THE AUSTRALIAN NATIONAL UNIVERSITY

Working Papers in Trade and Development

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July 2009
Working Paper No. 2009/07

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Globalization of R&D by U.S-based Multinational Enterprises

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Abstract

This paper examines patterns and determinants of overseas R&D investment by US-based manufacturing MNEs using a new panel dataset over the period 1990-2004. The analysis reveals that R&D intensity of operation of US MNE affiliates is mainly determined by the domestic market size, overall R&D capability and cost of hiring R&D personnel. There is no evidence to suggest that financial incentives have a significant impact on inter-country differences in R&D intensity when controlled for other relevant variables. Overall, our findings cast doubts on the efficacy of efforts by host country governments entice MNEs affiliates to engage in domestic R&D in a global context where R&D is becoming a truly global activity.

JEL Codes: F21, O19, O32

Key words: R&D, multinational enterprises, foreign direct investment

This is a revised/updated version of Working Paper 06/06: *Multinational Enterprises and Globalization of R&D: A Study of US-Based Firms*.

Globalization of R&D by U.S-based Multinational Enterprises*

1. Introduction

Multinational enterprises (MNEs) play a pivotal role in the generation of technology and its transmission across countries.[1] The potential contribution of MNE affiliates to innovatory capability of the countries in which they operate (the host countries) is therefore central to the contemporary policy debate on the developmental impact of foreign direct investment (FDI). There are two ways in which an MNE affiliates provide technology to host countries; importing technology produced elsewhere within the global branch networks (technology transmission) and developing new technology locally through R&D (technology generation). The host-country governments generally attach greater importance to technology generation over technology transmission, in the hope that R&D activities undertaken within the national boundaries may have important externalities for indigenous scientific and technology activity. This expectation has resulted in a strong competition among countries to attract R&D-intensive FDI through investment promotion campaigns and by offering generous R&D-related tax concessions.[2]

There is a large literature on R&D activities of MNEs and the propensity to locate R&D overseas in aggregate.[3] However, notwithstanding the growing emphasis placed on enticing MNE participation as part of national R&D effort in many countries, studies specifically dealing with determinants of inter-country distribution of overseas R&D activities are sparse.[4] The present study complements and extends this fledgling literature by examining the global spread of R&D investment of US-based MNEs using a new rich panel data set for the period 1990-

* We are grateful to the two anonymous referees for excellent comments .

[1] MNEs account for nearly two thirds of total global business R&D (UNCTAD 2005).

[2] Of course, in reality attractiveness of a given host country for technology generation depends on its technological capabilities closely linked to its stage of development. However, placing greater emphasis on technology generation over technology transfer is a common feature observable in foreign direct investment policy across all countries, regardless of their stage of development (UNCTAD 2005:212-3, Sheehan and Wyckoff 2003).

[3] For surveys of this literature, see Caves 2006 and UNCTAD 2005.

[4] These are Kumar 1996 (US MNEs), Kumar 2001 (US and Japanese MNEs), Hines 1995 (US MNEs), Odagiri and Yasuda 1996 (Japanese MNEs), Zejan 1990 (Swedish MNEs), and Fors 1998 (Swedish MNEs).

2004, a period characterized by significant changes in international production as part of the on-going process of economic globalization. The key research issue is the relative importance of policy-related variables in explaining inter-country differences in R&D intensity over and above the relevant non-policy (structural) variables. Compared to previous studies, we examine inter-country variation in R&D intensity of MNE by taking into account a larger number of explanatory variables suggested by the theory of MNE behaviour, with a view to minimizing potential omitted variable bias in estimation. To the best of our knowledge, ours is the first attempt to examine patterns and determinants of overseas R&D activity using panel data econometrics. The panel data approach offers a solution to the problem of bias caused by unobserved heterogeneity (in this case, country-specific peculiarities not captured by the explanatory variables), a common problem in the estimation of models with cross-section data as in the previous studies. Working with panel data also has the advantage of capturing dynamics that are difficult to detect with cross-section data. Another novelty of our analysis is the attention paid to the impact of the stage of development of host countries on the hypothesized relationship between the R&D intensity and the explanatory variables.

There is no fully developed theory or standard model which explains inter-country differences in R&D intensity of MNE operation. Consistent with previous studies, we therefore formulate our empirical model in an eclectic fashion, drawing upon the analytical foundations of MNE behavior. We strongly believe that our approach is preferable to working with an optimizing model derived from first principles assuming a 'representative' firm. This approach, notwithstanding its analytical elegance, cannot adequately address issues that arise from imperfect information and heterogeneity relating to industry characteristics and government policies (Kirman 1992, Dunning 2000, Vernon 2000).

