JCER DISCUSSION PAPER

No.100

R&D ACTIVITIES IN EAST ASIA BY JAPANESE, EUROPEAN, AND US MULTINATIONALS

Paper for presentation at the Conference,
Japan Center for Economic Research, Tokyo, June 1, 2006
(This research project "Multinational Firms' Strategies in East Asia: A Comparison of Japanese, U.S., European and Korean Firms" was sponsored by Nihon Keizai Shimbun, Inc.)

René Belderbos

(Katholieke Universiteit Leuven)

2006 年 8 月

社団法人 日本経済研究センター

Japan Center For Economic Research

R&D ACTIVITIES IN EAST ASIA BY JAPANESE, EUROPEAN, AND US MULTINATIONALS*

Paper for presentation at the conference "Multinational Firms' Strategies in East Asia: A Comparison of Japanese, U.S., European, and Korean Firms"

Japan Center for Economic Research, Tokyo, June 1, 2006

René Belderbos

Katholieke Universiteit Leuven, Technische Universiteit Eindhoven, and GSEC (Keio University)

* The author is grateful to Shinya Suzuki and Bart Leten for research assistance.

R&D ACTIVITIES IN EAST ASIA BY JAPANESE, EUROPEAN, AND US MULTINATIONALS

-SUMMARY-

We contribute to the expanding literature on the internationalization of R&D by providing evidence on the extent and pattern of R&D activities by European, Japanese, and US multinational firms in 10 Asian countries and regions: PR China, India, the Asian NIEs (South Korea, Taiwan, Hong Kong, and Singapore),. and the ASEAN countries Malaysia, Thailand, Philippines, and Indonesia. We examine European patent application data of 186 top R&D spending firms in the chemicals, pharmaceuticals, engineering, IT and electronics industries during 1996-2003. It is shown that R&D activities by these firms in Asia are still very limited, although all indicators show a continuous increase. Only 35 out of 186 firms had patent applications based on inventions in the Asian regions, and the share of patents originating from Asia for the 186 firms reach 0,7 percent in 2003. Leading R&D performers in Asia are electronics and engineering firms such as Thomson, Siemens, Hewlett Packard, Matsushita Electric, and Philips, while chemical firms and in particular pharmaceutical firms are much less active. The multinationals are still responsible for a sizeable share (20-50 percent) of host country patenting activity in electronics related sectors in Singapore, Thailand, India, and Malaysia. The influence of these firms in contrast is almost negligible in South Korea and very small in Taiwan. An econometric analysis of the number of patents originating in different host countries and industries applied for by the 186 firms showed positive impacts of host country technological strength, market attractiveness, and the strength of the IPR protection regime, with the latter suggesting that policies to strengthen IPR protection can be effective in attracting R&D investments by multinational firms. Controlling for host country and firm factors, foreign R&D was found to be less extensive in the most recent period (2000-2003), suggesting that there has certainly not been a structural change in firm behavior favoring foreign R&D. Furthermore, R&D in Asia was found to show a distinctive pattern: it was shown to be much less sensitive to market attractiveness variables, but was found to be structurally higher than in other host countries. These findings are in line with the view that R&D in Asia is also largely driven by cost considerations, and only partially by market considerations.

R&D ACTIVITIES IN EAST ASIA BY JAPANESE, EUROPEAN, AND US MULTINATIONALS

1. Introduction

The internationalization of R&D by multinational firms has been a growing phenomenon in the last two decades. 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 most foreign R&D activities is an intra-TRIAD affair, with Japan, the United States, and the European Union serving both as major home and host countries, the most recent evidence also suggests a growing importance of countries in Asia (in particular China and India) and Latin America as locations for foreign R&D (United Nations, 2005; OECD 2005). Systematic information on the features of emerging R&D in Asian countries, and differences between strategies of multinational firms in this region depending on industry and country or origin is however mostly lacking.

This growing importance of international R&D has implications for policy makers of both recipient countries wishing to attract inward R&D investments, and source countries, who are concerned that the internationalization of R&D may potentially erode ("hollow out") their knowledge base. The environment for overseas R&D has improved in recent years 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.

In this study we contribute to the expanding literature on the internationalization of R&D by providing evidence on the extent and pattern of R&D activities by European, Japanese, and US multinational firms in 10 Asian countries and regions: PR China, India, the Asian NIEs (South Korea, Taiwan, Hong Kong, and Singapore), and the ASEAN countries Malaysia, Thailand, Philippines, and Indonesia. Given the limited data available on R&D expenditures available, in particular for European firms, this study utilizes data on patents and the location of inventors listed on these patents to examine R&D internationalization patterns. We analyze patent data of 186 top R&D spending firms in the United States, Europe, and Japan in five broadly defined industries: engineering & general, pharmaceuticals, chemicals, information technology hardware (computers and communication equipment), and electrical machinery. The study makes use of patents applied for at the European Patent Office during 1996-2003 to observe the most important trends in the internationalization of innovative activities. Differences in internationalization strategies can be observed by country or origin and by industry. Using information on the type of patented technology and the industry or origin of such technologies, the extent of the multinational firms' innovative activities in Asia can be related to local strength in specific technologies and industries as indicated by patenting activities of local firms and inventors. Finally, we perform a statistical analysis explaining the number of these multinational firms' patent application originating from foreign countries by a number of factors at the industry, country, and firm level, such as local technological strengths and the degree of IPR protection.

The remainder of this report is organized as follows. The next section provides an overview of the extant literature on R&D internationalization. Section 3 describes the data on patenting activity of US, European and Japanese multinationals and the empirical approach followed in this study. Section 4 presents detailed information on location of patenting activity per industry, year, country, and by (origin of) multinational firms. Section 5 presents the result of the econometric analysis of R&D activities of the multinational firms by industry and host country, as evidenced by their patenting activity. Section 6 concludes.

2. Literature Review

A large number of studies have provided evidence of an increasing importance of international R&D by multinational firms. R&D expenditures by foreign affiliates increased by more than 50% in the OECD area between 1991 and 2001 (OECD, 2005).[1] US multinationals increased R&D spending abroad from 5.2 billion US dollars in 1987 to 14.1 billion dollars in 1997. The latter figure was 11 percent of total R&D expenditures in the US (Dalton et al., 1999). Similarly, the share of R&D in the US performed by wholly owned non-bank subsidiaries has grown from 9.2 percent of total US R&D in 1992 to 14.4 percent in 2002 (Slaughter, 2004). For Japanese multinational firms, reported overseas R&D in a survey by Japan's Ministry of Economics, Trade, and Industry stood at 279 billion Yen in 1997 increasing to 411 billion Yen in 2002, with the latter representing a more limited share of 4.1 percent of domestic R&D. At the firm level, Gassman and von Zedtwitz (2002) find substantially higher foreign R&D ratios for leading multinational firms, especially from smaller EU economies.

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; Chung and Alcacer, 2002; Reger 2001, Le Bas and Sierra 2002) 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). R&D is found to be attracted to larger local markets and markets with high per capita income, and to follow MNEs manufacturing and sales activities, reflecting technology exploitation motives. R&D activities

[1] Although in many OECD countries (e.g. thee US, France and the UK), the share of foreign affiliates in R&D is smaller than their share in manufacturing production, demonstrating that R&D activities are still less internationalized than manufacturing activities.

are also located in countries with an abundance of scientists and engineers and a technological lead in the industry of the investing firm, reflecting technology sourcing motives, while higher wage costs of scientists and engineers discourage R&D.

The growing importance of 'technology sourcing' strategies, where affiliate R&D is used as vehicle to access local technological expertise abroad, is also confirmed by studies analyzing patent citation data.[2] Almeida (1996) analyses the citations contained in a sample of patents granted by the USPTO to MNEs in the US semiconductor industry and finds that foreign subsidiaries build upon localized sources of knowledge, since the patents cited by foreign affiliates are more likely to have originated in the US or in the same US State where they operate. Frost (2001) also confirmed that geographic proximity matters substantially for technology sourcing and spillovers: foreign firms' subsidiaries were found to cite research by other institutions and firms in the same US state relatively frequently. This is consistent with the finding of Branstetter (2000) that Japanese firms investing in the US have a significantly higher probability of citing other US firms' patents.

Internationalization of R&D also has implications for the internal knowledge flows between parents and subsidiaries. Knowledge flows from foreign units to the parent company will be more likely if foreign affiliates are undertaking 'home base' augmenting type of activities that generate knowledge valuable for the rest of the organization. The challenge for a globally innovating MNE is to effectively transfer locally acquired know-how across its units. Effective intra-firm knowledge diffusion requires 'dual embeddedness' on the part of the subsidiary, i.e. embeddedness in both external and in intra-firm networks' (Frost, 1998). Recent empirical evidence suggests that overseas R&D geared towards technology sourcing has a positive impact on the productivity of parent operations (Iwasa and Odagiri, 2003; Griffith, Harrison & van Reenen, 2003; Shimizutani and Todo, 2005), suggesting effective reverse technology flows associated with technology sourcing R&D-FDI. The evidence has been

[2] These findings relate to a larger body of literature on the degree of localization of spillovers and know-how (e.g. Audretsch and Feldman, 1996). Jaffe et al. (1993) found that being close to an external information source increases the impact of spillovers from that source on internal technological capabilities and know-how.

positive for Japanese firms, which can be related to their use of joint ventures and acquisitions to build up effective overseas R&D bases more rapidly, with technologically lagging firms most active in this regard (e.g. Belderbos, 2003; Belderbos et al., 2005).

A traditional factor favoring centralization of R&D at home rather than dispersing R&D abroad, beyond the classical economies of scale in R&D argument, is the greater risk of dissipation of know how to local competitors, the flip side of potential technology sourcing from local sources. As patent citation data show, foreign subsidiaries do not only acquire local know-how, they are also sources of knowledge spillovers to the local economy. Both Almeida (1996) and Branstetter (2000) provide evidence that patents belonging to foreign firms investing in the US are disproportionally US firms. Veugelers & Cassiman (2002) using survey data from a sample of innovating Belgian firms confirm bi-directional knowledge transfers between foreign subsidiaries and local Belgian firms. In particular when multinational firms are technology leaders and affiliates are located in countries with an insufficiently developed intellectual property rights protection regime, maintaining control over core technologies is a key issue and can discourage foreign R&D. Studies have found that multinational firms adapt the type of activities located abroad in response to intellectual property rights concerns, with knowledge intensive and higher value added activities reserved for countries with stronger IPR regimes (Lee and Mansfield, 1996; Smarzynska, 2004). Zhao (2004) shows that foreign R&D labs in China mostly engage in R&D for technologies where the parent can maintain control over key complementary resources. Hence, overseas R&D does not only provide sourcing opportunities, it may also increase the risk of dissipation of R&D results to foreign rivals, in particular when there are fewer possibilities to protect know how and intellectual property. The negative consequences of unintended outgoing knowledge spillovers will be greatest when the foreign rivals are direct competitors of the multinational in the host country product market, and even more so if the foreign rivals are also competing within the multinational’s main markets.

