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ABSTRACT

We develop a model of the location of global R&D investments by multinational firms, where research investments increase the number of varieties of goods sold globally by the firm, and development activities reduce the cost of producing existing varieties in specific countries. Intellectual Property Rights (IPR) protection in a country enhances the efficiency of the firms' local research as well as the profitability local development efforts. We test predictions of the model on survey data on foreign and domestic R&D for 605 Japanese multinational firms with manufacturing activities in 42 foreign countries in 1996. We find the strength of IPR protection to have a positive impact both on development expenditures and research expenditures in a country, while both research and development expenditures are also sensitive to local wage costs. Research expenditures depend positively on technological opportunities in the industry and country, while development expenditures are positively affected by potential local demand for the firm's products.

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Intellectual Property Rights Protection and the Location of Research and Development Activities by Multinational Firms

1. Introduction

An expanding literature has developed focusing on the determinants and role of R&D conducted in foreign affiliates (e.g. Kuemmerle 1997, Frost 2001, Florida 1997, Belderbos, 2001; 2003; Kuemmerle, 1999; von Zedtwitz and Gassman, 2002; Odagiri and Yasuda, 1999; Zejan, 1990; Kumar 1996) and the possible impact of such R&D and overseas knowledge sourcing on productivity of parent operations (Iwasa and Odagiri, 2003; Griffith, Harrison, and van Reenen, 2003, Fors, 1996). This literature suggests that whereas traditionally overseas R&D was conducted to adapt home-developed technologies to foreign markets ('home base exploiting' R&D), foreign R&D activities are now becoming more important vehicles to access local technological expertise abroad and to create new technologies ('home base augmenting' R&D). Although Japanese firms have been relatively slow to internationalize R&D activities, recent evidence has suggested that a growing share of R&D activities is now performed abroad (e.g. Belderbos 2001; Odagiri and Iwasa 2004; von Zedtwitz and Gassmann) and that the role of home base augmenting research is likewise increasing. Such overseas R&D may serve as a source of complementary knowledge flowing back to the firms' R&D activities in Japan and increasing R&D productivity (Odagiri and Iwasa 2003, Branstetter 2000).

The environment for overseas R&D has much improved due the changes in institutions related to patent and other intellectual property rights systems as a consequence of the agreement on trade related aspects of intellectual property rights (IPR). The advantages and disadvantages to developing countries of adopting stronger protection measures for IPR continue to be subject of a debate among policy makers and academics. There have been a number of theoretical contributions (e.g. Helpman, 1993; Lai, 1988; Glass and Saggi, 2002) suggesting that the welfare implications to developing countries could either be negative or positive. Empirical work on the impact of IPR has concentrated on the effect on the value of US firms' licensing

(Smith, 2001; Yang and Maskus, 2000), the value and composition of foreign firms' FDI (Lee and Mansfield, 1996; Smarzynska, 2004; Maskus, 1998) and imports (Smith, 1999). Overall these studies have suggested a positive impact of IPR protection on imports, FDI, and incoming technology transfer through licensing, although some studies suggest that no impact of IPR protection can be found in the absence of a degree of economic development.

A further possible positive consequence of IPR protection is obviously increased R&D investments by multinational firms. However, empirical research in this area appears to be very scarce. Kumar (1996) presents an analysis of aggregate data in a cross country study of Japanese and US R&D and finds a positive impact on R&D decisions but not on the level of R&D, but his analysis of 1989 data predates the TRIPS agreement. A recent study by Branstetter et al (2003) examines the impact of reforms in intellectual property rights protection regimes in 12 countries on R&D and intra-firm licensing arrangements by US multinationals firms to their local affiliates at the firm level. Using a fixed effects model estimated on panel data over a 1982-1999, they find a robust positive impact of IPR reform on both licensing and R&D activities by US affiliates, but only for multinational firms that possess an above median patent portfolio. The intuition is that firms that do not actively use patents to protect their inventions benefit less from changes in the patent regime abroad.