The findings suggest that that R&D intensity of operation of US MNE affiliates is mainly determined by the domestic market size, overall R&D capability and cost of hiring R&D personnel. There is no evidence to suggest that tax incentives and intellectual property protection have a significant impact on inter-country differences in R&D intensity when controlled for other relevant variables. In particular, the significant positive impact of tax incentives on R&D investment reported in some previous studies failed to withstand our attempt to redress omitted variable bias using a considerably richer data set than have been used by prior researchers. The postulated impact on inter-country variation in R&D intensity of the all but one

(domestic market orientation) explanatory variable found to be insensitive to the stage of development of the host country. As regards domestic market orientation, it appears to be a significant positive determinant of R&D in low-income countries only, presumably reflecting the need for product adaptation to suit special demand conditions associated with low-income levels and the lower degree of global integration of these countries. It seems that in an era of rapid global economic integration the nature of market orientation is not a significant determinant of R&D patterns in advanced industrialized nations and newly industrialized countries. We also find that industry composition is an important determinant of the overall R&D intensity of MNE operation in a given country over and above the other variables considered here.

The paper is organized as follows. Section 2 provides a succinct review of the theory of overseas R&D activities of MNEs in order to set the stage for the ensuing empirical analysis. Section 3 examines trends and patterns of overseas dispersion of R&D expenditure of US MNEs. Section 4 deals with model specification, data sources and the econometric methodology used in the regression analysis of the determinants of inter-country differences in R&D propensity. Section 5 presents the results and interprets them in the context of the existing literature. The final section summarises the key inferences.

2. Theoretical Framework

The R&D location decision of the MNE is governed both by considerations which compel it to keep R&D as a headquarter function (*centripetal factors*) and those which tend to pull it away from the centre and into peripheral locations (*centrifugal factors*) (Caves 2006, p 117). The *centripetal factors* are of two major forms. First, technology - the assets created by the innovatory process – is an important part of 'knowledge capital' of the MNE which determines its market power or 'ownership advantage' in international operation. There is always the possibility that geographical decentralization of R&D leads to leakage of proprietary technology to foreign competitors, attenuating the MNE's market power. Such leakage can happen through either defection of R&D personnel to competitors or starting up their own ventures, or simply through the 'demonstration' effect. Thus, the desire to maintain strategic knowledge within the firm is a compelling reason for keeping R&D as a headquarter function. Second, production of technology is an activity subject to firm level (rather than plant level) scale economies. The innovatory process essentially involves communication and cooperation

with personnel involved in product design, marketing and other related key functions. There is also the need for better motivation of R&D efforts towards objectives set by the top management through face-to-face meetings, inter-departmental relationships, and highly networked teams. Because of these reasons, dispersion of resources for executing parallel R&D projects at plant level could be wasteful and reduce productivity of the overall R&D effort (Daft and Lengel 1986).

The above factors are generally expected to have a significant impact on the MNE's decision to keep R&D fundamentally as a headquarter function. However, there two '*centrifugal*' forces which necessitate some dispersion of R&D activities among various production locations. Firstly, there may be a need to adapt production processes and characteristics of products to local conditions and regulations. This consideration is particularly relevant when demand and/or production conditions in the host country differ significantly from the conditions in the home country, or when the geographical proximity of research facilities to manufacturing facilities in the host country reduce the time lag in adjusting production techniques or product characteristics to host country conditions. While improved communications mitigate some of the difficulties created by distance, it is presumably an imperfect substitute for physical proximity needed for effective communication between R&D and other functional areas, notably marketing and production.

Second, MNEs may have to undertake R&D in overseas locations in order to source technology and to benefit from localized technology spillovers in these locations, with a view to maintaining their competitive edge. Locating R&D facilities in prominent centres of excellence in specific technologies across the world would enable MNEs to enrich their own R&D. There is indeed evidence that independent R&D is the most effective way of 'learning' about other firms' products and processes near the sources of the spillover, when compared with licensing, patent disclosures, the hiring of competitors' R&D employees and reverse engineering (Levin ***et. al***. 1987). This is because knowledge spillover is positively related to proximity. R&D units set up in global innovatory centers could also serve as stations for recruiting local scientists and technicians, and points of contact with the scientific community in the host country (Cohen and Levin 1989, OECD 1998).

