 1). The highest capital stocks are present in capital intensive industries such as Petroleum Refinery and Iron & Steel. Average investment ratios range from 0.12 for the Food and Beverage industry to 0.67 for Other Transport Equipment. Table 2 shows that among foreign countries, affiliates in the United States (248), China, Taiwan and Thailand are best represented. On average the capital stock is much higher in Japan than abroad, showing that most multinational firms still have most of their assets located in Japan. The ratio of investment to total fixed tangible assets is however smaller in Japan compared with the comparable ratio in most overseas affiliates.

Explanatory Variables

The wage rate (WAGE*i*) is measured by the industry wage rate and is calculated as salary paid divided by the total number of employees in a country and industry, using data on salaries and employees of the population of Japanese manufacturing affiliates in the industries and countries in 1995. The average wage rate in other countries in which the firm is active (WAGE*j*) is calculated similarly, with wage rates in other countries weighted with the firm's fixed tangible assets in each country in 1995. Effective demand (DEMAND*i*) is taken as the sum of industry demand of the host country and demand in all other countries weighted by the distance between countries, with weights $1/0.5r$ (where r is distance).[11] Demand in the host country is weighted by taking as parameter r the radius of the country using the country's area size. Industry demand in the countries is calculated as production levels plus imports minus exports. The industry output and export and import data were collected from UNIDO (2003a), the OECD's STAN database for industry analysis, and Statistics Canada's World Trade Analyzer. For China data were taken from the China Statistical Yearbook and for Taiwan data were drawn from Input-Output Tables published by the Republic of China's Statistics Bureau. Demand in other countries (DEMAND*j*) is calculated in the same manner, and then weighted by the firm's fixed tangible assets in each country in 1995.

We proxy for industry and country level differences in total factor productivity by the ratio of the number of patents generated by inventors domiciled in the countries over industry level output (per 1 million US dollar) in the country (PRODV*i*). The industry-level patent

[11] This follows Head and Mayer (2004) who term this potential demand. The weight assumes that demand is equally distributed in a circle of radius *r*.

intensity measure is an indicator of the technology intensity of production in the industry and country. While direct measures of total factor productivity estimates would obviously be preferred, TFP estimates do not exist for all the countries in the sample at the detailed industry level. We assigned patents to industries based on the patent to industry concordance tables developed by Frauenhofer/OST (Smoch et al. 2003), adapted to third revision ISIC classifications. This concordance attaches to each international patent classification code (IPC, describing the technological domain of the patent) a probability that it is originating in a specific ISIC industry, based on the industries of applicant firms. The technology level in other countries (PRODV*j*) is calculated in the same manner and weighted by the firm's fixed tangible assets in each country in 1995.

Since information on the number of product or product varieties is not available, we assume that product development is a function of R&D investments and we proxy $\frac{Z}{\sum_{c=1}^{C} K_c}$ by the R&D to capital stock ratio. The R&D variable (RDINT*f*) is R&D expenditures in 1995 divided by total global assets in the world at the end of fiscal year 1995.

We lack a suitable proxy for the unit cost of capital goods $p_{c,t}$ as it may differ across countries and industries, or firms. To the extent that multinational firms buy capital goods on global markets or use capital goods developed in Japan, we may not expect strong country variation in the cost of capital goods. Industry variation in the costs of capital goods is taken into account in the empirical model through the inclusion of industry dummies.[12] We augment the equation with a measure of liquidity constraints faced by the firm to control for potential interaction in investment decisions through the marginal cost of capital facing the

[12] We experimented with inclusion of a variable measuring the share of capital goods procured from local sources, following the idea that local over international sourcing is most likely to occur if the cost of capital goods in the host country market is relatively low, but found no significant impact on investment.

firms (Stevens and Lipsey, 1992). We control for liquidity constraints by including the firm's global coverage ratio in 1995 (COVERAGE*f*). The global coverage ratio is calculated as total interest payments divided by total interest payment plus cash flow for the firm's global operations at the end of fiscal 1995.