As a consequence of the agreement on trade related aspects of intellectual property rights, the institutions related to patent and other intellectual property rights systems have much improved in developing countries in recent years. 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. Belderbos, Fukao, and Kwon (2006), examining R&D expenditures by Japanese multinationals abroad, similarly find a positive impact of the degree of host country IPR protection in a country relative to Japan on both research and development expenditures in host countries.[3]

[3] Wakasugi and Ito (2005) report similar findings for the pattern of intra-firm international licensing activities by Japanese firms abroad.

There has been surprisingly little formal economic analysis of R&D localization decisions by multinational firms. Norback (2001) develops a model of R&D localization and foreign manufacturing investment by a single multinational firm. He finds that R&D intensive firms are more likely to produce abroad, the lower the transfer costs of technology from the headquarters, and found empirical evidence for this in data on Swedish multinationals. Petit and Sanna-Randaccio (2000) study the interaction between R&D investments and reciprocal foreign direct investment by multinational firms based in two countries, but do not allow for R&D localization. The notion that establishing subsidiaries abroad leads to dissipation of know-how is developed in Ethier & Markusen (1996) who find that MNEs may prefer exports over FDI to be better able to control knowledge flows. Similarly, Fosfuri (2000) analyses the MNEs choice between FDI, exports and licensing and the vintage of the technology transferred. He assumes that while the licensee may decide to imitate, exports and FDI can perfectly prevent such imitation. He finds that if imitation is possible, e.g. because of a lower degree of patent protection in the host country, firms may prefer to choose exports or FDI, to license the older technology for which there are less incentives to imitate. Siotis (1999) develops a symmetric two-firm, two-country model where an MNE when serving the foreign market through FDI generates spillovers to local competitors, but will also be able to learn from local rivals. If the technology gap between the firms is large, the advanced firm prefers exports over FDI, while the technologically backward firm engages in FDI, which allows for technology sourcing. Bjorvatn and Eckel (2001) similarly model the export versus FDI choice for two firms based in different countries. The extent to which FDI is profitable depends on both the level of technology spillovers among the firms and the efficiency of technology transfers from affiliates to the headquarters.

A more limited number of papers have more specifically modeled the geography of R&D. Cadot and Desruelle (1998) are concerned with different location determinants of development and research activities. Firms located in smaller markets are, on average, less successful in transforming research outputs to products. This implies a pattern of international specialization in R&D activities according to which firms located in smaller countries do more research, while firms located in larger countries devote more resources to the development stage. Franck and Owen (2003) focus on the role of country-specific stocks of knowledge on R&D localization. In case foreign and domestic knowledge stocks are substitutes, firms have fewer incentives to locate R&D in the foreign market, while the opposite holds when knowledge stocks are complementary. Gersbach and Schmutzler (1999) model a duopoly where firms have to decide on one specific location for their innovation activities, which may be the same or different from their manufacturing activities. They allow for both variation in internal transfers (due to transfer costs of knowledge from the location of innovation to the location of manufacturing) and geographically bounded external spillovers (from innovation to co-located manufacturing). In their model, which is more concerned with examining R&D agglomeration within a country than with international R&D, they find that efficiency of internal transfers promotes agglomeration of innovation. Sanna-Randaccio and Veugelers (2002) also allow for internal and external (spillover) knowledge flows while considering the impact of foreign competition. Belderbos et al. (2004) examine strategic interactions between simultaneous R&D location decisions by two multinational firms based in different home countries. They find that R&D tends to concentrated in the country with the strongest IPR protection (the lowest spillovers), and find that a technology leading multinational may respond to competitive rivalry by strategic overseas R&D to increase its markets share vis-à-vis a lagging rival. Summarizing, formal models of multinational firms' R&D generally confirm a positive role of IPR protection in R&D location decisions, while the also suggest that the precise pattern of R&D internationalization depends on the nature of (international) competition between rival firms in the industry.

3. Data and Methods

In order to investigate the importance of overseas R&D by multinationals firms from Europe, the United States and Japan in Asia, we collect data on patents applied by, or granted to, 186 multinational firms in five industries broadly defined industries: engineering & general machinery, pharmaceuticals, chemicals, information technology hardware (computers and communication equipment), and electronics & electrical machinery. In these industries R&D is important, but there are differences in emphasis on the motivations for overseas R&D, with require more local adaptive development work, while pharmaceuticals and IT hardware more focused on (basic) research and linkage with science bases. The firms are selected as the top R&D spenders in their country/region and industry, such that the sample contains roughly the same number of firms in each industry for each country/region of origin. Table 1 lists the number of firms by industry and country and in appendix 1 all firms are listed with their R&D expenditures in 2003. On average about 11 firms are selected per country and industry, with some deviations where there are a particularly large or small number of firms with extensive R&D budgets (e.g. the electronics sector in Japan and the United States, respectively). The smallest R&D budget amounts to 21 million dollars (Vaisala), and the largest reaches almost 6 billion dollars (Pfizer). The 186 firms were responsible for over 30 percent of all European patent applications during the 1996-2003 period.

For the selected firms we assembled patent application data derived from the European Patent Office database. While grants are more reliable indicators of real innovations, they are awarded with a time lag of 2-6 years, such that they are a poor indicator of the most recent innovation activities. We collected patent data for the period 1996-2003 at the consolidated level, e.g. we include in the patents assigned to the firm all patents assigned to its consolidated (majority owned) subsidiaries. In order to do so we used lists of subsidiaries included in annual reports, yearly 10-K reports filed with the SEC in the US, information on group structures obtained from the Linkages database published by Dun & Bradstreet, and for Japanese firms information on foreign subsidiaries published by Toyo Keizai in the yearly Directories of Japanese Overseas Investments. Using 'consolidated' patent data this way is crucial to analyze foreign innovative activities, as many patents based on inventions by overseas subsidiaries may be applied for by the overseas legal entity rather than the patent company. On average, 20 percent of the patents in the database were assigned to subsidiaries of the firms under a name that was not a direct variant of the parent name.

We use the data in these patents on the address of the inventor to investigate the location of innovative activities. If patents listed multiple inventors based in more than one country, we assigned the patent to multiple countries using weights based on the share of inventors from that country in total number of inventors of the patent. Patents are assigned to industries based on the MERIT concordance between 4-digit technology classes of the International Patent Classification (IPC) and third revision ISIC industry classifications. This concordance attaches to each international patent classification (IPC) code describing the technological domain of the patent, a probability that it is originating in a specific ISIC industry. Since patents list multiple IPC codes without a specific ranking, we used all this information and assigned the patent to ISIC industry codes based on the share of the 4-digt IPC code in the total number 4-digit IPC codes listed. This way we could classify all patents in the EPO database to countries and industries. Appendix B lists the 25 different industries in the 2-digit ISIC classification.

The advantage of using patent data is the information on technological domains, its public availability and its systematic information on location of innovations. Disadvantage are a poor coverage of software innovations (important in particular in the communication and IT fields) and the likely under-representation of adaptive developments efforts for local foreign markets (which if patented at all, are less likely to be patented in the US or Europe). The advantages clearly outweigh the disadvantages given that systematic data (certainly at the firm level) on overseas R&D are either not collected or not generally available for analysis, while the coverage of R&D survey data is far from complete.

We examine the patents applied for by these firms (EPO data) on inventions originating from 10 Asian countries and regions: PR China, India, the Asian NIEs (South Korea, Taiwan, Hong Kong, and Singapore), and the ASEAN countries Malaysia, Thailand, Philippines, and Indonesia. We compare this patent activity per ISIC industry with patents of the firms originating from Japan, Europe, and the United States. We also compare this patent activity with the total patents per ISCI industry originating from these countries. The latter comparison indicates the potential growing attractiveness and strength of the local R&D base per industry and will give an indication of the role of foreign firms in host country R&D activity.

A few caveats have to be noted in interpretation of the data. Firms will apply for European patents if they want protection for their technologies in Europe. The European market naturally is more important for European firms than for US or Japanese firms, such that the propensity to patent in Europe is substantially higher for European firms. Although increasingly multinational firms file 'priority' patent applications simultaneously in the US, Japan, and Europe, European Patent Office data report much higher absolute numbers of patent applications originating in Europe. No strong differences are to be expected, on the other hand, in the pattern of patent activities in Asia by the three groups of multinational firms. Second, the year 2003 shows a declining number of patent applications. This is partly due to the fact that not all applications filed in 2003 had been published and recorded in our patent database. Partly it appears also due to a trend in filing patents directly at the WIPO instead of with the individual patent offices. In particular, US firms appear to have chosen this route in recent years, as their patent applications recorded with EPO have declined.

4. R&D Activities of Multinational Firms in Asia

In this Section we examine the patterns of R&D activities by the 186 multinational firms in Asia as evidenced by patent data in the period 1996-2003. In order to examine the role of these multinational firms in R&D activities in the region, we first present data on the technological strength of the countries in different industries, as indicated by all patents applied for at the EPO. We will compare two four-year periods, 1996-1999 and the more recent period for which data are available, 2000-2003.

Technological Strength of Asian Countries as Evidence by Patent Data

We first examine the country or origin of patent applications. Tables 2a and 2b provide the number of patent applications originating from the Asian countries, as well as from Europe, Japan, and the North America (United States and Canada) for the two periods. Patent applications are classified by ISIC industry. Table 2a shows the expected dominance of European inventor locations in the patent applications at the European Patent Office: more than 163000 applications out of a total of more than

333000 originated from Europe. North American locations contributed 100000 patents and Japan around 57000. The patent applications originating in Asia were very small in number compared to the three developed regions. Largest patenting country was South Korea with just over 2500 patents, followed by Taiwan (648), Singapore (348), China (353), India (302) and Hong Kong (145). Barely any patenting activity was taking place in Malaysia (49), Thailand (25), Indonesia (19) and the Philippines (17). Table 2b shows a more positive picture in the more recent period. While the total number of applications increased by roughly one third to over 416000, many Asian countries doubled or tripled their patent applications compared to the previous period. South Korea clearly is the technological leader in Asia: it applied for more patents (6668) than all the other nine Asian countries taken together. China saw the strongest growth, to 1326 patents, almost catching up with Taiwan (1477). India’s applications surged to 784, but Singapore saw much less dramatic growth of its patent applications, to 586. Indonesia and the Philippines were the exceptions, as they did not record substantially more applications.