The early literature on R&D activities of MNEs generally considered product adaptation, which normally involves cross border transfer of mature technologies, as the dominant motive for decentralization of R&D geographically (Vernon, 1974; Caves 2006, Ch. 6; Dunning 2000, Lal 1979). Recent survey-based evidence, however, suggests that over the years the technology-seeking motive has become a significant contributing factor in decentralization of R&D by MNEs in R&D intensive industries such as pharmaceuticals, consumer chemicals, professional and scientific equipment and office equipment (Ronstadt 1977, Pearce 1999, Fors and Svensson 1994, Birkinshaw and Morrison 1995, Vernon 2000). There are also numerous cases of acquisition of companies by MNEs outside their home base in the hope of unlocking some priced technological secrets for worldwide use. In sharp contrast to the role of a conventional R&D department that was primarily engaged in adapting established group products for the local market, the mission of the modern knowledge seeking R&D labs is to draw upon geographically differentiated frontier technology in an attempt to preserve the technological lead of the MNE. These labs are engaged in original product development or providing inputs into programs of basic or applied research to support the longer term evolution of the core technology of the MNE group at the world technology frontier.

Even if there are compelling reasons to decentralize R&D globally, the MNE's decision to undertake R&D in a given host country depends on the domestic business environment. The availability and cost of hiring of technical personnel, the nature of property right legislation, tax concessions and other incentives for R&D activities, skilled labour, and the general business climate for foreign direct investment (including political stability and policy certainty, and the foreign trade regime) are among the relevant factors in making the R&D location decision.

Assuming these prerequisites are met, the entry of MNEs to a given host country and the expansion of its R&D activities are likely to take place in a sequential manner. The process would begin with the establishment of production activities entirely based on technology provided by the parent company. Setting up of local R&D research support activities would take place only after the subsidiary gain experience in that particular location and if the future growth prospects are promising, and resources/capabilities are accumulated within the subsidiary over time. The activities of the research departments may then grow, in terms of both the staff employed and the complexity of tasks, hand in hand with the expansion of the subsidiary's business. This sequence suggests that, after some time, the R&D departments of some overseas

affiliates may establish themselves as centres of technology 'sourcing' for other affiliates in the MNE's global network (Lall 1979). The compositional difference between headquarter R&D operations and overseas R&D operations of an MNE would narrow over time as part of the process of *subsidiary evolution*: the enhancement of capabilities in the subsidiary over time. At a certain stage in this process, there will be an explicit change in the subsidiary's charter from a pure market seeker to a full-fledged part of the overall operation of the MNE (Birkinshaw and Hood 1998, Cantwell and Mudambi 2005). The subsidiary will then undertake R&D activities on its own initiative in response to changing business conditions or environmental considerations in the host country.

3. Trends and Patterns of R&D Internationalization

Annual overseas R&D expenditure of US MNEs increased rapidly from almost US$ 600 million in 1966 to around US$ 10 billion in 1990 and to US$ 27.5 billion in 2004 (Table 1). Over the past decade, the share of overseas R&D expenditure in total corporate R&D expenditure (domestic + overseas) has varied in the narrow range of 11.4 per cent to 13.6 per cent. Overall, apart from some minor variations in either direction, overseas R&D expenditure has kept pace with domestic R&D expenditure. Thus, contrary to inferences of some survey-based studies (eg. Pearce 1999, Cantwell and Piscitello 2002), there is no evidence of dramatic globalization of R&D activities in the 1990s, as far as the US-based MNEs are concerned; the conventional wisdom about the dominant role played by *centripetal factors* in the MNE R&D decision (Section 2) still seems to hold.

Insert Table 1 about here

How does the degree of internationalization of R&D by US MNEs compare with that of MNEs from other countries? There are no data for a systematic comparison, but the available fragmentary data suggest that overseas R&D activities of MNEs based in other countries may have grown faster. For instance, the share of overseas R&D in total R&D expenditure of Swedish manufacturing MNEs increased from 9 per cent in 1970 to 13 per cent in 1978, and further to 24.7 per cent in 1994 (Fors 1998, p 117). There are no complete records of overseas R&D activities of German MNEs, but there is survey-based evidence that the percentage of overseas employed in total R&D staff of German MNEs increased from 15 per cent in the late

1970s to over 18 per cent by the early 1990s (Golberman 1997, 141). Bloom and Griffith (2001, p. 350) report that in the 1990s British MNEs increased their R&D spending in their overseas research labs at much faster pace than in labs in the UK; the overseas share of R&D expenditure of British pharmaceutical industry increased from 48 per cent in 1994 to over 55 per cent in 1999. Internationalization of R&D by the Japanese MNE is a more recent phenomenon. However, the overseas share of total R&D of Japanese MNEs increased persistently from less than one per cent during 1989-1990 to 2.3 per cent in 1996-97 (Kumar 2001, 161).