All the variables are taken in natural logarithms.[13] We estimate equation (12) both under $\alpha_2^* = 0$ and $\alpha_2^* > 0$. In the latter case, the first differences (1994-1995) of the variables (DEMAND, WAGE, and PRODV) are included as well. We calculated the weighted differenced variables for other countries with the firm's fixed tangible assets in each country in 1995 as weights. Table 3 contains the descriptive statistics for the variables; the correlation matrix is relegated to appendix 2.

INSERT TABLE 3

5. Empirical Results

The Tobit estimation results of equation (12) are presented in Table 4. We allow for heteroscedasticity in the error term dependent on affiliate size (the logarithm of the affiliate's total assets) and we allow standard errors to be correlated across observations of the same parent firm by clustering error terms at the firm level.

INSERT TABLE 4

Model 1 in Table 4 contains the results for the model with $\alpha_2^* = 0$ and Model 2 adds the differenced values of the country variables ($\alpha_2^* > 0$) in line with the assumption of an AR(2)

[13] For variables that can also take the value zero (R&D, patents, and investment) we added the value one before taking logarithms.

process for the marginal rate of return on capital. In both models, the weighted R&D intensity of the multinational firms (RDINT*f*) is positive as predicted, and significant. The coverage ratio (COVERAGE*f*), as indicator of liquidity constraints faced by the firms in their global operations, has the expected negative sign and is also significant. The estimated parameter for heteroscedasticity shows that the variance of the error term is negatively related to affiliate size.

In model 1, the wage rate in the country and industry (WAGE*i*) has a significantly negative impact on the gross fixed capital investment ratio. At the same time, the weighted average wage rate in other countries in which the firm is active (WAGE*j*) has the predicted positive impact and is significant. These two findings imply that a country becomes an attractive location for the purpose of investing if its wages are low and if wages in other countries are high. The proxy variable for productivity (PRODV) has no significant impact. The industry demand variable for other countries (DEMAND*j*) is marginally significant but has a counterintuitive positive sign.

Results for model 2 are overall more in line with predictions. The model has a significantly improved fit, with the loglikelihood ratio test statistic at 14.8 against a critical value of the Chi-square distribution of 12.53 (at 5 percent significance). The results show that it is host country wage growth that has the most robust negative impact on fixed capital investments, rather than wage levels: wage growth is significantly negative, while the wage level looses its significance. We again find that the average wage rate in other countries in which the firm operates (WAGE*j*) is positive and significant. In addition, host country demand growth (ΔDEMAND*i*) has the expected positive impact on investment and is significant, while the level variables for DEMAND are insignificant. The productivity level (PRODV*i*) in the host country industry is positive and significant at the 10 percent level in column 2.

Overall the results provide qualified support for the model of global fixed capital investments. Although levels of significance differ, investment ratios by the multinational firms in a country are determined by (growth in) local wage costs, local productivity and demand growth, and R&D intensity as a proxy for product scope. Interaction in investment decisions cross countries takes places as a function of differences in wage levels and wage growth, while such influences cannot be found for demand and productivity. This implies that investment rates are not only driven by host features of the local economy, but also depend on the multinational firm's existing configuration of affiliates and capital in other countries and the relative wage in these countries. Interaction furthermore occurs through financial constraints in the global operations of the multinational firm, which implies that liquidity constraints of operations in one country affect investments in another.

The marginal effects of the country level and firm drivers of the investment rate are not insubstantial. We calculated the change in the mean predicted investment rate in the sample due to a standard deviation change in explanatory variables, with other variables kept at their actual levels.[14] A standard deviation increase in the host country wage rate causes the mean predicted investment rate to decrease by 7.5 percent, while a standard deviation increase in wage j increases the investment rate by 5.5 percent (model 1) . In model 2, a standard deviation increase in growth of host country wages decreases the investment rate by 4.5 percent, while a standard deviation increase in the wage j increases investment with 7 percent. A standard deviation increase in demand growth in model 2 increases the investment rate by

[14] See also Maddala (1983, p. 159) for the calculation of the expexted value in a tobit model. We see these changes in the mean prediction within the sample as slightly more conservative than estimates of marginal effects in the mean of the explanatory variables, as the latter are derived for a hypothetical firm. Marginal effects in the tobit model can be further decomposed in the effect on the probability of positive investment and the effect on the investment level (McDonald and Moffit, 1980). Given the limited censoring of the investment variable (5 percent of observations is zero), the elasticities are by and large representative of the effect on investment levels.