In terms of industries, Asia’s technological strength is firmly concentrated in the electrical and electronic sectors, in particular Office, Computing and Accounting Machinery (14), Electrical Machinery (15), and Radio, TV and Communication Equipment; (16). This specialization is present for South Korea (although this country has a more distributed technological strength), but also for China, Taiwan, and Singapore. Only India and South Korean reported a significant number of applications in pharmaceuticals (300-400). Table 3 shows more details on the trend in patent applications originating from Asia. China, South Korea, and Taiwan show consistent increases in patenting activity, whereas the total number of applications has been declining somewhat in 2002 and 2003. However this was much more modest than the general decline in patent applications at the EPO, and the share of Asian countries in European patent applications increased from just over 1 percent in 1996 to over 4 percent in 2003. South Korea, however, is responsible for three quarters of these applications.

We can examine to what extent patenting activity in the Asian countries relates to the level of IPR protection. Table 4 lists the index of patent protection for 1995 and 2000 as calculated by Park and Wagh (2002). The maximum score for the index is 5, a level reached by the United States in 2000. In 1995, South Korea, Taiwan, and Singapore already provided IPR protection at levels on or even above those of developed economies (IPR indices just below or above 4). In the five years to 2005, several Asian countries with the lowest levels of IPR protection increased protection, notably China (from 1,55 to 2,48), India (from 1,51 to 2,18), and Indonesia (from 1,24 to 2,27). The increase in IPR protection in the first two countries correlates positively with the strong increase in patent applications originating there. At the same time, however, developed countries significantly strengthened their patent protection regimes as well, while this was not or much less the case for the Asian frontrunners South Korea and Taiwan.

Patent Applications Originating in Asia by the US, European, and Japanese Firms

We now turn to the patenting activities of the 186 European, US, and Japanese multinationals and examine the pattern of their R&D in Asia. Given that these firms are active in selected industries, we focus on the main industries where patenting activities are concentrated: Chemicals, Drugs & Medicines, Non-Electrical Machinery, Office, Computing and Accounting Machinery, Electrical Machinery, Radio, TV and Communication Equipment, Professional Goods, Medical & optical & precision equipment. Tables 5-7 show the number of patent applications by European, US, and Japanese firms in the sample, respectively, by industry and country.

European firms (Table 5) rely for the large majority of European patent applications on European inventor locations: more than 31000 applications in the 1996-1999 period out of a total of close to 37000 (85 percent) originated in Europe. North America was the second most important location with over 5000 patents. In Asia, patent application numbers of some significance were only present in Singapore (70) and concentrated in the communication equipment sector (43 patents). The most recent period shows a similar pattern, but with more R&D activities in other Asian countries, particularly

China (84), India (55), and South Korea (50). In this period, 0,7 percent of patent applications originated in Asia (an increase from , with slight higher percentages in computers and electrical machinery.

Table 6 shows a comparable share of the home country in the location of R&D activities for US firms: in the period 1996-1999 close to 19000 patents out of a total of almost 23000 originated in North America (81 percent). Europe is the second most important location, followed at a distance by Japan. Asian countries with the exception of Singapore (39) were insignificant locations. In the more recent period, perhaps surprisingly, China, Singapore, and South Korean only record a very modest increase, with only India recording a larger number of patents (46). The share of patent originating in Asia was 0,6 percent in the 2000-2003 period, up from 0,4.

Japanese firms show an even greater reliance on the home country for their R&D activities: almost 25688 out of 27451 originated in Japan in the earlier period (94 percent), with Europe and the US responsible for less than 900 patents each. Among Asian countries, only Singapore was a location of some importance (31). In the second period, this pattern hardly changed and the share of home country patents only decreased slightly to 93 percent. Some patenting activity occurred in South Korea (15) but the number of patents originating in Singapore decreased (23) and the number of patents in China remained small (9). In contrast to European and US firms, Japanese firms do not show any R&D activities in India. The share of patents originating from Asia has been almost negligible, at 0,1 percent.

Overall, the patent data suggest very limited R&D activities in Asia by the highest R&D spending US, European and Japanese firms, even in the more recent period. This is exemplified by Table 9, which shows the growth in the patent applications of the 186 firms between 1996 and 2003. The share of Asia has been increasing to a 0, 7 in 2003 from 0,2 in 1996. At the same time, small numbers of patents originating from Asia is also a reflection of the limited R&D and patenting activities in the Asian host countries in general, as seen in Tables 2a and 2b. Combining the latter tables with tables 5-

7, we can calculate the share of the 186 firms in host country and host industry patenting activity. Table 9 shows substantial variation in the importance of these foreign multinationals in Asian countries' patent applications. Reflecting its policy to attract foreign high tech multinationals, Singapore's patenting activity is dominated by multinationals firms, with the 186 firms responsible for 37 percent of patent applications. The share is between 40 and 50 percent for the three sectors computers, electrical equipment, and communication equipment. In these sectors and the sector medical and optical equipment, the firms are also responsible for large share of local patenting activity in Indonesia, Malaysia, Thailand (with the exception of electrical machinery) and also India. Generally lower percentages are reported for chemicals and particularly pharmaceuticals. A picture that clearly emerges is that the multinational firms have no or very little impact on local R&D activities in South Korea and Taiwan. They are also responsible for only modest shares of patenting activity in China and Hong Kong.

Which firms are most active in R&D in Asia? Table 10 lists the firms with patent application originating from Asia during the 8-year period 1996-2003. Only 35 firms have patent applications. The top 8 firms are in the computer and communication, and electrical equipment business, while the first chemical firm is Bayer (23 patents). Two French firms, Thomson and STI Microelectronics, lead with over a hundred applications, followed by Hewlett Packard and Siemens. Matsushita Electric (62 patents) is the only Japanese firm with a more substantial number of patent applications. Leading pharmaceutical firms such as Pfizer, Schering Plough, and Eli Lilly have very little presence in Asia.

5. IPR and the Location of R&D Activities: a Preliminary Analysis

We perform a statistical analysis to explain the number of patented innovations in each Asian country and industry by the multinational firms in the sample. The extent of innovative activities of a firm in a country will be related to local technological strengths (host country patenting activity in the industry), and its level of IPR protection as major variables of interest. We examine patent applications aggregated per period 1996-1999 and 2000-2003 in order to ensure a greater number of positive observations. The dependent variable, the number of patent applications by a sample firm, can vary by firm, country, industry, and period. All host countries where European patent applications originated are included as potential R&D locations, but in we analyze only cases where the each firm has at least one patent (partially) assigned to the specific industry and host country. Hence we examine the determinants of extent of R&D activities in host countries.[4] This gave us 9096 unique observations.

We include explanatory variables at the country and firm level. Following earlier studies (e.g. Belderbos, Fukao, and Kwon, 2006) we measure *technological strength of the country* in a specific industry by the number of patent applications originating in the country and assigned to the industry in the two periods (see Tables 2a and 2b; we subtract the patents of the investing firm from these counts. Technological strength should attract multinational firms' R&D investments. We also include *GDP* as a market size indicator and *GDP per Capita* (averages over the two periods, 1996-1999, and 2000-2003) as a measure of market sophistication. Both higher GDP and GDP per capita should attract more R&D activities to adapt technologies to local markets. As the measure for IPR protection we include the Park and Wagh (2002) indices reported in Table 4, with the 1995 index assigned to the first period and the 2000 index assigned to the second period.

At the firm level we include for *firm technological strength*, the number of patent applications assigned to the industry by the firm. Firm with greater strength in an industry are expected to have more foreign based R&D activity as well. We also control for the total number of the firms' patents (*firm total patents*) as a measure of the overall patentable R&D activities of the firm. We include *country or origin* dummies for the multinational firms, and take the US as the reference group of

[4] To be precise, given that we used weights to assign patents to multiple origin countries and industries, the raw patent 'numbers' are reals rather than integers. We rounded these number to get count data. This transformed raw patent 'counts' below 0,5 to zeroes.

firms. Finally we include a dummy for *pharmaceuticals and chemicals*[5] and a dummy for second period (*2000-2003*). In an extension of the analysis, we examine whether the determinants of R&D in Asia are systematically different from the determinants of R&D in other locations, by including an Asia host country dummy, and its interaction with country variables. All non-dummy variables except the IPR index are taken in natural logarithms.

Since the dependent variable is a county variable, we estimate a negative Binomial model. The empirical results are presented in Table 10. The results of the basic model show highly significant impacts of the explanatory variables. R&D activity by the multinational firms increases with their technological strength in the specific industry. However it decreases with the total size of patent applications of the firm. The latter results appears more in line with earlier findings that larger firms tend to be more embedded in host c country innovation systems face relatively greater costs of transferring substantial R&D activities abroad (e.g. Belderbos, 2003). Host country technological strength has the expected positive impact and hence attracts R&D activities by foreign firms. The same is true for market size (GDP) and market sophistication (GDP per capita). After controlling for these factors, the strength of the IPR regime has an additional positive impact on firm's local R&D activities, showing the importance of IPR protection. The country of origin dummies indicate that Japanese firms, all things equal, are less inclined to conduct overseas R&D to a greater extent. Firms from most European countries, with the exception of Finland, Croatia, and Germany, are significantly more active in overseas R&D than US firms. There is significantly less R&D internationalization in the pharmaceutical and chemicals sector compared to the food industry. Perhaps surprisingly, R&D internationalization is less rather than more extensive in the second period, with the dummy for the 2000-2003 period significantly negative. This implies that the increase in patent by the multinational firms originating in Asia can is more than explained by host country changes such as increase in technological strength and GDP. Controlling for this, there is certainly no secular trend toward a greater propensity to invest in overseas R&D.

[5] Including a full set of industry dummies did not affect the results, and showed the chemical and pharmaceuticals industries as significant outliers.