Manufacturing accounts for the lion share (over four fifths) of both total and overseas R&D expenditure of US MNEs (Table 1). Over the past decade, the manufacturing share in overseas R&D has shown a mild, but persistent increase (from 81 per cent in 1990 to nearly 90 per cent in 2001-04), in contrast to a persistent decline in this share in this share in total overseas R&D expenditure (from 88 per cent to 83 per cent). Within manufacturing, chemical, electrical and electronic goods and motor vehicles account for over two thirds of total overseas R&D expenditure (Table 2). There has been a noteworthy increase the R&D expenditure share of electronics.

Insert Table 2 about here
Insert Table 3 about here

Table 3 summarises data on the inter-country distribution of overseas R&D expenditure in manufacturing. In order to place inter-country differences in R&D activities in the wider context of MNE operation, data on country shares of R&D expenditure and R&D intensity (R&D expenditure relative to total sales turnover) are put together with data on the percentage distribution of the total capital stock and sales.

The developed countries are by far the dominant location of R&D activities of US MNEs, accounting for nearly 90 per cent of total overseas R&D expenditure. However, there has been a mild, but persistent, decline in this share over time, from 94 per cent in the early 1990s to 87 per cent during the period 2002-04. This decline has largely mirrored an increase in R&D shares of some high-performing East Asian economies, in particular Singapore, Korea, Malaysia and China. All Asian countries listed in the table, with the exception of Hong Kong and Indonesia, have recorded some increase in the share. In Latin America, all countries except the special case

of Mexico, have recorded a decline in their relative importance as locations of R&D activities for US MNEs. In sum, the decline in the developed–country share of overseas R&D expenditure is predominately a reflection of the growing importance of East Asian countries in global operations of US MNEs.

Among developed countries, there has been a notable increase in the relative importance of the UK, Japan and Sweden. In the first half of the 1990s, Germany was by far the dominant location of R&D activities of US MNEs, accounting for over one fourth of the global total. However, by the end of the decade, the UK was at par with Germany, each accounting for about a fifth of the global total. In the early 1990s, Ireland (the 'Celtic Tiger') accounted for a sizeable share (7 per cent), reflecting perhaps the increased participation of US MNEs in the export-oriented FDI boom in the country at the time. However, the relative importance of Ireland as an R&D location has declined in the ensuing years, bringing its share down to 2 per cent by the period 2002-04. The R&D share of Canada has increased slightly to 11.3 per cent, reflecting perhaps the enduring importance of its proximity-related advantages.

There is a clear mismatch between developed and developing countries in terms of the size of the R&D share compared to FDI stock and total global sales turnover. For instance, in 2002-04, developed countries accounted for 86.5 per cent of total overseas R&D expenditure, compared to a share of 76.2 per cent in total FDI stock and 75.7 per cent in total sales turnover. By contrast, developing countries accounted for 23.9 per cent of FDI stock and 24.3 per cent of total sales turnover, but their share in total R&D expenditure stood at 13.5 per cent. Interestingly, in this comparison, the East Asian NICs occupy a middle position between developed countries and the other developing countries, with R&D shares comparable to FDI and sales shares.

The average R&D-sales ratio for developed countries (1.74 per cent in 2002-04) is more than double that of developing countries (0.85 per cent). Among developing countries, both NICs and other Asian countries show much greater R&D intensity (R&D-sales ratios of 1.4 per cent and 1 per cent respectively) compared to countries in Latin America (0.3 per cent). Among developed countries, MNE affiliates operating in Israel, Sweden, Finland, Japan, and Germany (in that order) exhibit above average R&D intensity compared to other countries. The exceptionally high figures for the small economies such as Israel, Sweden and Finland seem to

suggest the importance of these countries as innovatory centres, with a greater attraction to knowledge-seeking investment.

Among the developing Asian countries, the R&D-sales ratio of MNE affiliates in China increased from a mere 0.4 per cent in the early 1990s to 1.6 per cent in 2002-04, a figure comparable to that of many developed countries. R&D intensity of MNE affiliates in Korea and Taiwan has also increased over the years, approaching the average developed-country level. MNE affiliates in Singapore, Malaysia and the Philippines have also recorded some notable increases in their R&D activities, but they still lag behind their counterparts in the four NIC. Among the other developing countries, R&D-sales ratios of India and Brazil are notably high (notwithstanding some decline in the Indian ratio between 1990-02 and 2002-04), perhaps because of the importance of product-adaptation type R&D activities in these large economies.