In this study we contribute to the literature by examining the impact of IPR protection on Japanese multinational firms R&D investments domestically and abroad. We use data at the firm level from the survey on Trends in Business Activities of Foreign Affiliates conducted by the Ministry of Economy, Trade and Industry in fiscal year 1996 (year ending April 1, 1997). We extend the analysis in Branstetter et al. (2003) by including more than 40 countries and by examining the R&D response of Japanese firms. We measure the strength of patent protection regimes in different countries by adopting the patent system score method developed by Ginarte and Park (1997), for which data are available in 1995. We further explore the R&D responses of Japanese firms by making an explicit distinction between research activities on the one hand and development activities on the other hand. Development activities form the core of R&D activities in developing countries but may be determined differently from research activities such that estimation of one model for both research and development may obscure the real impact of IPR regimes. We formalize this intuition by developing a model in which firms determine the allocation of research and development expenditures over home and host countries.

2. A Model of the Location of Research and Development Activities

We develop a simple model of the location of research and development activities by firm j in industry i., where research activities increase the variety in commodities produced, and development activities in each country reduce local production costs. Let C denote the set of all the countries in the world. We consider a two period model. In period 0 a multinational firm j produces a set of commodities and also conducts research and development activities in one or more countries. $R_{c,j}$ and $D_{c,j}$ denote the firm's research and development activities in country c. In period 1, firm j produces an expanded set of commodities, with $Z_{j,t}$ denoting the index of the variety of commodities that the firm can produce in period t. We assume that research expenditures augment the variety of products the firm can produce, and that research in all locations contributes to the variety expansion. Hence, $Z_{j,1}$ is a function of the existing variety of commodities in period 0 ($Z_{j,0}$) and research expenditure in all the countries in which the firm performs research activities $R_{c,j}$ ($c \in C$). We assume the following relationship between that the variety index in period 1 and the variety index in period 0:

$$Z_{j,1} = \left[\left\{ \sum_{c=C} \left(1 + \varphi_{c,i} R_{c,j}\right)^{\sigma} \right\}^{\frac{1}{\sigma}} \right]^{\eta} Z_{j,0} \tag{1}$$

where $\varphi_{c,i} > 0$ is the effectiveness of research in a country. This depends on the country's technological opportunities in the industry ($O_{c,i}$), the quality and availability of scientists and engineers in the country (N_c), the cost of R&D (U_c), and the degree of IPR protection (P_c). If intellectual property rights (IPRs) in country c are not well protected or enforced, local firms in country c will be able to learn from the research efforts of the firm and mimic some of the firm's new products, which will reduce the effectiveness of product innovation:

$$\varphi_{c,i} = \varphi(O_{c,i}, N_c, U_c, P_c) > 0 \tag{2}$$

Equation (1) implies that if the firm does not conduct research, it can not expand the variety of its products. $1/(1\text{-}\sigma)$ denotes the elasticity of substitution of research between countries, with $0 < \sigma < 1$. The scale parameter η is assumed to be smaller than 1, implying decreasing return to the scale in research.

We assume that in each commodity market the firm is in monopolistic competition and faces a demand curve with a price elasticity of $1/(1\text{-}\gamma)$, with $0 < \gamma < 1$. We also assume constant returns to scale in the production of each commodity. Let $m_{c,j,z,t}$ denote firm j's marginal production cost of a commodity z in country c in period t. Then, firm j's profit from the production of the commodity in country c in period 0 is given by:

$$\pi_{c,j,z,0} = E_{c,i,0}\left(\frac{m_{c,j,z,0}}{m_{c,z,0}*}\right)^{-\frac{\gamma}{1-\gamma}} = (1-\gamma)S_{c,j,z,0} \tag{3}$$

where $E_{c\ i,0}$ is the index of market demand in the commodity's industry i in country c in period 0. $m_{c,z,0}*$ is the index of other firms' production costs for commodity z in country c in period 0, and $S_{c,j,z,0}$ denotes sales of the commodity in country c in period 0.[1] Firm j can reduce the marginal cost in period 1 ($m_{c,j,z,1}$) by investing in development efforts in country c: $D_{c,j}$.[2] Development activities in country c are conducted in order to adapt firm j's products or production processes to local market conditions. We express this firm's relative cost competitiveness for commodities in country c at time 1 as:

$$\frac{m_{c,j,z,1}}{m_{c,z,1}*} = \left(1+\theta_c D_{c,j}\right)^{-\xi}\frac{m_{c,j,z,0}}{m_{c,z,0}*} \tag{4}$$

where θ_c (θ_c>1) is the effectiveness of development expenditures in country c. ξ denotes the degree to which there are declining returns to scale in development

[1] To simplify our analysis, we assume the firm's products are not internationally traded (e.g. because of large trade costs or the need to adapt products to local market conditions).