10 percent, a standard deviation increase in productivity 8 percent, and the effects of R&D and the coverage ratio are 8 and minus 6 percent, respectively.

Supplementary Analysis

The relatively weak results for effective demand and productivity effects may be partly caused by the restrictions of the data we are working with. Patent to output ratios are a very imperfect proxy for local productivity at the country and industry level. The weaker demand effects may be due to the assumption that effective demand is only weighted by trade cost related to distance, which abstracts from various degrees of trade barriers between countries. Also, in case affiliates in host countries manufacture product variants tailored to the host country, demand in other countries may not be consequential for investment decisions. We estimated alternative models including a local (host country) demand variable replacing the effective demand variable, but the empirical results did not show a strong pattern of local demand driving investment decisions. Similarly,we did not find stronger results by replacing industry output for revealed demand, or by applying a different weighing method to host country demand.

We also performed supplementary analysis of extended models including a measure of the effective tax rate in the countries of investment (e.g. Wheeler and Mody, 1992; Head and Mayer; 2004; Chen and Moore 2009), measured as the average ratio of Japanese firms' effective tax payments to profits as indicated by their reporting in the METI surveys. Neither the tax rate in country i nor the tax rate in other countries j in which the firms operate manufacturing affiliates exerted a significant influence on the investment rate.

6. Conclusions

We examine the determinants of, and interaction between, fixed capital investments decisions by multinational firms at the micro level. Our focus is on the simultaneous determination of investment decisions in all locations in which the multinational firms are active, and we infer interactions between investments in all these locations (including the home country) from their determinants. To guide our empirical analysis, we developed a simple model of the simultaneous gross fixed capital formation decision by multinational firms. Starting point is the notion of optimal dynamic investment behaviour under nonconvex adjustment costs, following Abel and Eberly (1994), Eberly (1994) and Barnett and Sakellaris (1998). We treat multinational firms as multi-product firms choosing optimal locations for each unique product based on effective (host country and potential export) demand, productivity, and wage costs at the industry level. Our model emphasizes interactions through the manufacturing side and allows for demand as well as cost considerations in FDI decisions, while controlling for financial constraints. We test the predictions of the model on a sample of 1707 fixed capital investment decisions by Japanese multinational firms in 1996.

We find qualified support for the predictions of the model where it concerns interactions through relative wages. The rate of investment is not only determined by factors affecting the return on investment in the country itself (i.e. effective demand, wages and productivity), but also (positively) by relative wage levels in other countries in which the firm operates manufacturing affiliates. R&D intensive firms, assumed to have broader product line-ups, show higher investment ratios over all locations. Global liquidity levels of the firm, as indicated by the coverage ratio, also increase investment rates. The results provide more support for an investment specification that includes first differenced drivers of the marginal product of capital consistent with a time path following an AR(2) process, than for a specification in levels which would be consistent with an AR(1) process.

Our findings suggest that Japanese multinational firms have been responsive to low cost opportunities abroad and have diverted investments in fixed capital from high wage countries to low wage countries in the period of study.[15] The presence of active wage arbitrage in fixed capital investment allocation depends on the expansion opportunities and cost (increases) the multinational firms are facing in their existing configuration of global activities. This suggests that features of multinationality itself are another source of firm heterogeneity affecting foreign investment decisions, in addition to heterogeneity related to competitive advantage and technological strength represented by R&D intensity or productivity (Yeaple 2009, Chen and Moore 2009).

Our analysis suggests two routes through which multinational firms transmit local shocks affecting wages or liquidity across countries through their capital investment allocation decisions. A local wage shock in countries with an important presence of multinational firms, positively affects capital investment in other countries in which these firms are active. This transmission mechanism can exacerbate the effects of a local wage shock and deepen recessions through a sharper reduction in investments in countries with a sizeable presence of multinational firms. In addition, substitution effects between investments can occur through increases or decreases in the cost of capital and variation in the cross-border intra-firm provision of internal funds. Given financial constraints and increasing marginal costs of capital, a tightening of financial constraints for firms, e.g. as a consequence of a domestic financial shock, also reduces investments abroad.