Table 4 depicts the relative importance of R&D expenditure of US MNE affiliates in total national R&D expenditure in host countries over the period 1990-2004. It is important to note that data on national R&D expenditure in these countries are fragmentary and not directly comparable with that of US MNEs, which are presumably collected and compiled with greater care. Nevertheless, the general picture emerging from the table is clear; although the share of the total R&D expenditure of US MNEs is small, US MNE affiliates account for a significant share of total R&D activities in a number of host countries, both among developed and developing countries. The average share of US MNEs in total R&D expenditure of host developing countries is 1.7%, but this masks more than 10 per cent figures for Singapore, China, Malaysia, the Philippines, and Mexico. Among the developed countries, individual-country figures are relatively uniform, with the exception of high figures for Ireland, Canada and the UK. The developed-country average (3.4%) is double of that for developing countries.

Table 4 about here

4. The Model, Data and Econometric Methodology

We have seen in the previous section that, while the degree of R&D intensity of MNE affiliates operating in developed countries is on average much higher than those operating in NICs and other developing countries, there are notable inter-country differences among countries

within each group. Interestingly, there is a considerable overlap between developed countries and NICs, with many developed countries recording R&D intensities comparable to or lower than those in NICs. We now turn to a formal examination of what forces shape inter-country differences in R&D intensity. In this section, we first focus on model formulation, followed by a brief discussion on the data and the estimation methods before presenting the results.

4.1: The Model

The dependent variable of our analysis is R&D intensity defined as the ratio of R&D expenditure to total sales (*RDS*). The explanatory variables are specified in the context the conceptual framework developed in the previous sections, within the constraints set by the nature of data availability.

Product adaptation

We include three variables to capture the importance of adapting products and production processes to suit domestic market conditions in determining inter-country variation in R&D intensity. They are, domestic market size measured by real gross domestic product (*GDP*), geographic distance measured by great circle distance between Washington DC and the capital city of the given host country (*DIST*), and domestic market orientation of MNE affiliates measured by the percentage of domestic sales in total sales turnover of affiliates (*DMS*).

A positive relationship is hypothesized between *GDP* and *RDS* intensity: a large domestic market should provide incentives to perform R&D for adapting products and production processes to suit local demand patterns. *DIST* is a proxy for the 'search problem' that seems to induce MNEs to undertake product-adaptation type R&D closer to its consumer base (Rangan and Lawrence 1999, 94). Here 'search' refers to acts performed in identifying potential exchange patterns and these acts gain importance as economic opportunities become spatially dispersed. *DIST* may also capture the impact of market segregation associated with transport cost. Technological advances during the post-war era have certainly contributed to 'death of distance' (*a la* Cairncross 1997) when it comes to international communication cost. However, there is evidence that the geographical 'distance' is still a key factor in determining differences in international transport cost, in particular shipping cost (Hummel 2007). For these reasons, we hypothesize a positive relationship between *DIST* and *RDS* intensity.

At first blush, R&D activities of a MNE affiliates should depend positively on the extent to which the host-country market is served from local production (Lal 1979, Hirschey and Caves 1981). However, in practice, when controlled for the market size, the impact of domestic market orientation on local R&D effort can go either way, depending on the differences in demand conditions between the host country and regional markets and the degree of market segmentation resulting from tariff and non-tariff barriers. If MNE affiliates located in a given country produce for wider regional or global markets in addition to serving the domestic market, a high degree of export orientation can in fact be positively associated with R&D intensity. In particular, this would be the case if the differences in technological levels between the subsidiary and its export market were greater than the technological gap between the latter and the parent company. On the other hand, it is quite likely that a technology seeking subsidiary will have a large domestic sale ratio, if it is located in a country with a large market. It that case exports from the subsidiary are likely to be knowledge, not commodity exports.

Domestic Technological Competency

Domestic technological competency of the host country (henceforth referred to as the national 'technology intensity') is an important consideration for MNEs' R&D location decision. As already discussed, this is a particularly important consideration if technology seeking is a driving force behind overseas R&D activities. However, even in the case of domestic market adaptation type R&D, domestic technology base is an important facilitating factor.

We use a 'technology effort index' (henceforth denoted as *TECH*) developed by Lal (2002) to measure domestic technology intensity of host countries. This is a composite index of two well-known R&D indicators, namely national productive-enterprise R&D expenditure and the number of patents registered by the country in the USA (both normalized by mid-year population). Productive-enterprise R&D expenditure is defined here as total R&D expenditure net of R&D expenditures on agriculture, defense and various tertiary-sector activities which are not directly related to innovatory activities of private agents. The number of patents taken out in the US is used as a proxy for innovative activities of a country. The rational behind its use here is that practically all innovators who seek to exploit their technology internationally take out patents in the US, given its market size and technology strength. The values for each variable is first standardized so that the highest country scores 1 and the lowest scores 0 and then the composite index is obtained as the average of the two (Lal 2002, 8-9).