[2] We assume that developments efforts are geared toward cost reduction. An alternative specification would be to let developments effort expand relative demand in the country. This would lead to similar results.

efforts, with $0 < \xi < 1$ and $0 < 1 - \gamma - \xi\gamma$. The effectiveness of development efforts depends on the quality and availability of scientists and engineers in the country (S_c), the cost of R&D (U_c) in the country, and the degree of IPR protection (P_c). If IPRs are not well protected, other firms will mimic this firm's new technology for cost reduction and reduce the effectiveness of the firm's development efforts:

$$\theta_c = \theta(P_c, N_{c,}, U_c) \tag{5}$$

Firm j's profit from the production of a commodity z in country c in period 1 is given by:

$$\pi_{c,j,z,1} = G_{c,i} E_{c,i,0} \left(\frac{m_{c,j,z,1}}{m_{c,z,,1}*} \right)^{-\frac{\gamma}{1-\gamma}} = (1-\gamma) G_{c,i} S_{c,j,z,0} \left(1 + \theta_c D_{c,j}\right)^{\frac{\xi\gamma}{1-\gamma}} \tag{6}$$

where $G_{c,i}$ denotes one plus the growth rate of the market demand in the commodity's industry i in country c.

The firm chooses R and D in each country to maximize the following profit function:

$$\max_{R_{c,j}, D_{c,j}} r \int_{z \in Z_{j,1}} \sum_{c \in C} \pi_{c,z,j,1} dz + \int_{z \in Z_{j,0}} \sum_{c \in C} \pi_{c,z,j,0} dz - \sum_{c \in C} R_{c,j} - \sum_{c \in C} D_{c,j} \tag{7}$$

where r denotes a discount factor. Since commodity profit functions are independent of z we can write:

$$r \int_{z \in Z_{j,1}} \sum_{c \in C} \pi_{c,z,j,1} dz + \int_{z \in Z_{j,0}} \sum_{c \in C} \pi_{c,z,j,0} dz = r Z_{j,1} \sum_{c \in C} \pi_{c,z,j,1} + Z_{j,0} \sum_{c \in C} \pi_{c,z,j,0} \tag{8}$$

Differentiating (7) with respect to R and D, using (1) – (6) and (8), we obtain the following first order conditions:

$$r\eta \left(\sum_{c \in C} \Gamma_{c,i,j}{}^{\sigma} \right)^{\frac{\eta}{\sigma}-1} \Gamma_{c,i,j}{}^{\sigma-1} \sum_{c \in C} (1-\gamma) G_{c,i} S_{c,j,0} \Delta_{c,i,j}{}^{\frac{\xi\gamma}{1-\gamma}} = \frac{1}{\varphi_{c,i}} \tag{9}$$

$$r\xi\gamma\left(\sum_{c\in C}\Gamma_{c,i,j}{}^{\sigma}\right)^{\frac{\eta}{\sigma}} G_{c,i}S_{c,j,0}\Delta_{c,j}{}^{\frac{\xi\gamma}{1-\gamma}-1} = \frac{1}{\theta_c} \qquad (10)$$

where $\Gamma_{c,i,j} = 1+\varphi_{c,i}R_{c,j}$, $\Delta_{c,j} = 1+\theta_c D_{c,j}$. $S_{c,j,0}$ is equal to $Z_{j,0}*S_{c,j,z,0}$ and denotes firm *j*'s total output in country *c* at time 0.

In equation (9), the left-hand side represents the marginal gain due to an increase in research expenditures *R* measured on an efficiency basis ($\Gamma_{c,i,j}$), while the right-hand side denotes the marginal cost of the increase in $\Gamma_{c,i\,j}$. Equation (9) implies:

$$\frac{\Gamma_{c,i,j}}{\Gamma_{c',i,j}} = \left(\frac{\varphi_{c,i,j}}{\varphi_{c',i,j}}\right)^{\frac{1}{1-\sigma}} \qquad (11)$$

The ratio of research expenditures in any two countries measured on an efficiency basis only depends on the relative efficiency of research activities in the two countries, with $1/(1-\sigma)$ denoting the elasticity of substitution. Similarly, equation (10) implies:

$$\frac{\Delta_{c,j}}{\Delta_{c',j}} = \left(\frac{\theta_{c,j}G_{c,i}S_{c,j,0}}{\theta_{c',j}G_{c',i}S_{c',j,0}}\right)^{\frac{1-\gamma}{1-\gamma-\xi\gamma}} \qquad (12)$$

The ratio of the optimal development expenditures *D* in any two countries measured on an efficiency basis depends on the relative efficiency of development activities in the two countries, relative output in the two countries, and the relative future market potential in the two countries.