[15] We note that we cannot derive explicit implications on how exchange rate changes will affect multinational firms' capital investment, as a currency appreciation will on the one hand raise the country's relative wage rate (negatively affecting investment), but on the other hand it will raise purchasing power and increase demand for multinational firms' output (positively affecting investment).

Our finding that financing constraints are another source of interaction between investments is in line with earlier work (Stevens and Lipsey 1991). It is consistent with the notion that internal capital markets of multinational firms are important and frequently used by multinational firms to deal with host country capital market imperfections (Desai et al. 2004). It suggests that multinational firms, though they have broader options to source funds for their global operations affiliates, may still be unable to offset financing restrictions on investments.

Our results contrast with the findings in Desai et al (2005a), which suggest a positive impact of foreign investment activity on domestic capital formation by US multinationals.[16] There are several possible causes for these differences. First, we examined investment decisions in multiple countries and did not limit attention to investment in the home country. Secondly, we explicitly examined cost motivations in investment decisions with wage costs the driver of interactions in addition to the demand growth motivation studied by Desai et al. (2005a). Third, the pattern of foreign investments by Japanese firms with a concentration in South East Asia differs from that of US multinationals which have a greater focus on Western Europe (e.g. Fukao et al. 2003). Investments in Asia have been driven by cost considerations and labour cost has been an important driver of location decisions (e.g. Blomström et al. 2000, Head and Ries 2002). Potential complementarities between investments in different countries, e.g. through intra-firm trade between upstream and downstream activities (Hanson et al. 2005), may occur through the operations of other firms and particularly firms within the Japanese business group, rather than within the boundaries of the multinational firms (e.g. Belderbos and Sleuwaegen 1998, Blonigen et al. 2005). Further investigation could examine long term inter-firm relationships and investment interactions within Japanese business groups.

[16] The results are in line with studies in the international business literature on the sensitivity of affiliate employment to international wage differentials (e.g. Belderbos and Zou 2008).

Our results also suggest a number of other fruitful improvements and extensions in future research. Empirically, future models of fixed capital investments preferably take into account the dynamics of investment processes, which can only be uncovered through the use of panel data. Our finding on finance constraints driving interaction between investment decisions suggests that further research should model these explicitly integrating manufacturing and finance interactions. Replication of this type of study on data for multinationals from other countries would show if differences in empirical results on investment interactions are due to the empirical specification or the different nature of investment motives. Future modelling work on global investment decisions would pay attention to more complex intra-firm relationships between manufacturing affiliates (Grossman et al. 2006), and could combine decisions on establishing affiliates in additional countries (extensive margin) with capital investment decisions for existing affiliates. Finally, our analysis assumed that multinational firms operating in a given country and industry face the same given wage level. Recent evidence by Budd et al. (2005) suggests that wage bargaining processes in multinational firms are such that wages at the affiliate level are also a function of profitability of the parent. Perhaps the effects of wage differentials between countries may be mitigated over time if local unions can bargain for global rent sharing. Future work can examine the joint determination of investment and wages at the affiliate level and investigate to what extent wage differentials within the multinational firm persist.

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Appendix 1: Derivations

1.1. Derivation of gross profit function

In the short run, the firm's capital stock K_c is given and the firm determines optimal labour input in country *j*, L_j to maximize its current profit. Let w_c be the wage cost per unit of labour in country *c*. Using the production function given in equation (6) to obtain an expression for $\frac{L_c}{z_c}$, the variable and marginal cost functions for production of each product in country *c* are given by:

$$\text{(A1)} \quad VC_c = w_c\left(\frac{L_c}{z_c}\right) = w_c\Omega_c^{-\frac{1}{1-\beta}}\left(\frac{K_c}{z_c}\right)^{-\frac{\beta}{1-\beta}}Q_c^{\frac{1}{1-\beta}}$$

$$\text{(A2)} \quad MC_c = \frac{\partial VC_c}{\partial Q_c} = \frac{w_c}{1-\beta}\Omega_c^{-\frac{1}{1-\beta}}\left(\frac{K_c}{z_c}\right)^{-\frac{\beta}{1-\beta}}Q_c^{\frac{\beta}{1-\beta}} = \frac{VC_c}{(1-\beta)Q_c}$$