The results of the extended model with an Asian host country dummy and its interactions included shows that R&D in Asia follows a different pattern than R&D in other countries. R&D in Asia is significantly less responsive to market variables (GDP and GDP per capita), but not significantly less responsive to IPR protection (the interaction term here is negative but not significant) or to technological strength. At the same time the dummy variable for Asian host country is significantly positive. Apparently the motives for R&D in Asia are not well captured by the general model, and are less related to market factors. The likely explanation is that R&D in Asia is for a large part driven by the motive to reduce the cost of R&D, benefiting from a relatively cheap pool of scientists and engineers, in particular in India and China. The interaction term of Asian host country and the 2000-2003 is positive but not significant, indicating that the propensity to conduct R&D in Asia was not higher in the second period. Neither are US or Japanese firms more likely to conduct R&D in Asia compare to European firms, as suggested by the insignificant interaction term with the US and Japan country of origin dummies.[6]

6. Conclusions

This paper contributed to the expanding literature on the internationalization of R&D by examining R&D activities in Asia by 186 top R&D spending firms based in the US, Europe and Japan in the chemicals, pharmaceuticals, IT, engineering and electronics industries. We derive information on the location and industry of R&D activities from patent applications submitted to the European Patent Office during 1996-2003, by examining the location of inventors listed on the patents and the technology classification of the patents. We focus on R&D activities in 10 Asian countries and regions: PR China, India, the Asian NIEs (South Korea, Taiwan, Hong Kong, and Singapore). Analysis of the full population of patents applied demonstrated a rising technological strength of

[6] As a robustness check, we allowed for correlated errors terms between observations for the same firms. This produced qualitatively identical results.

several Asian countries, in particular South Korea, China, India, which recorded rapid rises in patent applications. The share of patent applications originating in Asia rose from just over 1 percent in 1996 to over 4 percent in 2003. However, South Korea is responsible for three quarters of these applications, while countries such as Indonesia, the Philippines, and Thailand remained behind. In terms of industries, patenting activity is strongly concentrated in the electronics and IT sectors. Only India has a significant activity in pharmaceuticals.

The pattern of R&D activities in Asia by the 186 firms generally follows the host country pattern, with some exceptions. The firms concentrate a large part of patenting activity in their home region: 79 percent (US firms), 85 percent (European firms), and 93 percent (Japanese firms). The remainder is mostly located in the two other developed regions. Roughly 0,7 percent of patenting activity is located in Asia in the most recent year (2003), but this percentage is substantially lower for Japanese firms. Many firms have no patent applications based on Asian inventions at all, with only 35 out of 186 firms reporting positive patent applications. Leading R&D performers in Asia are electronics and engineering firms such as Thomson, Siemens, Hewlett Packard, Matsushita Electric, and Philips, while chemical firms and in particular pharmaceutical firms are much less active. The multinationals are still responsible for a sizeable share (20-50 percent) of host country patenting activity in electronics related sectors in Singapore, Thailand, India, and Malaysia. The influence of these firms in contrast is almost negligible in South Korea and very small in Taiwan.

An econometric analysis of the number of patents originating in different host countries industries and applied for by the 186 firms in the two periods, 1996-1999 and 2000-2003, showed that both host country technological strength and host country market attractiveness (GDP and GDP per capita) positively impact multinational R&D activity. In addition to this, more patents applications originated from countries with a stronger IPR protection regime, suggesting that policies to strengthen IPR protection can be effective in attracting R&D investments by multinational firms. At the firm level, the firms' technological strength in the industry positively impact foreign R&D activity, while the total number of patents of the firm had a negative impact. The latter finding may suggest that larger high tech firms are more embedded in home country innovations and find it relatively costly to relocate substantive R&D activities abroad. An interesting observations was that there was significantly less, rather than more, foreign R&D in the most recent period. Hence, increasing share of foreign R&D activity are not due to a structural break in R&D internationalization patterns, but can be explained by the increasing attractiveness of host countries. Further analysis revealed significant differences in R&D location decision in Asia, compare to other host economies. R&D in Asia is much less sensitive to market attractiveness variables, but is structurally higher than in other countries. The most likely explanation is that R&D in Asia is partly driven by a factor not well captured in the analysis: the abundant availability at low cost of scientists and engineers in particular in India and China.

Finally, we note a number of caveats in our analysis and suggestions for further research. First, the use of European patent data created a bias in the direction of patents applied for by European firms and originating from Europe. This bias leads to a greater share of European firms in the patent data overall and also affects the absolute patent numbers of these firms originating in Asia. A more complete picture of multinational firms' R&D in Asia should be obtained by using US and Japanese patent data in parallel. Second, the empirical analysis can be improved in several ways. The analysis can be extended to cover decisions not to conduct R&D in (potentially relevant) locations, and the model can be made more comprehensive by including financial firm level variables (international sales, R&D) and indicators of the attractiveness of host countries from a cost perspective (e.g. wages of scientists and engineers). More sensitivity analysis can then be conducted by estimating separate models for US, EU, and Japanese firms, or by different host regions. This leaves a broad agenda for future research.

References

Almeida, Paul, 1996, Knowledge sourcing by foreign multinationals: patent citation analysis in the US semiconductor industry, *Strategic Management Journal*, 17, 155-165.

Audretsch, D. and M. Feldman, 1996, R&D spillovers and the geography of innovation and production', *American Economic Review*, **86**, 630-40.

Basant, R. and B. Fikkert, 1996, The Effects of R&D, Foreign Technology Purchase, and Domestic and International Spillovers on Productivity in Indian Firms, Review of Economics and Statistics, Vol 78 (2), 187-199.

Belderbos, R. A., 2003 Entry Mode, Organizational Learning, and R&D in Foreign Affiliates: Evidence from Japanese Firms, *Strategic Management Journal*, **24** (3), 235-259.

Belderbos, R., 2001. Overseas Innovation by Japanese Firms: An Analysis of Patent and Subsidiary Data. *Research Policy* 30(2): 313-332.

Belderbos, Rene, Elissavet Lykogianni and Reinhilde Veugelers, 2005, *Strategic R&D Location by Multinational Firms: Spillovers, Technology Sourcing, and Competition Spillovers*, CEPR Discussion Paper 5060, Centre for Economic Policy Research, London.

Belderbos, Rene, Kyoji Fukao and Tomoko Iwasa, 2006 *Domestic and Foreign R&D Investment*, ICSEAD Working Paper 2006-01, Kitakyushu. Presented at the MERIT-INTECH seminar, 17 May 2005.

Belderbos, Rene, Kyoji Fukao and Hyeog Ug Kwon, 2006, Intellectual Property Rights Protection and the Location of Research and Development Activities by Multinational Firms, ICSEAD Working Paper 2006-02, KitaKyushu.

Belderbos, Rene, Kyoji Fukao and Keiko Ito, 2005, Foreign Fixed Capital Investments by Multinational Firms, ICSEAD Working Paper 2005-31, KitaKyushu.

Bjorvatn K. and C. Eckel, 2001: 'Technology Sourcing and Foreign Direct Investment', Norwegian School of Economics Discussion Paper n. 28/01.

Braga, Helson, and Larry Willmore, 1991, Technological Imports and Technological Effort: An Analysis of Their Determinants in Brazilian Firms, *The Journal of Industrial Economics*, 39 (4), 421-432.

Branstetter, L. G., 2000, *Is Foreign Direct Investment a Channel of Knowledge Spillovers: Evidence from Japan's FDI in the United States*, NBER working paper 8015, NBER, Cambridge, MA.

Brantstetter, L G., R. Fisman, and C. F. Foley et al, 2004, Do Stronger Intellectual Property Rights Increase International Knowledge Transfer? Empirical Evidence from U.S. Firm-Level Panel Data, Working paper.

Cabral, L., 2003, R&D competition when firms choose variance, *Journal of Economics and Management Strategy*, 12, 139-150.

Cadot, O., D. Desruelle, 1998, R&D: who does the R, who does the D?, *Journal of International Economics*, 46, 87-103.

Cassiman, B., D. Pérez-Castrillo and R. Veugelers, 2002, Endogenizing know-how flows through the nature of R&D investments, *International Journal of Industrial Organization,* **20** (6), 775-799.

Chung, W. and J. Alcacer, 2002. Knowledge Seeking and Location Choice of Foreign Direct Investment in the United States, *Management Science* 48(12): 1534-1554.

Cohen, W. and D. Levinthal, 1989, Innovation and learning: the two faces of R&D, *Economic Journal*, 569-96.

Cohen, W. and S. Klepper, 1996, A Reprise of Size and R&D, Economic Journal, 106, 925-951.

Dalton, D. H., M. G. Serapio, and P. Genther Yoshida, 1999, Globalizing Research and Development, U.S. Department of Commerce, Office of Technology Policy.

Florida, R., 1997 The globalization of R&D: results of a survey of foreign -affiliated R&D laboratories in the USA, *Research Policy,* 26, 85-103.

Fors, G., 1996, Utilization of R&D Results in the Home and Foreign Plants of Multinationals, *Journal of Industrial Economics*, 45, 3, 341-358.

Fors, Gunnar, 1998, Locating R&D Abroad: The Role of Adaptation and Knowledge-Seeking, in: Pontus Braunerhjelm and Karolina Ekholm, eds., *The Geography of Multinational Firms*, Kluwer Academic Publishers, Dordrecht.

Franck, B. and Owen, R, 2003, Fundamental R&D Spillovers and the Internationalization of a Firm's Research Activities, Cowles Foundation Discussion Paper, No. 1425.

Frost, Thomas, 2001, The geographic sources of foreign subsidiaries' innovation, *Strategic Management Journal*, 22, 101-124.

Gersbach and Schmutzler, 1999, External Spillovers, Internal Spillovers and the Geography of Production and Innovation, *Regional Science and Urban Economics*, **29** (6), 679-696.

Gerybadze, Alexander and Guido Reger, 1999, Globalization of R&D: recent changes in the management of innovation in transnational corporations, *Research Policy*, 28 (2-3), 251-274.

Ginarte, and Park, 1997, Determinants of patent rights: A cross-national study *Research Policy* 26 (3), 283-301.

Glass, A. and K. Saggi, 2002, Intellectual Property Rights and Foreign Direct Investment, Journal of International Economics 56, 387-410.

Granstrand, Ove, Lars Hakanson, and Sören Sjölander, 1993, Internationalization of R&D: A Survey of Some Recent Research, *Research Policy*, 22, 413-430.

Griffith, Rachel, Rupert Harrison, and John van Reenen, 2003, technology sourcing by UK Manufacturing firms: an empirical analysis using firm-level patent data, working paper, Institute of Fiscal Studies, London.

Guellec, D. and B. van Pottelsberghe, 2001, The Internationalisation fo Technology Analysed with Patent data, *Research Policy*, 30 (8), 1256-1266.

Gupta, A. K. and V. Govindarajan, 2000, Knowledge Flows within Multinational Corporations, *Strategic Management Journal*, 21, 473-496.

Hakanson, L. and R. Nobel, 1993b, Determinants of foreign R&D in Swedish multinationals, *Research Policy*, 22, 397-411.

Helpman, E., 1993, Innovation and Intellectual Property Rights, Econometrica 61, 1247-1280.

Himmelberg, C.P. and B.C. Petersen, 1994, R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries, Review of Economics and Statistics, 76, 51.

Hines, J. R. Jr. (1995), Taxes, Technology Transfer, and R&D by Multinational Firms, in: Feldstein, Martin; Hines, James R. Jr.; Hubbard, R.Glenn, eds., Taxing multinational corporations. A National Bureau of Economic Research Project Report. Chicago and London: University of Chicago Press, 1995, pages 51-62.