Next, we explicitly solve for optimal expenditures on *R* and *D*. From equation (10), we have:

$$\Delta_{c,j} = (r\xi\gamma)^{\frac{1-\gamma}{1-\gamma-\xi\gamma}}\left(\sum_{c\in C}\Gamma_{c,i,j}{}^{\sigma}\right)^{\frac{\eta}{\sigma}\frac{1-\gamma}{1-\gamma-\xi\gamma}}\left(G_{c,i}S_{c,j,0}\theta_{c,j}\right)^{\frac{1-\gamma}{1-\gamma-\xi\gamma}} \qquad (13)$$

Using (13) and (9), we get:

$$\frac{1}{\varphi_{c,i,j}} =$$

$$r\eta(1-\gamma)(r\xi\gamma)^{\frac{\xi\gamma}{1-\gamma-\xi\gamma}}\left(\sum_{c\in C}\Gamma_{c,i,j}{}^{\sigma}\right)^{\frac{\eta}{\sigma}\frac{1-\gamma}{1-\gamma-\xi\gamma}-1}\Gamma_{c,i,j}{}^{\sigma-1}\sum_{c\in C}\left(G_{c,i}S_{c,j,0}\right)^{\frac{1-\gamma}{1-\gamma-\xi\gamma}}\theta_{c,j}{}^{\frac{\xi\gamma}{1-\gamma-\xi\gamma}} \tag{14}$$

From this equation and equation (11) we can solve for *R*:

$$\begin{aligned}
R_{c,j} &= \frac{1}{\varphi_{c,i,j}}\left(\Gamma_{c,i,j}-1\right) \\
&= \left\{r\eta(1-\gamma)\right\}^{\left(1-\eta\frac{1-\gamma}{1-\gamma-\xi\gamma}\right)^{-1}}(r\xi\gamma)^{\frac{\xi\gamma}{1-\gamma-\xi\gamma}\left(1-\eta\frac{1-\gamma}{1-\gamma-\xi\gamma}\right)^{-1}} \\
&\quad \left(\sum_{c\in C}\varphi_c{}^{\frac{\sigma}{1-\sigma}}\right)^{-\left(1-\frac{\eta}{\sigma}\frac{1-\gamma}{1-\gamma-\xi\gamma}\right)\left(1-\eta\frac{1-\gamma}{1-\gamma-\xi\gamma}\right)^{-1}}\varphi_{c,i,j}{}^{\frac{\sigma}{1-\sigma}} \\
&\quad \left\{\sum_{c\in C}\left(G_{c,i}S_{c,j,0}\right)^{\frac{1-\gamma}{1-\gamma-\xi\gamma}}\theta_{c,j}{}^{\frac{\xi\gamma}{1-\gamma-\xi\gamma}}\right\}^{\left(1-\eta\frac{1-\gamma}{1-\gamma-\xi\gamma}\right)^{-1}} - \frac{1}{\varphi_{c,i,j}}
\end{aligned} \tag{15}$$

If there are diseconomies of scale in research (η is small) and research activities in different countries can be substituted relatively easily (the elasticity of substitution σ not much smaller than one), then $1-\eta\dfrac{1-\gamma}{1-\gamma-\xi\gamma}>0$. This implies that research expenditures in country *c* increase in the efficiency of basic research in that country ($\varphi_{c,i\,j}$), decrease in the efficiency of basic research in all the other countries ($\varphi_{c',i,j}$ if $c' \neq c$), and increase with the global market potential for the firm ($\sum_{c\in C}G_{c,i}S_{c,j,0}$) augmented with the global efficiency of its development activities ($\sum_{c\in C}\theta_{c,j}$).