If we use equation (9), (A1) to substitute for VC_c, (8) to substitute for Q_c, and (7) to substitute for $D_{c,c'}$ in order to derive the first order condition with respect to the price $p_{c,c'}$, then the optimal pricing behaviour of the firm is:

$$\text{(A3)} \quad p_{c,c'} = \frac{1+\mu_{c,c'}}{\sigma}MC_c$$

We note that $p_{c,c'}$ is determined for a given allocation of *Z* across countries. Hence, z_c for *c*=1, .. , *C* is given at this stage of the firm's decision making process. Using equation (7) in (8) and applying (A3) and (A2), we have the following condition for optimal output in country *c*, (A4) $$Q_c = \Gamma_c MC_c^{-\frac{1}{1-\sigma}}$$

where $\Gamma_c = \sum_{c'=1}^{C} \left\{ \sigma^{\frac{1}{1-\sigma}} \left(\frac{P_{c'}}{1+\mu_{c,c'}} \right)^{\frac{\sigma}{1-\sigma}} E_{c'} \right\}$.

Using (A2) in (A4) and solving for Q_c we get:

(A5) $$Q_c = \Omega_c^{\theta} \Gamma_c^{(1-\sigma)(1-\beta)\theta} \left(\frac{w_c}{1-\beta} \right)^{-(1-\beta)\theta} \left(\frac{K_c}{z_c} \right)^{\beta\theta}$$

where $\theta = \frac{1}{(1-\sigma)(1-\beta)+\beta} > 1$. From equation (A1), (A2), and (A5), we also have:

(A6) $$VC_c = (1-\beta)^{\theta} \Omega_c^{\sigma\theta} \Gamma_c^{(1-\sigma)\theta} (w_c)^{1-\theta} \left(\frac{K_c}{z_c} \right)^{\sigma\beta\theta}$$

(A7) $$MC_c = (1-\beta)^{\beta\theta-1} \Omega_c^{(\sigma-1)\theta} \Gamma_c^{\beta(1-\sigma)\theta} (w_c)^{(1-\sigma)(1-\beta)\theta} \left(\frac{K_c}{z_c} \right)^{(\sigma-1)\beta\theta}$$

Using equation (9), (A3), (8) and (A4) respectively we can derive the gross profit function:

(A8) $$\sum_{c=1}^{C} \left[z_c \cdot \left(\sum_{c'=1}^{C} p_{c,c'} D_{c,c'} \right) - z_c VC_c \right] = \sum_{c=1}^{C} \left[z_c \cdot \left(\Gamma_c MC_c^{-\frac{\sigma}{1-\sigma}} - VC_c \right) \right] = \beta(1-\beta)^{\theta-1} \sum_{c=1}^{C} \Omega_c^{\sigma\theta} \Gamma_c^{(1-\sigma)\theta} (w_c)^{1-\theta} (K_c)^{\sigma\beta\theta} (z_c)^{1-\sigma\beta\theta}$$

Since the firm chooses its output prices for a given allocation of products across countries, gross profit depends on z_c for c = 1, 2, .. , C. Gross profit in country c increases with higher total factor productivity (Ω_c), with higher market potential (Γ_c), with lower wages w_c and a higher initial stock of capital in country c.

1.2. Derivation of optimal allocation products across countries

We derive the optimal allocation of Z across countries. To this end the firm maximizes (9) with respect to z_c for c = 1, 2, .. , C subject to the constraint in equation (5). Optimization of this problem making use of the Lagrangian implies that the firm should equalize the marginal gain across all countries:

$$\text{(A9)} \quad \Omega_c^{\sigma\theta}\Gamma_c^{(1-\sigma)\theta}w_c^{1-\theta}\left(\frac{K_c}{z_c}\right)^{\sigma\beta\theta} = \Omega_{c'}^{\sigma\theta}\Gamma_{c'}^{(1-\sigma)\theta}w_{c'}^{1-\theta}\left(\frac{K_{c'}}{z_{c'}}\right)^{\sigma\beta\theta}$$