Hines, James R. Jr, 1994, No Place Like Home: Tax Incentives and the Location of R&D by American Multinationals, in: Poterba, James M., ed., *Tax policy and the economy*, Volume 8, Cambridge: MIT Press for the National Bureau of Economic Research, pages 65-104.

Hirschey, Robert C., and Richard E. Caves, 1981, Internationalisation of Research and Transfer of Technology by Multinational Enterprises, *Oxford Bulletin of Economics and Statistics*, 42, 115-130.

Iwasa, Tomoko; Odagiri, Hiroyuki, 2004, Overseas R&D, knowledge sourcing, and patenting: an empirical study of Japanese R&D investment in the US, *Research Policy*, 33 (5), 807-829.

Jaffe, Adam B; Trajtenberg, Manuel; and Henderson, Rebecca, 1993, Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations, *Quarterly Journal of Economics,* August 1993, **108**(3), pp. 577-598

Kleinknecht, Alfred, 1987, Measuring R&D in Small Firm: How Much are We Missing?, *Journal of Industrial Economics*, 36 (2), 253-257.

Kuemmerle, W., 1997, Building Effective R&D Capabilities Abroad, *Harvard Business Review*, March / April, 61-70.

Kuemmerle, W., 1998, Optimal Scale for Research and Development in Foreign Environments: An Investigation into Size and Performance of Research and Development Laboratories Abroad, *Research Policy*, 27, 111-126.

Kuemmerle, W., 1999, The Drivers of Foreign Direct Investment into Research and Development: an Empirical Investigation, *Journal of International Business Studies*, **30**(1), 1-24.

Kumar, N., 1996, Intellectual property protection, market orientation and location of overseas R&D activities by multinational enterprises, *World Development* **24**: 673-688.

Kumar, Nagesh, and Mohammed Saquib, 1996, Firm Size, Opportunities for Adaptation, and In-house R&D Activity in Developing Countries: The Case of Indian Manufacturing, *Research Policy* 25, 713-722

Lai, E, 1998, International Intellectual Property Rights Protection and the Rate of Product Innovation, Journal of Development Economics 55, 133-153.

Le Bas, C. and C. Sierra, 2002, Location versus home country advantages in R&D activities: some further results on multinationals locational strategies, *Research Policy*, **31**, 589-609.

Leahy, D. and P. Neary (1999): 'Absorptive capacity, R&D spillovers and public policy', University College Dublin, Economics Dept, mimeo.

Lee, J. Y. and E. Mansfield, 1996, Intellectual Property Rights Protection and U.S. Foreign Direct Investment, Review of Economics and Statistics, 79: 181-186.

Maskus, K., 1998, The International Regulation of Intellectual Property, Weltwirtschaftliches Archiv 134, 186-208.

Maskus, K., 2000, Intellectual Property Rights in the Global Economy, Institute for International Economics, Washington D.C.

Ministry of Economics, Trade and Industry (2003), Kaigai Toushi Tokei Souran (Basic Survey on Foreign Direct Investment), Tokyo.

Ministry of International Trade and Industry (MITI), 1994, *Kaigai Toushi Tokei Souran (Basic Survey on Foreign Direct Investment)*, Okurashou Insatsukyoku, Tokyo.

Norback, P.-J., 2001, Multinational firms, technology and location, *Journal of International Economics,* **54**, 449-69.

Odagiri H. and Yasuda H., 1996, The determinants of overseas R&D by Japanese firms: an empirical study at the industry and company levels, *Research Policy* **25**: 1059- 1079.

OECD, 2005, Background report to the Conference on "Internationalisation of R&D", Brussels, March**.**

Patel, Pari, 1995, Localized Production of Technology for Global Market, *Cambridge Journal of Economics*, 19, 141-153.

Park, Walter G. and Smita Wagh (2002) "Index of Patent Rights" in *Economic Freedom of the World: 2002 Annual Report*, Chapter 2, pp. 33-43.

Petit M.L. and F. Sanna-Randaccio, 2000, Endogenous R&D and Foreign Direct Investment in International Oligopolies, *International Journal of Industrial Organization,* **18**, 339-367.

Reger, Guido, 1999, How R&D is coordinated in Japanese and European Multinationals, *R&D Management*, 29 (1), 71-88.

Roper, S, 1999, Under Reporting of R&D in Small Firms: The Impact on International R&D Comparisons, Small Business Economics, 12, 131-135.

Sanna-Randaccio F. and R. Veugelers, 2001, Multinational Knowledge Spillovers with Centalized vs Decentralized R&D, CEPR discussion paper, n. DP3151.

Shimizutani, S. and Y Todo, 2005, Overseas R&D Activities by Japanese Multinational Enterprises: Causes, Impacts, and Interaction with Parent firms, ESRI Discussion Paper Series No 132, Economic and Social Research Institute, Tokyo.

Siotis, G., 1999, Foreign Direct Investment Strategies and Firm Capabilities, *Journal of Economics and Management Strategy*, 8, 251-270.

Slaughter, M., 2004, Insourcing Jobs: Making the global economy work for America, BEA report

Smarzynska, Beate, 2004, Composition of Foreign Direct Investment and Protection of Intellectual Property Rights: Evidence from Transition Economies, *European Economic Review*, vol. 18 (1), 39-62.

Smith, P, 1999, Are Weak Patent Rights a Barrier to U.S. Exports? Journal of International Economics 48, 151-177.

Smith, P, 2001, How do Foreign Patent Rights Affect U.S. Exports, Affiliate Sales, and Licenses?, Journal of International Economics 55, 411-439.

United Nations, World Investment Report 2005, Transnational Corporations and the Internationalization of R&D, United Nations: New York and Geneva.

Wakasugi, Ryuhei, and Banri Ito, 2005, The Effects of Stronger Intellectual Property Rights on Technology Transfer: Evidence from firm-level Japanese data, G-SEC Working paper, Keio University

Yang, G. and K Maskus, 2000, Intellectual Property Rights and Licensing: An Econometric Investigation, working paper, US-Boulder

Zedtwitz, M. Von, and Gassmann, O. (2002): Market versus Technology Drive in R&D Internationalization: Four Different Patterns of Managing Research and Development, in: Research Policy, Vol. 31, 2002, No. 4, 569-588

Zejan, Mario C., 1990, R&D Activities in Affiliates of Swedish Multinational Enterprises, *Scandinavian Journal of Economics*, 92 (3), 487-500.

Table 1. Multinational Firms in this Study

Industry	Europe	Japan	United States
Engineering & General machinery	12	11	13
Pharmaceuticals	13	12	13
Chemicals	11	11	12
IT hardware	12	12	15
Electronics & Electrical, Precision Equipment	15	15	6
Total	**66**	**61**	**59**

Table 2a. Patent Applications by Industry and Country of Invention, 1996-1999

period1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
China	5	6	0	8	34	52	8	2	11	2	3	27	51	10	37	26	0	5	1	6	33	21	3	1	2	**353**
Hong	0	8	1	4	3	2	0	1	2	0	0	7	14	19	19	17	1	2	0	4	21	18	0	0	2	**145**
India	8	2	0	3	66	128	5	0	1	2	1	5	18	21	4	9	0	1	0	0	21	4	2	0	0	**302**
Indonesia	3	3	0	1	3	1	1	0	1	0	0	1	2	1	0	0	0	1	0	0	0	0	0	0	0	**19**
Malaysia	2	1	0	0	9	2	0	0	2	0	0	3	7	3	7	6	1	1	0	1	3	2	0	0	0	**49**
Philippine	0	0	0	0	6	1	0	1	0	0	0	1	2	0	0	3	0	1	0	1	0	1	0	0	0	**17**
Republic	29	20	2	35	166	219	6	6	20	17	8	100	175	429	272	599	1	70	0	26	250	47	4	2	11	**2512**
Singapore	11	5	2	2	10	17	0	1	4	1	0	16	27	51	36	115	1	1	0	4	24	16	2	0	3	**348**
Taiwan	3	26	12	12	37	29	1	6	3	1	0	70	58	64	78	76	3	22	0	17	66	59	0	1	5	**648**
Thailand	2	0	0	1	3	3	0	0	1	0	0	2	5	1	2	0	0	0	0	1	1	4	0	0	0	**25**
Europe	2210	1978	944	3123	14478	12202	610	689	3310	1403	855	16328	27080	6177	13277	17188	488	8101	399	4048	21403	5103	141	258	1948	**163738**
Japan	544	418	41	1063	5548	3661	206	271	767	394	619	2339	6172	6891	5363	9907	33	2104	30	868	8088	1635	35	9	219	**57222**
North	1447	717	184	1650	11034	12534	694	297	1244	391	418	5065	10453	8785	5998	13395	139	1930	321	1109	19529	2769	193	34	415	**100745**
Rest of the	145	52	26	126	576	772	31	27	140	79	35	563	886	440	407	558	43	141	20	85	1491	259	24	11	78	**7016**
Total	**4409**	**3235**	**1213**	**6026**	**31972**	**29622**	**1562**	**1302**	**5506**	**2290**	**1939**	**24529**	**44949**	**22891**	**25498**	**41900**	**708**	**12378**	**771**	**6167**	**50930**	**9938**	**404**	**315**	**2684**	**333138**

Industries: 1=Food, Beverages and Tobacco; 2=Textiles,Clothing,Leather and Footwear; 3=Wood & Furniture; 4=Paper, Printing and Publishing; 5=Chemicals; 6=Drugs & Medicines; 7=Petroleum and Coal Products and Refinery; 8=Rubber and Plastic; 9=Non Metallic Mineral Products; 10=Iron & Steel; 11=Non-Ferrous Metals; 12=Metal Products; 13=Non-Electrical Machinery; 14=Office, Computing and Accounting Machinery; 15=Electrical Machinery ; 16=Radio, TV and Communication Equipment; 17=Shipbuilding and Repairing; 18=Motor Vehicles; 19=Aerospace & Aircraft; 20=Other Transport Equipment; 21=Professional Goods/Medical & optical & precision eq; 22=Other Manufacturing; 23=Agriculture; 24=Utilities; 25=Building and Construction