Lastly, we solve for the optimal value of *D*. From equation (13) we can also derive:

$$
\begin{aligned}
D_{c,j} &= \frac{1}{\theta_{c,j}}\left(\Delta_{c,j}-1\right) \\
&= \left(r\xi\gamma\right)^{\frac{1-\gamma}{1-\gamma-\xi\gamma}}\left(G_{c,i}S_{c,j,0}\right)^{\frac{1-\gamma}{1-\gamma-\xi\gamma}}\theta_{c,j}{}^{\frac{\xi\gamma}{1-\gamma-\xi\gamma}} \\
&\quad \left\{r\eta(1-\gamma)\right\}^{\left(1-\eta\frac{1-\gamma}{1-\gamma-\xi\gamma}\right)^{-1}\eta\frac{1-\gamma}{1-\gamma-\xi\gamma}}\left(r\xi\gamma\right)^{\frac{\xi\gamma}{1-\gamma-\xi\gamma}\left(1-\eta\frac{1-\gamma}{1-\gamma-\xi\gamma}\right)^{-1}\eta\frac{1-\gamma}{1-\gamma-\xi\gamma}} \\
&\quad \left(\sum_{c\in C}\varphi_{c,i,j}{}^{\frac{\sigma}{1-\sigma}}\right)^{\left\{\frac{1}{\sigma}-\left(1-\frac{\eta}{\sigma}\frac{1-\gamma}{1-\gamma-\xi\gamma}\right)\left(1-\eta\frac{1-\gamma}{1-\gamma-\xi\gamma}\right)^{-1}\right\}\eta\frac{1-\gamma}{1-\gamma-\xi\gamma}} \\
&\quad \left\{\sum_{c\in C}\left(G_{c,i}S_{c,j,0}\right)^{\frac{1-\gamma}{1-\gamma-\xi\gamma}}\theta_{c,j}{}^{\frac{\xi\gamma}{1-\gamma-\xi\gamma}}\right\}^{\left(1-\eta\frac{1-\gamma}{1-\gamma-\xi\gamma}\right)^{-1}\eta\frac{1-\gamma}{1-\gamma-\xi\gamma}} - \frac{1}{\theta_{c,j}}
\end{aligned}
\tag{16}
$$

Under the conditions of decreasing returns to research and an elasticity of substitution σ not much smaller than one, the following condition will apply:

$$
\frac{1}{\sigma}-\left(1-\frac{\eta}{\sigma}\frac{1-\gamma}{1-\gamma-\xi\gamma}\right)\left(1-\eta\frac{1-\gamma}{1-\gamma-\xi\gamma}\right)^{-1}>0
$$

Under this condition, development expenditures in country c ($D_{c,j}$) is an increasing function of the efficiency of development efforts in country c ($\theta_{c,j}$), an increasing function of local output and the expected growth rate of local demand, and an increasing function of the global efficiency of the firm's research activities and the global market potential for the firm. In contrast with research expenditures, there is no competition for development expenditures among countries and the efficiency of development activities in all countries ($\theta_{c,j}$) has an additional positive impact on development expenditures in country c. The reason is that efficiency of development activities stimulates global market shares and hence research activities and the firm's variety in commodities, which in turn make development activities more effective in local markets.

3. Empirical Specification and Data

Empirical Model

Equation (15) suggests an empirical specification for research expenditures in a country, in which $R_{c,j}$ depends positively on $\varphi_{c,i\ j}$. and on a number of variables describing the firm's global research efficiency, development efficiency, and market potential. It is then convenient to express *R* and *D* in each country relative to *R* and *D* in a base country, for which we take the home country *h*. If we hence take as the dependent variable the ratio of research expenditures in each foreign country relative to research expenditures in the home country, the variables related to the firm's global R&D efficiency and global market potential no longer have an impact and the ratio should only be a function of the relative efficiency of research activities in the two countries. We assume a logarithmic specification between the ratio of research expenditures in country c and h, and the factors determining the relative efficiency of research, giving:

$$\log(R_{c,i} / R_{h,i}) = \\ \alpha_0 + \alpha_1 \log(O_{i,c} / O_{i,h}) + \alpha_2 \log(N_c / N_h) + \alpha_3 \log(U_c / U_h) + \alpha_4 \log(P_c / P_h) \tag{17}$$