From this condition one can find an explicit solution for $z_{c'}$ in terms of z_c:

$$\text{(A10)} \quad z_{c'} = z_c\left(\frac{\Omega_{c'}}{\Omega_c}\right)^{\frac{1}{\beta}}\left(\frac{\Gamma_{c'}}{\Gamma_c}\right)^{\frac{1-\sigma}{\sigma\beta}}\left(\frac{w_{c'}}{w_c}\right)^{-\frac{1-\beta}{\beta}}$$

Next, using equation (5) we can derive the optimal value of z_c:

$$\text{(A11)} \quad z_c = \frac{\Lambda_c s_c}{\Lambda_c s_c + \overline{\Lambda}_c} Z$$

where $\Lambda_c = \Omega_c^{\frac{1}{\beta}}\Gamma_c^{\frac{1-\sigma}{\sigma\beta}}\left(w_c\right)^{-\frac{1-\beta}{\beta}}$; $s_c = \frac{K_c}{\sum_{c=1}^{C} K_c}$; and $\overline{\Lambda}_c = \sum_{c' \neq c} \Lambda_{c'} s_{c'}$.

1.3. Derivation of marginal profit of capital

To derive the marginal profit of capital we use equation (9), (A8) and (A11) to substitute for z_c and obtain

$$\text{(A12)} \quad \Pi(K_1, K_2, .., K_C, Z) \propto \sum_{c=1}^{C} \frac{Z^{(1-\sigma)\theta} \Lambda_c \cdot K_c}{\left(\sum_{c'=1}^{C} \Lambda_{c'} \cdot K_{c'} \right)^{(1-\sigma)\theta}}$$

We find after some calculations that

(A13)

$$\frac{\partial \Pi(.)}{\partial K_c} \propto \frac{Z^{(1-\sigma)\theta} \cdot \Lambda_c - (1-\sigma)\theta \cdot Z^{(1-\sigma)\theta} (\Lambda_c)^2 K_c \left(\sum_{c'=1}^{C} \Lambda_{c'} K_{c'} \right)^{-1}}{\left(\sum_{c'=1}^{C} \Lambda_{c'} K_{c'} \right)^{(1-\sigma)\theta}} +$$

$$- \sum_{c'' \neq c} \frac{(1-\sigma)\theta \cdot Z^{(1-\sigma)\theta} \Lambda_c \Lambda_{c''} K_{c''} \left(\sum_{c'=1}^{C} \Lambda_{c'} K_{c'} \right)^{-1}}{\left(\sum_{c'=1}^{C} \Lambda_{c'} K_{c'} \right)^{(1-\sigma)\theta}} =$$

$$= \frac{z_c [Z - (1-\sigma)\theta z_c]}{K_c Z} \left[\frac{\sum_{c'=1}^{C} \Lambda_{c'} K_{c'}}{Z} \right]^{\sigma\beta\theta} - \sum_{c'' \neq c} \left[\frac{(1-\sigma)\theta z_{c''} z_c}{K_c Z} \right] \left[\frac{\sum_{c'=1}^{C} \Lambda_{c'} K_{c'}}{Z} \right]^{\sigma\beta\theta} =$$

$$= \left[\frac{\sum_{c=1}^{C} \Lambda_c K_c}{Z} \right]^{\sigma\beta\theta} \frac{z_c}{K_c} \cdot \sigma\beta\theta = \frac{\Lambda_c}{\left(\Lambda_c s_c + \overline{\Lambda}_c \right)^{1-\sigma\beta\theta}} \left(\frac{Z}{\sum_{c=1}^{C} K_c} \right)^{1-\sigma\beta\theta}$$