Table 2b. Patent Applications by Industry and Country of Invention, 2000-2003

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
China	26	14	3	19	95	151	8	4	13	2	4	89	88	124	165	263	1	13	1	11	146	75	1	0	10	**1326**
Hong	5	1	1	2	4	4	1	1	1	0	0	16	11	18	35	15	1	1	0	2	14	19	0	0	1	**151**
India	26	4	0	5	140	332	4	1	7	3	3	10	39	51	27	65	0	1	0	3	48	14	2	0	1	**784**
Indonesia	1	1	0	1	1	0	0	0	1	0	0	1	6	4	0	2	0	5	0	0	2	1	0	0	1	**28**
Malaysia	2	2	4	2	17	10	1	0	3	0	0	13	21	8	8	21	0	0	0	0	22	3	0	0	0	**139**
Philippine	0	0	0	1	4	2	0	0	1	0	0	2	4	2	2	2	0	0	0	0	1	1	0	0	0	**22**
Republic	53	47	10	53	341	395	8	15	56	16	21	246	628	971	785	1913	2	121	0	53	698	208	7	1	22	**6668**
Singapore	8	1	2	11	21	28	1	1	4	6	3	18	31	103	33	221	1	4	0	6	65	14	2	1	2	**586**
Taiwan	12	40	20	20	61	66	1	7	8	1	2	178	107	160	171	217	1	37	1	57	162	143	0	1	4	**1477**
Thailand	3	1	0	2	5	8	0	0	2	0	0	9	8	1	3	1	1	0	0	3	6	4	0	0	0	**59**
Europe	2509	2101	1145	3707	14801	15091	689	889	3671	1354	849	19512	32873	11047	15838	24608	628	11450	583	5046	27681	6245	136	286	2351	**205091**
Japan	658	495	69	1458	6029	4245	196	330	948	418	743	3139	8500	9594	8012	13725	51	3659	53	1591	11510	2206	40	10	196	**77874**
North	1546	672	184	1754	9949	13244	693	307	1270	355	433	5418	11212	12565	6518	17118	145	2524	333	930	22446	3079	155	30	360	**113240**
Rest of the	172	66	31	134	644	1129	43	26	157	89	50	637	1074	1038	446	1048	45	173	21	74	1847	344	25	9	89	**9413**
Total	**5020**	**3444**	**1469**	**7169**	**32113**	**34707**	**1645**	**1581**	**6142**	**2244**	**2107**	**29286**	**54601**	**35686**	**32045**	**59218**	**875**	**17988**	**991**	**7776**	**64649**	**12354**	**370**	**338**	**3036**	**416856**

*Industries***:** 1=Food, Beverages and Tobacco; 2=Textiles,Clothing,Leather and Footwear; 3=Wood & Furniture; 4=Paper, Printing and Publishing; 5=Chemicals; 6=Drugs & Medicines; 7=Petroleum and Coal Products and Refinery; 8=Rubber and Plastic; 9=Non Metallic Mineral Products; 10=Iron & Steel; 11=Non-Ferrous Metals; 12=Metal Products; 13=Non-Electrical Machinery; 14=Office, Computing and Accounting Machinery; 15=Electrical Machinery ; 16=Radio, TV and Communication Equipment; 17=Shipbuilding and Repairing; 18=Motor Vehicles; 19=Aerospace & Aircraft; 20=Other Transport Equipment; 21=Professional Goods/Medical & optical & precision eq; 22=Other Manufacturing; 23=Agriculture; 24=Utilities; 25=Building and Construction.

Table 3. Trend in the Number of Patents Applications Originating in Asia, 1996-2003

	1996	1997	1998	1999	2000	2001	2002	2003	Total
China	61	75	99	118	236	319	365	407	**1679**
Hong Kong	41	27	33	45	28	43	29	51	**296**
India	40	63	86	112	151	194	281	158	**1086**
Indonesia	2	3	6	9	11	7	6	4	**47**
Malaysia	9	14	14	12	29	38	38	35	**188**
Philippines	3	2	5	7	4	13	3	1	**39**
South Korea	436	487	642	948	1065	1303	1544	2756	**9179**
Singapore	53	79	94	122	137	146	174	129	**934**
Taiwan	125	142	158	222	235	319	434	489	**2125**
Thailand	5	3	9	9	20	18	14	7	**85**
Share Asia (%)	*1,1*	*1,1*	*1,3*	*1,7*	*1,8*	*2,2*	*2,7*	*4,3*	*2,1*
Europe	33329	38814	44165	47430	51997	53857	52627	46607	**368828**
Japan	12514	14066	14920	15722	18084	20566	18424	20800	**135097**
North America	22247	23575	26382	28543	30684	30842	29641	22072	**213985**
Rest of the World	1353	1498	1972	2194	2618	2776	2626	1392	**16429**
Total	**70218**	**78848**	**88583**	**95490**	**105299**	**110441**	**106205**	**94910**	**749994**

Table 4. Patent Protection (IPR) index by Country, 1995 and 2000

Country	1995	2000
Indonesia	1,24	2,27
India	1,51	2,18
China	1,55	2,48
Thailand	2,24	2,24
Hong Kong	2,57	2,90
Philippines	2,67	2,67
Malaysia	2,85	3,07
South Korea	4,20	4,19
Taiwan	N.A.	N.A.
Singapore	3,90	4,05
United States	4,86	5,00
United Kingdom	3,57	4,19
Germany	3,86	4,52
France	4,05	4,05
Japan	3,94	4,19

Sources: Park and Wagh (2002); Ginarte, and Park (1997)

Table 5. European Multinationals' Patent Applications by Main Industry and Country or Origin, 1996-1999 and 2000-2003

Period 1 (1996-1999)

Country	SIC							
	chem	pharm	mach	comp	elec	comm	precis	Total
China	3	1	4	0	0	9	1	**17**
Hong Kong	0	0	2	1	0	1	0	**4**
India	1	6	1	3	0	2	3	**17**
Indonesia	1	0	0	0	0	0	0	**1**
Malaysia	1	0	1	0	1	3	0	**6**
South Korea	3	1	0	1	0	1	1	**7**
Singapore	0	0	3	6	14	43	4	**70**
Taiwan	2	0	3	0	0	0	1	**5**
Philippines	0	0	0	0	0	0	0	**0**
Thailand	0	0	0	0	0	0	0	**0**
share Asia	*0,2*	*0,2*	*0,3*	*0,4*	*0,3*	*0,5*	*0,2*	***0,3***
Europe	4393	2776	4004	2545	3873	10021	3711	**31323**
Japan	106	52	49	14	11	49	23	**304**
North America	794	428	494	258	483	1808	773	**5038**
Rest of the world	44	26	26	16	9	50	32	**202**
Total	**5348**	**3290**	**4585**	**2845**	**4392**	**11987**	**4549**	**36996**

Period 2 (2000-2003)

Country	SIC							
	chem	pharm	mach	comp	elec	comm	precis	Total
China	5	5	9	16	6	39	5	**84**
Hong Kong	1	0	0	5	2	1	0	**9**
India	1	2	0	14	4	24	10	**55**
Indonesia	0	0	0	1	0	1	1	**3**
Malaysia	0	0	0	0	5	4	2	**11**
Philippines	0	0	0	0	0	2	0	**2**
South Korea	2	2	0	1	37	7	2	**50**
Singapore	4	0	2	21	10	69	4	**111**
Taiwan	5	0	0	0	0	3	0	**9**
Thailand	0	0	0	0	0	0	1	**1**
share Asia	*0,4*	*0,2*	*0,2*	*1,1*	*1,4*	*0,9*	*0,4*	***0,7***
Europe	3851	3514	4312	4358	4122	13706	4795	**38658**
Japan	67	79	31	21	12	96	38	**344**
North America	749	664	503	625	435	2158	840	**5974**
Rest of the world	35	16	24	31	31	125	57	**319**
Total	**4721**	**4282**	**4882**	**5093**	**4664**	**16236**	**5754**	**45631**

Industries: chem =Chemicals; pharm=Drugs & Medicines; mach =Non-Electrical Machinery; compu=Office, Computing and Accounting Machinery; Elec=Electrical Machinery; comm=Radio, TV and Communication Equipment; precis=Professional Goods/Medical & optical & precision eq;

Table 6. US Multinationals' Patent Applications by Main Industry and Country or Origin, 1996-1999 and 2000-2003

Period 1 (1996-1999)

Country	SIC							
	chem	pharm	Mach	comp	elec	comm	precis	Total
China	0	0	0	0	0	1	0	**2**
Hong Kong	0	0	1	1	0	2	1	**5**
India	2	4	0	7	1	2	0	**15**
Malaysia	0	0	0	1	0	0	0	**1**
Philippines	2	1	0	0	0	0	0	**3**
South Korea	1	5	0	1	1	1	0	**8**
Singapore	0	0	2	14	7	8	8	**39**
Taiwan	0	0	1	1	7	2	0	**12**
Thailand	0	0	0	0	0	0	0	**0**
share Asia	*0,2*	*0,2*	*0,2*	*0,7*	*1,2*	*0,3*	*0,2*	***0,4***
Europe	362	665	436	385	230	775	589	**3442**
Japan	46	81	25	98	89	72	59	**469**
North America	2282	3991	1453	2782	1057	3904	3151	**18620**
Rest of the world	8	23	21	38	13	63	76	**241**
Total	**2703**	**4769**	**1939**	**3328**	**1405**	**4830**	**3884**	**22857**

Period 2 (2000-2003)

Country	SIC							
	chem	pharm	Mach	comp	elec	comm	precis	Total
China	2	3	0	2	1	2	2	**12**
Hong Kong	0	0	0	1	0	1	0	**2**
India	2	4	1	12	2	23	3	**46**
Malaysia	0	0	0	3	0	7	2	**13**
Philippines	0	0	0	0	0	0	1	**1**
South Korea	3	3	3	2	2	4	0	**17**
Singapore	2	2	0	22	3	17	5	**51**
Taiwan	0	1	0	5	1	10	1	**17**
Thailand	0	0	1	1	0	1	1	**3**
share Asia	*0,3*	*0,2*	*0,2*	*1,2*	*0,7*	*1,0*	*0,3*	***0,6***
Europe	327	967	636	702	238	1285	730	**4885**
Japan	67	88	37	54	55	61	56	**418**
North America	2540	5279	1911	3045	1013	4924	3836	**22548**
Rest of the world	22	38	24	57	18	112	130	**401**
Total	**2965**	**6383**	**2612**	**3907**	**1332**	**6447**	**4766**	**28412**

Industries: chem =Chemicals; pharm=Drugs & Medicines; mach =Non-Electrical Machinery; compu=Office, Computing and Accounting Machinery; Elec=Electrical Machinery; comm=Radio, TV and Communication Equipment; precis=Professional Goods/Medical & optical & precision eq;

Table 7. Japanese Multinationals' Patent Applications by Main Industry and Country or Origin, 1996-1999 and 2000-2003

Period 1 (1996-1999)