If we follow a similar approach for the equation for development expenditures, we obtain an equation in which the ratio of development expenditures only is a function of relative market demand and the relative efficiency of development activities:

$$\log(D_{c,i} / D_{h,i}) = \\ \alpha_o^* + \alpha_1^* \log\left(G_{c,i} S_{c,j,0} / G_{h,i} S_{h,j,0}\right) + \alpha_2^* \log(N_c / N_h) + \alpha_3^* \log(U_c / U_h) + \alpha_4^* \log(P_c / P_h) \tag{18}$$

Data

We apply the model to the R&D investments by Japanese multinational firms in Japan and abroad in 1996. Our main source of data is the survey of Trends in

Business Activities of Foreign Affiliates conducted by the Ministry of Economy, Trade and Industry in fiscal year 1996 (the year ending March 31, 1997). This survey contains information on the overseas affiliates of Japanese firms, including their expenditure on R&D. This official survey is regulated under the Statistics Law of Japan and received a response rate of 78 percent at the affiliate level.[3] The responses are seen as representative and include large numbers of major multinational firms. From this survey we select parent firms active in manufacturing industries and operating at least one manufacturing affiliate abroad. A further selection had to be made because the response rate for the R&D question is relatively low. Our analysis requires that for parent firms with multiple affiliates in a country, reliable data are available on R&D for all such affiliates, in order to calculate overall R&D expenditures by the parent in the country. We also require accurate data on R&D expenditures by the parent firm in Japan, which are (not in all cases) available from the Basic Survey of Business Enterprises. In total this left us with 605 parent firms active in 42 foreign countries, giving 1702 observations. Total R&D expenditure by these firms was 5792 billion Yen in Japan and 140 billion Yen abroad.

Variable definitions

The variables in equations (17) and (18) are defined as follows:

$R_{j,c}$ = research expenditures by the parent firm in foreign country c in 1996;

$R_{j,h}$ = research expenditures by the parent firm in Japan in 1996;

$D_{j,c}$ = development expenditures by the parent firm in foreign country c in 1996;

$D_{j,h}$ = development expenditures by the parent firm in Japan in 1996;

$O_{i,c}$ = number of patents granted in the 2-digit ISIC industry of the parent firm on innovations in country c (1994-1997);

$O_{i,h}$ = number of patents granted in the 2-digit ISIC industry of the parent firm on innovations in Japan (1994-1997);

$S_{j,c}$ = sales of manufacturing affiliates of the firm in country c in 1996;

$S_{j,h}$ = (unconsolidated) sales of the Japanese parent firm in 1996;

---

[3] Affiliates are included in the survey if the Japanese firm owns at least 10 percent of equity.

$G_{i,c}$ = percentage growth 1994-1996 in production of the 2-digit ISIC industry in country *c*;

$G_{i,h}$ = percentage growth 1994-1996 in production of the 2-digit ISIC industry in Japan;

P_c = the index of intellectual property rights protection in 1995 for country *c;*

P_h = the index of intellectual property rights protection in 1995 for Japan*;*

U_c = wage costs in country *c;*

U_h = wage costs in Japan*;*

N_c = number of scientists and engineers per capita in country *c;*

N_h = number of scientists and engineers per capita in Japan*;*

Unconsolidated sales data of the Japanese parent firms are drawn from the METI survey, as are the figures on total sales of manufacturing affiliates. As proxy for technological opportunity we take the number of patent grants (1994-1997) to inventors in the country *c* and Japan in the ISIC industry in which the firm is active. The number of patent grants is likely to be a suitable proxy for technological opportunity, as differences in patenting activities indicate more rapid technological developments that are likely to lead to appropriable benefits. A three year period, 1994-1997, appears a suitable horizon to measure innovative activities relevant to 1996 R&D investment decisions. Since patents are granted with a 1-3 year lag, grants in 1997 will reflect innovation activity in 1994-1996. The patent grants are assigned to country residents on the basis of the address of the inventor listed in the patent information. Patents are assigned to ISIC industries based on the MERIT patent to industry concordance, 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. Data on production growth in the ISIC manufacturing industries are gross output data drawn from the OECD STAN Database for Industrial Analysis and UNIDO's Industrial Statistics database. For China, data were taken from the China Statistical Yearbook. Production figures were converted into Yen. All 1994 nominal values were converted into 1996 prices using the GDP deflator. The index of intellectual property rights is due to Ginarte and Park (1997)[4] and measures the strength of patents laws and enforcement. The advantage is that it allows a systematic comparison of IPR protection across countries. Wage costs are 1996 monthly manufacturing wages (converted into Yen) drawn from UNIDO's Industrial Statistics database. The number of scientists and engineers per country was drawn from the OECD's Indicators of Science and Technology database, and UNIDO's World Development Indicators database.