Of the two composite indices of *TECH,* patent registration in the US has been widely used in previous studies examining the national innovative capability.[5] However, the country of origin appearing in patent records could simply reflect the strategic decision of the inventor rather than the true origin of the particular invention. Mindful of this limitation, in experimental runs we used two alternative technology indices to as robustness checks: the technology sophistication index and quality of scientific research institutes indexes, both from the *Global Competitiveness Report*.[6] The results were remarkably insensitive to the use of these alternative measures.

Investment environment

Three variables are used to capture various aspects of the economic environment of the host country, namely, R&D personnel per million population (*RDPN*), the cost of hiring technical personnel (*TPWG*), tax intensives for firm-level R&D activities (*TINS*), and intellectual property right protection (*IPR*).

RDPN is used to capture the ability of host countries to meet human capital requirement for undertaking R&D activities, which obviously contributes to the attractiveness of a given country as a location for R&D activities. Holding other relevant influences constant, *TPWG* is presumably a key determinant of the profitably of undertaking R&D locally compared to importing technological know-how from the parent company or other overseas affiliates.

Tax incentives for R&D activities clearly have the potential to affect the propensity to undertake R&D, since higher tax rates depress after tax returns, thereby reducing incentives to commit investment funds. Higher domestic corporate tax rates make importing technology a more attractive option compared to domestic technology generation because royalty payment for imported technology is tax deductible in the host country (Hines 1995). The measure of tax incentives used here is the Global Investment Forum index of tax incentives for firm-level R&D which ranges from 1 (no incentives) to 7 (incentives most prevalent). Preferably, we should have measured tax incentive, but unfortunately required data are readily available for some OECD member countries only.

[5] See Porter 2003 and the works cited therein.
[6] These are questionnaire-based indices that reflect perception of world business leaders around the world about capability of a given country.

Intellectual property right protection (IPR) is widely considered as an important policy tool for promoting innovative activities in countries with appropriate complementary endowments and policies. Private agents will not fully exploit their innovative capabilities even when the other preconditions are met, unless they can appropriate returns to their innovations (Maskus 1998 and 2000). We use the index of patent rights constructed by Ginarte and Park (1997) for the period 1960-1990 and updated to 2005 by Park (2008) as our measure of IPR protection. This index measures the strength of patent protection system (particularly relating to the treatment of foreigners) in term of five criteria: (1) extent of coverage, (2) membership in international patent agreements, (3) provisions for loss of protection, (4) enforcement mechanisms, and (5) duration of protection. The composite index for each country is the simple average of the five separate scores. It ranges from zero to five, with higher values indicating stronger levels of intellectual property right protection.

Other variables

As discussed, R&D intensity of a given country is potentially influenced by the nature of industry mix; production processes of some industries are inherently more R&D intensive than that of the others. Moreover, the need for adaptation of products to suit local market conditions varies from industry to industry. For instance, most product lines in chemical, electrical and electronic, and automobile industries generally tend to have more complex configurations than other goods, necessitating more R&D effort to modify or adapt them to markets abroad. Ideally, one should therefore work with country-level data disaggregated by industry (or better still at the firm level). Unfortunately, this is not possible because published industry-level R&D data of the US Bureau of Economic Analysis (BEA) are plagued by missing values (see below). As the second-best alternative, we use an index measuring the R&D potential of the industry composition (which we dub the 'R&D potential index', *RDP*) as an additional control variable:[7]

$$RPI_{jt} = \left[\frac{\sum_{i}^{N} \alpha_{it} X_{ijt}}{\frac{1}{N} \sum_{i}^{N} X_{ijt}} \right] * 100$$

[7] We are grateful to Kyoji Fukao, Hitotsubashi University for the suggesting this index.

where, α_i denotes the share of industry *i* in total R&D expenditure incurred by the overseas affiliates of US manufacturing MNEs, X_{ij} is gross output of industry *i* in total manufacturing output of US MNE affiliates in host country *j*, *N* is number of industries and *t* is the time subscript. For a given country, *j*, *RPI* is simply the global-R&D-share-weighted average of manufacturing output of US manufacturing MNE affiliates normalized at the mean (un-weighted) output. By construct, the index help compares patterns of output across countries after controlling for the relative size or scale of MNE operation in individual countries. If the industry composition of MNE output in country j is identical to industry composition of R&D expenditure in global operation of US MNEs, the index will take on value of 100. A higher numerical value of the index implies greater R&D potential of the output composition of MNE affiliates operation in a given country, the other factors influencing R&D propensity remaining constant.