Country	SIC							
	chem	pharm	Mach	comp	elec	comm	precis	Total
China	0	0	0	0	0	0	0	**0**
India	0	0	0	0	0	0	0	**0**
Indonesia	0	0	0	0	0	0	0	**0**
Malaysia	1	0	1	0	0	2	0	**4**
Philippines	0	0	0	0	0	0	0	**0**
South Korea	2	0	0	0	1	1	0	**5**
Singapore	0	0	1	11	0	19	0	**31**
Taiwan	0	0	0	0	0	0	0	**0**
Thailand	0	0	0	0	0	0	0	**1**
share Asia	*0,1*	*0,0*	*0,1*	*0,2*	*0,0*	*0,3*	*0,0*	***0,2***
Europe	47	21	38	142	79	349	133	**810**
Japan	2679	1576	2054	4567	3054	7853	3906	**25688**
North America	66	49	23	248	51	355	69	**862**
Rest of the world	0	0	2	31	1	13	2	**50**
Total	**2796**	**1648**	**2120**	**4999**	**3185**	**8592**	**4110**	**27451**

Period 2 (2000-2003)

Country	SIC							
	chem	pharm	Mach	comp	elec	comm	precis	Total
China	0	1	0	3	0	5	0	**9**
India	0	0	0	1	0	1	0	**2**
Indonesia	0	0	0	0	0	0	0	**0**
Malaysia	0	0	1	0	0	0	0	**1**
Philippines	0	0	0	0	0	0	0	**1**
South Korea	8	0	0	3	2	2	1	**15**
Singapore	0	2	1	4	1	13	2	**23**
Taiwan	0	0	0	0	0	0	0	**1**
Thailand	0	0	0	0	0	0	0	**0**
share Asia	*0,2*	*0,1*	*0,1*	*0,2*	*0,1*	*0,2*	*0,0*	***0,1***
Europe	178	81	55	290	91	717	145	**1556**
Japan	3182	1809	2470	6493	4082	10553	5839	**34428**
North America	76	78	36	258	56	355	147	**1005**
Rest of the world	1	1	2	27	0	11	4	**47**
Total	**3445**	**1972**	**2566**	**7079**	**4232**	**11656**	**6137**	**37086**

Industries: chem =Chemicals; pharm=Drugs & Medicines; mach =Non-Electrical Machinery; compu=Office, Computing and Accounting Machinery; Elec=Electrical Machinery; comm=Radio, TV and Communication Equipment; precis=Professional Goods/Medical & optical & precision eq;

\

Table 8. Trend in the Number of Patents Applications by the Multinational Firms, Originating in Asia, 1996-2003

	1996	1997	1998	1999	2000	2001	2002	2003	Total
China	1	4	5	11	14	33	28	39	**135**
Hong Kong	3	3	5	0	4	5	3	1	**24**
India	7	4	6	17	11	16	32	44	**137**
Indonesia	0	1	0	1	0	2	0	1	**6**
Malaysia	2	3	2	4	3	7	7	9	**37**
Philippines	0	0	0	3	0	2	0	1	**7**
South Korea	4	4	6	13	17	10	31	34	**118**
Singapore	24	37	40	50	36	50	50	62	**350**
Taiwan	6	4	4	10	6	14	5	10	**58**
Thailand	0	0	1	0	1	4	0	0	**7**
Share Asia (%)	*0,2*	*0,3*	*0,3*	*0,4*	*0,3*	*0,4*	*0,5*	*0,7*	*0,4*
Europe	8309	9734	10867	12251	13392	14412	14120	9961	**93047**
Japan	6422	7259	8010	8345	9576	10847	9557	9990	**70005**
North America	5819	6701	7103	7831	8679	8913	8374	7145	**60565**
Rest of the world	126	137	161	170	247	285	189	192	**1506**
Total	**20723**	**23890**	**26211**	**28705**	**31985**	**34601**	**32397**	**27489**	**226001**

Table 9. Share of the 186 Multinational Firms' in Patent Application Originating from Asian Countries in Main Industries, 2000-2003

%

Country	**SIC**							
	chem	**pharm**	**mach**	**comp**	**elec**	**comm**	**precis**	**Total**
China	8	5	10	18	4	18	4	**10**
Hong Kong	24	0	1	34	6	10	0	**11**
India	2	2	2	53	20	73	26	**14**
Indonesia	21	0	0	25	50	60	52	**22**
Malaysia	0	3	5	47	67	53	15	**23**
Philippines	4	0	0	0	11	100	59	**20**
South Korea	4	1	0	1	5	1	0	**1**
Singapore	30	13	10	46	41	45	18	**37**
Taiwan	8	2	0	3	0	6	1	**3**
Thailand	5	1	15	71	0	64	17	**13**

Industries: chem =Chemicals; pharm=Drugs & Medicines; mach =Non-Electrical Machinery; compu=Office, Computing and Accounting Machinery; Elec=Electrical Machinery; comm=Radio, TV and Communication Equipment; precis=Professional Goods/Medical & optical & precision eq;

Table 10. Multinational Firms' Patent Applications Originating in Asia, 1996-2003

	China	Hong Kong	India	Indo-nesia	Malay-sia	Philip-pines	Korea	Singa-pore	Taiwan	Thai-land	Total
THOMSON	28	9	4	0	10	0	5	48	0	0	**105**
STMICROELECTRONICS	1	0	32	1	1	0	0	69	0	0	**104**
HEWLETT PACKARD	1	1	14	0	10	0	7	55	1	0	**89**
SIEMENS	3	0	9	0	3	0	1	43	3	1	**63**
MATSUSHITA ELECTRIC	3	0	0	0	1	1	3	54	0	0	**62**
PHILIPS	0	1	0	0	0	0	39	10	0	0	**50**
NOKIA	18	3	3	2	0	2	1	4	0	0	**33**
TEXAS INSTRUMENTS	0	0	20	0	0	0	1	4	2	0	**28**
BAYER	12	1	1	1	1	0	1	1	4	0	**23**
BASF	9	1	1	1	0	0	3	4	1	0	**21**
MOLEX	0	0	0	0	0	0	6	6	8	0	**20**
ASTRAZENECA	0	0	18	0	0	0	0	0	0	0	**18**
ROHM AND HAAS	2	3	0	0	0	0	10	0	1	0	**16**
LUCENT TECHNOLOGIES	2	0	5	0	0	0	1	4	4	0	**16**
JOHNSON JOHNSON	3	0	4	0	0	4	1	2	0	0	**15**
ERICSSON	5	0	1	0	1	0	1	8	0	0	**15**
MOTOROLA	2	3	1	0	0	0	0	8	1	0	**14**
BROADCOM	0	0	4	0	0	0	0	2	7	0	**13**
ALCATEL	12	0	0	0	0	0	1	1	0	0	**13**
ASM	9	0	0	0	0	0	0	4	0	0	**13**
AMD	0	0	0	0	1	0	0	7	1	4	**12**
INTEL	2	0	5	0	3	0	0	0	0	0	**10**
DANAHER	1	0	0	0	0	0	0	0	9	0	**10**
ASEA BROWN BOVERI	5	0	1	0	1	0	0	0	2	0	**9**
MERCK KGAA	0	0	0	0	0	0	2	1	5	0	**8**
TORAY INDUSTRIES	0	0	0	0	0	0	7	0	0	0	**7**
APPLIED MATERIALS	0	0	0	0	0	0	2	1	1	0	**5**
NOVARTIS	2	0	1	0	0	0	2	0	0	0	**5**
SONY	0	0	1	0	1	0	0	2	0	0	**4**
MILLENNIUM PHARMACEUTICALS	0	0	2	0	0	0	0	0	0	0	**2**
PFIZER	0	0	0	0	0	0	0	1	0	0	**1**
SCHERING PLOUGH	1	0	0	0	0	0	0	0	0	0	**1**
MITSUBISHI HEAVY	0	0	0	0	0	0	1	0	0	0	**1**
ELI LILLY	0	0	0	0	0	0	0	0	0	0	**1**
Total	**121**	**22**	**127**	**5**	**35**	**7**	**94**	**339**	**52**	**5**	**807**

Table 11. Results of Negative Binomial Model Explaining Patent applications by EU, US, and Japanese Multinational Firms Per Country and Industry, 1996-1999 and 2000-2003

	Basic Model			Extended Model		
	coefficient	**st err**		**coefficient**	**st err**	
Firm technological strength	0,579	0,013	***	0,585	0,014	***
Firm total patents	-0,066	0,017	***	-0,067	0,017	***
Host country technological Strength	0,108	0,022	***	0,092	0,023	***
IPR protection	0,305	0,055	***	0,350	0,057	***
GDP	0,276	0,043	***	0,250	0,060	***
GDP per Capita	0,179	0,025	***	0,168	0,025	***
Country of origin:						
Japan	-0,502	0,067	***	-0,481	0,069	***
Belgium	0,499	0,079	***	0,482	0,078	***
Switzerland	0,687	0,119	***	0,670	0,117	***
Croatia	0,110	0,277		0,104	0,264	
Denmark	0,790	0,141	***	0,749	0,138	***
Finland	-0,034	0,089		-0,036	0,090	
France	0,584	0,074	***	0,600	0,075	***
Germany	0,040	0,079		0,026	0,078	
Netherlands	0,289	0,084	***	0,333	0,086	***
Sweden	0,166	0,077	**	0,148	0,077	
Spain	-0,313	0,262		-0,324	0,255	
United Kingdom	0,546	0,097	***	0,528	0,095	***
2000-2003 (dummy)	-0,118	0,044	***	-0,130	0,045	***
Pharmaceuticals & chemicals	-0,511	0,053	***	-0,517	0,053	***
Asia (host country)				7,537	2,295	***
Asia * host country Tech. strength				0,036	0,070	
Asia * IPR				-0,197	0,197	
Asia * GDP per Capita				-0,300	0,136	**
Asia * GDP				-0,425	0,143	***
Asia * 2000-2003				0,269	0,155	
Asia * US firm				0,189	0,147	
Asia * Japanese firm				0,175	0,232	
Constant	-8,007	0,459	***	-7,647	0,603	***
Alpha	1,515	0,037	***	1,493	0,035	***
chi2(21, 28)	4258,360			4378,810		
Pseudo R2	0,118			0,120		
Observations	9096,000			9096,000		

Notes: ***, ** = significant at the 1 and 5 percent levels. US is the reference groups for the country dummies: dummies are for country of origin of the multinational. Standard errors corrected for heteroscedasticity using the White-Huber-Sandwhich correction.