The analysis requires a distinction between *R* and *D*. The METI survey asks affiliates for the (multiple) purpose(s) of R&D, distinguishing between basic or applied research or development and design of products and processes for local or international markets. Given that affiliates often mention multiple purposes we cannot assign R&D expenditures to research or development uniquely, but the data allow us to make a rough decomposition over the different types of R&D activities in different countries. We treat the R&D expenditures of affiliates answering that they engaged in research activities (either in combination or without development expenditures) as research expenditures. Affiliates that do not report to be engaged in research are treated as being engaged in development activities only.[5] For R&D in Japan no similar firm-level data on R&D functions are available. Instead we utilized industry-level data on the share of research and development, respectively, in total R&D expenditures, as published by Japan's Science and Technology Agency in the Survey of Research and Development.

One problem in estimating equations (17) and (18) is that we have a substantial number of firms reporting zero R&D in countries, while the logarithmic form for the dependent variable rules out zero values for *R* or *D*. One solution to this problem is to assume that all Japanese firms with US affiliates will engage in some kind of limited R&D activities, which remains unreported. Kleinknecht (1987) and Roper (1999) find that small and medium sized enterprise engage in process and product development efforts but do not report this in official surveys. In overseas affiliates of Japanese firms likewise no accounting system may be in place to record R&D efforts that are taking place, if such efforts are very limited. If we assume that all firms underreport R&D expenditures abroad by a very small amount, we can add a small ratio of (0.1

[4] We thank Walter Park for generally providing us with an extended list of country IPR indices.
[5] This method was chosen because in practice, affiliates only engaging in research are very rare, while it is more common that affiliates only engage in development activities.

percent) to each R&D ratio. The means and standard deviations of the variables are given in Table 1.

4. Empirical Results

Since the decision by firms to conduct development and research activities abroad are not independent, we estimate a Seemingly Unrelated Regression (SUR) model allowing for correlation between the error terms of the equations. Table 2 reports the empirical results. The results broadly confirm the validity of our model. Relative IPR protection and relative technological opportunity increase relative research expenditures significantly, while wage costs reduce them. The relative availability of scientists and engineers (number of scientists and engineers per capita) is wrongly signed but not significantly different from zero. In accordance with our model, relative development expenditures increase in relative market growth and relative strength of the IPR regime, while relative wage costs reduce development expenditures. The relative availability of scientists and engineers has the correct sign but is not significantly different from zero.

It is interesting to note that the estimated coefficient for wage costs in the research equation is higher than the coefficient in the development equation. For IPR protection a similar but much less pronounced pattern is visible. This is consistent with our model, which showed that research efficiency in other countries (e.g. Japan) has a negative impact on research expenditures in a country, whilst there is no such rivalry in attracting development expenditures. Hence, research expenditures are more sensitive to wage levels in a country, since higher wages do not only reduce research efficiency and hence research efforts directly, but also lead to a reallocation of research efforts to other countries as *relative* research efficiency is reduced.

The coefficient of correlation of the error terms is significant and negative. Given the positive interaction between research efforts and developments efforts implied by our model, there is however no reason to expect a tradeoff between research and development expenditures in host countries. The negative correlation term is therefore likely to be correcting for the impact of the applied decomposition rule, according to which all R&D expenditures are assigned to research (and none to development) if affiliates report to be involved in research activities. This creates a negative correlation between research and development at the affiliate level.