Appendix 2: Correlation matrix

	(obs=1707)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1)	*INVRATIO*	1													
(2)	*RDINTf*	0,0971	1												
(3)	*COVERAGEf*	-0,0249	-0,1668	1											
(4)	*WAGEi*	-0,0916	0,0259	0,0091	1										
(5)	*WAGEj*	0,1605	0,1408	-0,0138	-0,3817	1									
(6)	*PRODVi*	0,0293	0,1412	-0,031	0,312	-0,0184	1								
(7)	*PRODVj*	0,0569	0,1993	-0,0228	0,0002	0,1878	0,3015	1							
(8)	*DEMANDi*	-0,0648	-0,0081	0,0216	0,4533	-0,2546	-0,2195	-0,1085	1						
(9)	*DEMANDj*	0,0325	0,0562	-0,0095	-0,228	0,4485	-0,0884	-0,262	0,0854	1					
(10)	*Δ WAGEi*	-0,0519	-0,0268	0,0343	0,2301	-0,1186	-0,0292	-0,0293	0,0372	-0,097	1				
(11)	*Δ WAGEj*	0,0573	0,0288	0,0239	-0,1858	0,314	-0,0273	0,0033	-0,1377	0,098	-0,0606	1			
(12)	*Δ PRODVi*	0,0317	-0,0444	-0,0173	-0,3133	0,1418	-0,3461	-0,0407	-0,0598	0,1004	-0,0298	0,0971	1		
(13)	*Δ PRODVj*	-0,0969	-0,1891	-0,0214	0,1209	-0,3307	-0,093	-0,5714	0,1194	-0,0103	0,0881	-0,1162	-0,0891	1	
(14)	*Δ DEMANDi*	0,1229	0,2076	0,0284	-0,0628	0,135	-0,1131	0,1007	0,1252	0,0675	-0,048	0,0247	-0,0846	-0,2017	1
(15)	*Δ DEMANDj*	0,0553	0,2035	0,0428	0,0396	-0,0059	0,1094	0,0513	0,0429	0,0834	-0,0584	-0,0446	-0,1335	-0,2125	0,4359

Table 1. Descriptive statistics by industry

Industry	Number of observations	Average capital stock	Average investment ratio
Food, Beverages and Tobacco	61	17.618	0,120
Textiles,Clothing,Leather and Footwear	105	8.460	0,152
Wood & Furniture	16	19.730	0,173
Paper, Printing and Publishing	31	36.140	0,191
Chemicals	161	20.437	0,290
Drugs & Medicines	33	17.233	0,225
Petroleum and Coal Products and Refinery	6	180.728	0,186
Rubber and Plastic	88	8.581	0,234
Non Metallic Mineral Products	56	28.342	0,279
Iron & Steel	34	116.124	0,273
Non-Ferrous Metals	55	16.999	0,371
Metal Products	48	16.336	0,222
Non-Electrical Machinery	145	10.194	0,300
Office, Computing and Accounting Machinery	36	8.292	0,401
Electrical Machinery	259	7.881	0,292
Radio, TV and Communication Equipment	191	13.591	0,334
Motor Vehicles	274	15.038	0,304
Other Transport Equipment	8	25.721	0,672
Professional Goods/Medical & optical & precision eq	48	5.523	0,344
Other Manufacturing	52	4.341	0,238
Total	1707	16.159	0,280

Note: Amounts in million yen

Table 2. Descriptive statistics by country

Country	Number of observations	Average capital stock	Average investment ratio
Japan	502	50.051	0,160
United States	248	3.174	0,355
United Kingdom	62	1.651	0,376
Belgium	5	1.035	0,081
France	20	969	0,298
Germany	40	1.666	0,304
Italy	6	1.935	0,379
Netherlands	14	4.770	0,264
Sweden	2	(D)	0,555
Canada	15	8.414	0,243
Ireland	3	922	0,502
Portugal	3	632	1,127
Spain	13	2.069	0,297
Australia	11	733	0,388
New Zealand	4	2.192	0,305
Brazil	21	1.583	0,153
Colombia	2	(D)	0,230
Mexico	18	994	0,384
Hong Kong	49	541	0,333
India	11	4.575	0,419
Indonesia	65	2.042	0,361
Korea	77	1.044	0,374
Malaysia	73	2.828	0,284
Philippines	25	779	0,317
Singapore	89	1.435	0,417
Thailand	104	2.518	0,309
Taiwan	111	1.131	0,217
China	112	1.168	0,334
Hungary	2	(D)	0,302
Total	1707	16.159	0,280

Notes: Amounts in million yen.
(D) Suppressed to avoid disclosure of data of individual companies.