The capital stock of US MNEs affiliates in host countries (*KUSF*) is used as a control variable for two reasons. First relative importance of a given country as an investment location can presumably be an important consideration in R&D location decision of MNEs. Second, once controlled for the market size, the FDI stock is a reasonable proxy for the duration of MNE operation in a given country (Lipsey 2000). It should capture the evolving pattern over time of R&D activities in a given country. For these reasons we expect a positive relationship between R&D intensity and *KUSF*.

We consider three country-group dummies – developed countries (mature industrial countries, DIC) defined to cover OECD Europe, North America, Japan, Australia and New Zealand; the newly industrialized countries in East Asia (Hong Kong, Korea, Taiwan and Singapore, DNIC); and other developing economies (*DODC*) associated with the stage of development (with DICs as the controlled group).[8] *DNIC* and *DODC* will also be interacted with the other explanatory variables in alternative regression runs to test whether the hypothesized relationship between R&D intensity and each of these variables is sensitive to the stage of development of countries. In addition, two individual country dummies, Ireland and China, are

[8] In experimental runs, we also tested further desegregation of ODCs into East Asian developing countries (other than NICs) and other developing countries. These two grouped were finally combined (to form ODCs) because were not able to detect statistically significant difference between the two sub-groups in relation to the hypotheses impact of the explanatory variables on R&D intensity.

used. The former is widely recognized as the export-platform of electronics in Europe and its R&D intensity remains low by the standard of developed countries in the region (Barry, 2005: 680). Similarly, China has its own specific attraction for R&D activities (presumably of product adaptation variety), given its role as the major assembly centre within global production networks in electronics and electrical goods. The bullish investor perception of China as an emerging world economic powerhouse is also a relevant consideration (Bergsten *et al*. 2006).

A 'crisis dummy' (*CRIS*) is included to allow for the possible impact of the recent financial crisis for R&D activities of MNE affiliates in Korea, Indonesia, Malaysia, Singapore, Thailand and the Philippines. This variable takes value 1 for the sub-period 1996-98 and zero otherwise for these five countries. Time dummy variables (*TIME*) are included to capture time-specific fixed effects, with the first sub-period (1990-92) as the base dummy.

Based on the above discussion, the estimating equation is specified as follows:

$$RDS_{it} = \alpha + \beta_1 GDP_{it} + \beta_2 DMS_{it} + \beta_3 DIST_i + \beta_4 TECH_{it} + \beta_5 RDPN_{it} + \beta_6 TPWG_{it} + \beta_7 TINS_{it} + \beta_8 IPR_{it} + \beta_9 KUSF_{it} + \beta_1 RDP_{it} + \theta_1 DNIC_i + \theta_2 DODC_i + \theta_3 DIRL + \theta_4 DCHN + \theta_5 CRIS_i + \gamma TIME_t + \delta_i + \mu$$

where, *RDS* is research and development intensity (research and development expenditure as a percentage of sales turnover), and subscripts *i* and *t* denote the unit of observation (country) and the time period respectively. The explanatory variables are listed below (with the expected sign of the regression coefficient of each variable given in brackets):

GDP (+) Real gross domestic product

DIST (+) Distance

DMS (- or +) Percentage of domestic sales in total affiliate sale turnover

TECH (+) Technology intensity index

RDPN (+) R&D personnel per million population

TPWG (-) Wages of technical personnel

TINS (+) Tax incentives for firm-level R&D activities

IPR (+) Intellectual property right index

KUSF (+) Capital stock of US firms (at the beginning of the each sub period)

RDP (+) An index of *R&D* potential of output mix

DODC(?)	Dummy variable for developing countries other than NICs
DNIC(?)	Dummy variable for newly industrialized countries in East Asia
DIRL (?)	Dummy variable for Ireland
DCHN(?)	Dummy variable for China
CRIS(?)	Financial crisis dummy (for Korea, Thailand, Indonesia, Malaysia and the Philippines)
TIME	A vector of time dummy variables (which takes unity is the specific time period and zero otherwise) to capture time-specific 'fixed' effects
δ	'Unobserved effect' which represents the joint impact of unobserved explanatory variables
α	A constant term
μ	A disturbance terms assumed to satisfy the usual regression model conditions.