5. Conclusions

In this paper, we empirically examined the impact of the strength of intellectual property rights (IPR) protection on the location of research and development activities of multinational firms. We developed a monopolistic competition model of global investments in research and development, in which research activities increase the number of varieties of goods sold globally by a firm, and development activities reduce the cost of producing existing varieties in specific countries. The efficiency of development efforts in a country depends on the strength of the IPR regime, the quality of the local research base, and the wage costs of local researchers. The efficiency of research activities in a country is also dependent on technological opportunities in the industry. The model suggested that research expenditure in a country depends positively on research efficiency in the country, global market demand of the firm, and the global efficiency of the firm's development activities. The relative efficiency of research in other countries, however, has a negative impact, making research efforts in different countries substitutes. Development expenditures depend positively on the firm's market potential in the country and the efficiency of local development efforts, as well as global research efficiency of the firm and global demand potential. The efficiency of development activities in other countries has an additional positive impact, such that development efforts in different countries are complements. Global development activities stimulate global market shares and the incentive to invest in research. The resulting increase in the firm's variety in commodities in turn makes development activities more effective in local markets.

Based on the model, we derived an empirical specification for the ratio between research expenditures in a country and research expenditures in Japan, and an equation for the ratio of development expenditures in a country to development expenditures in Japan. We estimated these equations jointly using Seemingly Unrelated Regression, on a sample of 1702 observations on R and D by 605 Japanese multinational firms with manufacturing activities in 42 foreign countries in 1996. We found that the degree of IPR protection in a country, as indicated by its score on the strength of patent law and patent enforcement, has a significantly positive impact both on development expenditures and research expenditures. Both research and development expenditures are sensitive to local wage costs, but not to the quality of the research base if this is measured as the number of scientists and engineers per capita. Research expenditures depend positively on technological opportunities in the industry and country, while development expenditures are positively affected by potential local demand for the firm.

A number of implications follow from our analysis. The results imply that developing countries' efforts to strengthen IPR protection regimes will help them to attract more R&D activities by foreign multinationals. In case of development expenditures, the analysis suggest that such strengthening is not putting countries 'in competition' with their neighbors to offer the strictest IPR regime, as countries are not likely to attract development activities away from other countries. On the other hand, IPR protection and wage costs are also important factors to attract research, and countries with lower wages and strengthened IPR protection compete to attract a larger share of multinational firms' global research efforts.

There are a number of ways to improve the current analysis. First, a better distinction between research and development expenditures in Japan is necessary to improve the reliability of the results. Here perhaps use can be made of published reports on employment in, and purpose of, research laboratories in Japan at the firm level. Second, the insignificant impact of our proxy for the quality of the research base (scientists and engineers per capita) suggests exploring the impact of different proxies such as indicators of the importance of tertiary education. Third, a limitation of the analysis is the cross section nature of the data. We intend to replicate the analysis for a more recent year in order to gain insight into possible changes in the determinants of foreign R&D expenditures. Utilizing data on the strength of patent protection and enforcement in 2000, we can investigate whether the improvements in IPR regimes in several countries has led to an increase in research or development activities by Japanese multinational firms.

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TABLE 1. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
log(Rc,i/Rh,i)	1702	-6,496	1,632	-6,908	6,402
log(Dc,i/Dh,i)	1702	-6,593	1,034	-6,908	1,116
log(Oc,j,/Oh,j)	1702	-3,242	2,717	-10,095	1,798
log(Nc/Nh)	1702	-1,383	1,259	-4,004	-0,207
log(Uc/Uh)	1702	-0,592	0,995	-3,649	0,321
log(Pc/Ph)	1702	-0,185	0,310	-1,351	0,137
log((Gc,j * Sc,i) / (Gh,j * Sh,i)	1702	-3,930	1,859	-12,362	2,723

TABLE 2. Estimates of Equations (17) and (18) using SUR

	Coef.	Std. Err.	
Research equation			
log(Oc,j,/Oh,j)	0,107	0,024	***
log(Nc/Nh)	-0,051	0,048	
log(Uc/Uh)	-0,184	0,056	***
log(Pc/Ph)	0,567	0,244	**
Constant	-6,224	0,068	***
Development equation			
log((Gc,j * Sc,i) / (Gh,j * Sh,i)	0,133	0,013	***
log(Nc/Nh)	0,014	0,028	
log(Uc/Uh)	-0,139	0,035	***
log(Pc/Ph)	0,527	0,129	***
Constant	-6,036	0,062	***

Correlation coefficient residuals:	-0,1549		
Breusch-Pagan chi2(1) test of independence:	40.851		***
Observations	1702		
Chi square Research	69,15		***
Chi square Development	148,82		***
R square Research	0,037		
R square Development	0,067		

Note: **, *** is significant at the 5 and 1 percent levels, respectively.