Appendix A
Multinational Firms Covered in this Study by Industry and R&D expenditure

Company name	Industry	Country	R&D expenditures 2003
Bayer AG	Chemicals	Germany	2414
BASF	Chemicals	Germany	1105
EI du Pont de Nemours	Chemicals	United States	1069
Mitsubishi Chemical	Chemicals	Japan	673
Sumitomo Chemical	Chemicals	Japan	539
Solvay	Chemicals	Belgium	420
Asahi Kasei	Chemicals	Japan	365
Mitsui Chemicals	Chemicals	Japan	275
Toray Industries	Chemicals	Japan	264
PPG Industries	Chemicals	United States	230
ICI (Imperial Chemical Industries)	Chemicals	United Kingdom	221
Teijin	Chemicals	Japan	221
Shin-Etsu Chemical	Chemicals	Japan	195
Rohm & Haas	Chemicals	United States	189
Linde AG	Chemicals	Germany	179
Eastman Chemical	Chemicals	United States	149
Showa Denko	Chemicals	Japan	126
SNPE	Chemicals	France	115
JSR	Chemicals	Japan	112
Kaneka	Chemicals	Japan	103
Nitto Denko	Chemicals	Japan	102
Air Products and Chemicals	Chemicals	United States	96
L'air Liquide	Chemicals	France	94
Johnson Matthey plc	Chemicals	United Kingdom	77
Lubrizol	Chemicals	United States	74
Engelhard	Chemicals	United States	74
FMC	Chemicals	United States	69
Praxair	Chemicals	United States	59
Avery Dennison	Chemicals	United States	59
BOC group plc	Chemicals	United Kingdom	57
Valspar	Chemicals	United States	55
Kemira OYJ	Chemicals	Finland	48
Borealis as	Chemicals	Denmark	43
Süd-Chemie AG	Chemicals	Germany	29
Pfizer	Pharmaceuticals	United States	5653
Johnson&Johnson	Pharmaceuticals	United States	3714
Novartis AG	Pharmaceuticals	Switzerland	2978
AstraZeneca	Pharmaceuticals	United Kingdom	2736
Merk & Co inc	Pharmaceuticals	United States	2520
Eli Lilly and Company	Pharmaceuticals	United States	1863
Bristol-Myers-Squibb Co	Pharmaceuticals	United States	1807
Wyeth	Pharmaceuticals	United States	1660
Sanofi-Synthélabo	Pharmaceuticals	France	1316
Amgen inc	Pharmaceuticals	United States	1312
Schering Plough Corp	Pharmaceuticals	United States	1165
Schering AG	Pharmaceuticals	Germany	947
Takeda Chemical	Pharmaceuticals	Japan	919
Sankyo	Pharmaceuticals	Japan	641

Merck Kommanditgesellschaft	Pharmaceuticals	Germany	605
Allergan inc	Pharmaceuticals	United States	604
Yamanouchi Pharmaceutical	Pharmaceuticals	Japan	495
Fujisawa Pharmaceutical	Pharmaceuticals	Japan	462
Eisai	Pharmaceuticals	Japan	442
Altana AG	Pharmaceuticals	Germany	412
Daiichi Pharmaceutical	Pharmaceuticals	Japan	395
Millennium Pharmaceuticals inc	Pharmaceuticals	United States	387
Chiron	Pharmaceuticals	United States	310
Genzyme corp	Pharmaceuticals	United States	266
Applera corp	Pharmaceuticals	United States	256
Lundbeck	Pharmaceuticals	Denmark	246
Shionogi	Pharmaceuticals	Japan	231
Kyowa Hakko Kogyo	Pharmaceuticals	Japan	229
Ono Pharmaceutical	Pharmaceuticals	Japan	225
Taisho Pharmaceutical	Pharmaceuticals	Japan	218
UCB (en onderdeel Celltech)	Pharmaceuticals	Belgium	216
Tanabe Seiyaku	Pharmaceuticals	Japan	182
Sepracor	Pharmaceuticals	United States	175
Schwarz Pharma AG	Pharmaceuticals	Germany	144
Dainippon Pharmaceutical	Pharmaceuticals	Japan	113
Pliva d.d.	Pharmaceuticals	Croatia	86
Cambridge antibody technology group plc	Pharmaceuticals	United Kingdom	64
Zeltia SA	Pharmaceuticals	Spain	51
Siemens	Electronics & electrical	Germany	5511
Matsushita Electric	Electronics & electrical	Japan	4285
Sony	Electronics & electrical	Japan	3278
Koninklijke Philips Electronics	Electronics & electrical	Netherlands	2617
Canon	Electronics & electrical	Japan	1917
Sharp	Electronics & electrical	Japan	1125
Sanyo Electric	Electronics & electrical	Japan	894
Ricoh	Electronics & electrical	Japan	684
Schneider Electric SA	Electronics & electrical	France	494
ABB (Asea Brown Boveri)	Electronics & electrical	Switzerland	486
ALSTOM	Electronics & electrical	France	473
Pioneer	Electronics & electrical	Japan	381
Sumitomo Electric	Electronics & electrical	Japan	360
Omron	Electronics & electrical	Japan	298
Thomson	Electronics & electrical	France	295
Alps Electric	Electronics & electrical	Japan	280
Olympus Optical	Electronics & electrical	Japan	257
TDK	Electronics & electrical	Japan	236
Fuji Electric	Electronics & electrical	Japan	198
Yokogawa Electric	Electronics & electrical	Japan	187
Furukawa Electric	Electronics & electrical	Japan	184
Eaton Corp	Electronics & electrical	United States	177
Pitney Bowes Inc	Electronics & electrical	United States	117
Harman International industries inc	Electronics & electrical	United States	113
Molex inc	Electronics & electrical	United States	93
Symbol Technologies	Electronics & electrical	United States	86
SPX Corporation	Electronics & electrical	United States	76
BARCO	Electronics & electrical	Belgium	70
Solectron Corp	Electronics & electrical	United States	55
Spectris plc	Electronics & electrical	United Kingdom	48

Bang & Olufsen	Electronics & electrical	Denmark	48
Draka Holding NV	Electronics & electrical	Netherlands	44
Leoni AG	Electronics & electrical	Germany	36
Ingenico	Electronics & electrical	France	34
Vestas Wind Systems AS	Electronics & electrical	Denmark	28
Vaisala OYI	Electronics & electrical	Finland	21
Mitsubishi Heavy	Engineering	Japan	810
Caterpillar	Engineering	United States	530
Deere	Engineering	United States	458
MAN	Engineering	Germany	407
Komatsu	Engineering	Japan	315
Scania AB	Engineering	Sweden	237
Sandvik AB	Engineering	Sweden	185
Kubota	Engineering	Japan	172
Danaher	Engineering	United States	164
IHI	Engineering	Japan	163
Ingersoll-Rand	Engineering	United States	162
Cummins	Engineering	United States	159
Atlas Copco AB	Engineering	Sweden	128
Kawasaki Heavy Industries	Engineering	Japan	115
Ebara	Engineering	Japan	104
American Standard Companies	Engineering	United States	101
SMC	Engineering	Japan	97
ITT Industries	Engineering	United States	96
Schindler holding AG	Engineering	Switzerland	89
Kone oyi	Engineering	Finland	88
Illinois Tool Works	Engineering	United States	85
Tomkins plc	Engineering	United Kingdom	83
SKF AB	Engineering	Sweden	83
Rieter holding AG	Engineering	Switzerland	83
Dainippon Screen Mfg	Engineering	Japan	80
Danfoss as	Engineering	Denmark	78
Sumitomo Heavy Industries	Engineering	Japan	76
Saurer AG	Engineering	Switzerland	75
Stork NV	Engineering	Netherlands	74
Parker Hannifin	Engineering	United States	74
Wartsila OYJ ABP	Engineering	Finland	70
Claas Kommanditgesellschaft	Engineering	Germany	67
Hamamatsu Photonics	Engineering	Japan	65
Mettler-Toledo International	Engineering	United States	62
NSK	Engineering	Japan	61
AGCO	Engineering	United States	57
Nokia oyi	IT hardware	Finland	3978
Intel	IT hardware	United States	3457
Telefonab LM Ericsson	IT hardware	Sweden	3229
Motorola	IT hardware	United States	2990
Hewlett-Packard	IT hardware	United States	2895
Hitachi	IT hardware	Japan	2751
Toshiba	IT hardware	Japan	2491
Cisco Systems	IT hardware	United States	2485
Fujitsu	IT hardware	Japan	2114
NEC	IT hardware	Japan	1899
Alcatel	IT hardware	France	1593
Sun Microsystems	IT hardware	United States	1456

Texas Instruments	IT hardware	United States	1386
Lucent Technologies	IT hardware	United States	1180
STMicroelectronics	IT hardware	France	921
Applied Materials	IT hardware	United States	730
Xerox	IT hardware	United States	688
AMD	IT hardware	United States	676
EMC	IT hardware	United States	660
Micron technology inc	IT hardware	United States	520
Broadcom Corp	IT hardware	United States	518
Apple Computer	IT hardware	United States	373
Tokyo Electron	IT hardware	Japan	371
Analog Devices	IT hardware	United States	357
Kyocera	IT hardware	Japan	350
National Semiconductor	IT hardware	United States	345
LSI Logic Corp	IT hardware	United States	343
ASML holding NV	IT hardware	Netherlands	287
Rohm	IT hardware	Japan	235
Murata Manufacturing	IT hardware	Japan	232
Océ NV	IT hardware	Netherlands	208
Nikon	IT hardware	Japan	203
Advantest	IT hardware	Japan	175
Casio Computer	IT hardware	Japan	104
Anritsu	IT hardware	Japan	98
Spirent plc	IT hardware	United Kingdom	94
ASM International NV	IT hardware	Netherlands	79
ARM holdings plc	IT hardware	United Kingdom	68
Bull	IT hardware	France	60
Filtronic plc	IT hardware	United Kingdom	40
GN Store Nord as	IT hardware	Denmark	40
Micronic Laser Systems	IT hardware	Sweden	33

Appendix B: ISIC Industries

industry	Industry number
Food, Beverages and Tobacco	1
Textiles,Clothing,Leather and Footwear	2
Wood & Furniture	3
Paper, Printing and Publishing	4
Chemicals	5
Drugs & Medicines	6
Petroleum and Coal Products and Refinery	7
Rubber and Plastic	8
Non Metallic Mineral Products	9
Iron & Steel	10
Non-Ferrous Metals	11
Metal Products	12
Non-Electrical Machinery	13
Office, Computing and Accounting Machinery	14
Electrical Machinery	15
Radio, TV and Communication Equipment	16
Shipbuilding and Repairing	17
Motor Vehicles	18
Aerospace & Aircraft	19
Other Transport Equipment	20
Professional Goods/Medical & optical & precision eq	21
Other Manufacturing	22
Agriculture	23
Utilities	24
Building and Construction	25