Table 3. Description of variables

variable	*Symbol*	*Description*	*Mean*	*Std. Dev.*
INVRATIO	I_{ct} / K_{ct}	Gross investment ratio in 1996	0,28046	0,409218
PRODV	$\Omega_{c,t-1}$	Industry patent intensity in country *i* in 1995	0,010784	0,018964
PRODVj	$\overline{\Omega}_{c,t-1}$	Industry patent intensity in all other countries (*j*≠*i*) in 1995	0,011833	0,017557
DEMANDi	$\Gamma_{c,t-1}$	Industry demand in country *i* in 1995	20,35743	0,843602
DEMANDj	$\overline{\Gamma}_{c,t-1}$	Weighted average industry demand in all other countries (*j*≠*i*) in 1995	20,62594	0,727617
WAGEi	$w_{c,t-1}$	Industry wage rate in country *i* in 1995	0,486443	1,232282
WAGEj	$\overline{w}_{c,t-1}$	Industry wage rate in all other countries (*j*≠*i*) in 1995	1,051268	0,897609
Δ PRODVi	$\Delta\ \Omega_{c,t-1}$	Growth rate of industry patent intensity in country *i* from 1994 to 1995	-0,00093	0,002709
Δ PRODVj	$\Delta\ \overline{\Omega}_{c,t-1}$	Growth rate of industry patent intensity in all other countries from 1994 to 1995	-0,00149	0,0022
Δ DEMANDi	$\Delta\ \Gamma_{c,t-1}$	Growth rate of industry demand in country *i* from 1994 to 1995	0,143347	0,071238
Δ DEMANDj	$\Delta\ \overline{\Gamma}_{c,t-1}$	Growth rate of weighted average industry demand in all other countries from 1994 to 1995	0,138786	0,058231
Δ WAGEi	$\Delta\ w_{c,t-1}$	Growth rate of industry wage in country *i* from 1994 to 1995	-0,00795	0,375647
Δ WAGEj	$\Delta\ \overline{w}_{c,t-1}$	Growth rate of industry wage in all other countries from 1994 to 1995	0,034943	0,227872
RDINTf	$Z_{t-1} / \sum_{c=1}^{C} K_{c,t-1}$	R&D to global asset ratio in 1995	0,101167	0,110152
COVERAGEf	-	Global coverage ratio in 1995	-3,31739	0,969094

Notes: All variables in natural logarithms (investment ratio, patent intensity, and R&D intensity after adding 1).

Table 4: Tobit estimation results for the investment ratio (equation 14)

	(1)	(2)
CONSTANT	-0.068	0.257
	(0.372)	(0.410)
PRODVi	1.106	1.307*
	(0.726)	(0.765)
PRODVj	0.074	-0.178
	(0.377)	(0.471)
DEMANDi	-0.009	-0.019
	(0.014)	(0.014)
DEMANDj	0.014*	0.007
	(0.008)	(0.011)
WAGEi	-0.019**	-0.007
	(0.008)	(0.009)
WAGEj	0.018***	0.024***
	(0.005)	(0.008)
Δ PRODVi		4.138
		(3.517)
Δ PRODVj		1.082
		(3.257)
Δ DEMANDi		0.453***
		(0.174)
Δ DEMANDj		0.029
		(0.086)
Δ WAGEi		-0.037*
		(0.022)
Δ WAGEj		-0.020
		(0.019)
RDINTf	0.234***	0.225***
	(0.057)	(0.057)
COVERAGEf	-0.018***	-0.019***
	(0.005)	(0.004)
Heteroscedasticity (ln σ)		
CONSTANT	0.575***	0.575***
	(0.130)	(0.129)
AFFILIATE ASSETS	-0.265***	-0.265***
	(0.017)	(0.017)
No. of observations	1707	1707
Industry dummies	Yes	Yes
chi-squared	513.6	515.6
Log likelihood	-229.9	-222.5

Notes: standard errors in parentheses; *significant at 10% level, ** significant at 5% level, ***significant at 1% level (two-tailed test); clustering of standard errors at the parent firm level. Industry dummies (not reported) are jointly significant.