4.2: Data

The data on the dependent variable and three explanatory variables (*DMS*, *RPI*, *KUSF*) are compiled from the electronic data files of the Annual Survey of US Investment Abroad conducted by the Bureau of Economic Analysis, the US Department of Commerce. The data relate to majority-owned, non-bank affiliates of US-headquartered corporations tracked by the BEA. The BEA started reporting data on R&D on an annual basis with effect from 1990..[9] Our data set covers the fourteen-year period from 1990 to 2004, the latest year for which data are available. Because of confidentiality reasons, BEA does not divulge the response of individual firms and report only country-level data (disaggregated at the two-digit level of the standards industry classification) for those countries in which there are sufficient number of US firms with sizable activities. It is not possible however to construct continuous data series at the industry-level for sufficient number of countries because the incidence of data suppression resulting from the application of the single-firm disclosure rules is much severe at that level. Even for total manufacturing, there are considerable gaps in data for a sizable number of countries. Thus, with a view to achieving a reasonable time series dimension and a reasonable country coverage, we limited the sample coverage only to those countries for with there are no missing values for more than two consecutive years within the period 1990-2004.[10] By doing so, we were able to

[9] For details on this database see Hansen et al. (2001), Appendix.
[10] In cases where the reported amount is greater than zero but less than $500,000, we set the level of investment at $250,000.

construct a panel data set arranged at three-year intervals[11] for 42 countries (See Table 4). The use of three-year average rather than annual data is not a serious limitation because we are focusing here on long-term relations. Information on sources and time coverage of the other data series and the list of countries covered in the study are reported in Appendix A-1. All variables, other than the two ordered qualitative variables (IPR and TINS) and the dummy variables, are used in natural logarithms.

4.3 Econometrics

Of the three standard panel data estimation methods (pooled OLS, random-effects, and fixed-effects estimators), the fixed effect estimator is not appropriate in this case because the model contains a number of time-invariant explanatory variables (DIST, TINS, DODC, DNIC, IRELAND, and CHINA), many of which are central to our analysis. In experimental runs, we used both pooled OLS and random-effects estimators. The Bruesch -Pagan Lagrange multiplier test decisively rejected the null hypothesis of random effects, favoring the use of random effects estimator.[12] In the presence of random effects, pooled OLS regression will be subject to unobserved heterogeneity bias.

However, the simple random effect estimator can yield bias and inconsistent coefficient estimates if one or more explanatory variables are endogenous (that is, they are jointly determined together with the dependent variable). In our case, there are reasons to suspect that domestic market share (*DMS*), wages of technical personnel (*TPWG*), initial capital stock (*KUSF*), R&D tax incentives (*TINS*) and intellectual property protection (*IPR*) are potentially endogenous. Investment/R&D decision of MNE affiliates in a given host country can have a direct on *DMS*, *TPWG* and *KUSF*. Both R&D intensity and IPR strength are possibly interrelated through a third variable, namely the market size.[13] *TINS* is an index based on perceptions reported by MNEs and conceivable MNE's responses depend on the level of R&D that benefit from prevailing tax incentives. Perception based indices are also susceptible to measurement

[11] That is, an observation is a country's performance average over a three-year period, yielding five observations (averages for 1990-92, 1993-95, 1996-98, 1999-2001 and 2002-04) for each country. If a data point is missing within any three-year period, a two year-average is used and when two data points are missing, the available data point is used as the three-year average. Of the total 210 observations on R&D, only 17 observations have been 'approximated' in this way.

[12] See Appendix Table A-2 (last row and note 2) for the test results.

[13] Grossman and Lai (2004) demonstrate analytically that market size is a key determinant of IPR strength and Ginarte and Park (1997) provide empirical support for the proposition.

errors which could violate the assumption that the disturbance term is distributed independently of the explanatory variables. Mindful of these considerations, we re-estimated the model using the instrumental variable- random effect (IV- RE) estimator (Wooldridge 2002). This estimator allows for the use of the standard instrumental variable estimation (two-stage least squares) technique while retaining the key features of the RE estimator. First we tested the endogenously of each of these six variables using the Wu-Hausman test. The test failed to reject the null hypothesis of endogenously for *DMS*, *TINS IPR* and *TPWG*. At the second stage, we implemented IV-RE estimator by incrementing these four variables using instruments derived within the model.[14]

5. Determinants of R&D Intensity: Regression Results

The final IV-RE estimates of the model are reported in Table 5. For comparison, the pooled OLS and simple random effect estimates are reported in Appendix Tables A-2. Overall, the results based on the three estimation methods are broadly similar. Summary statistics of the variables and the correlation matrix are reported in Tables 6 and 7 to facilitate interpretation of the results. In experimental runs, we interacted the two country group dummies, *DNIC* and *DODC*, with other explanatory variables in order to test whether the hypothesized relationship between R&D intensity and each of these variables is sensitive to the stage of development of countries. Only the coefficient of the interaction terms of domestic market share *(DMS*DM)* turned out to be statistically significant.

Insert Table 5 here
Insert Table 6 here
Insert Table 7 here

Equation 1 in Table 5 is the estimate of the full model. In this Equation, the coefficients on *TINS and IPR* are statistically insignificant with the theoretically unexpected (negative) sign. The final equation estimated after deleting these variables (our 'preferred model') is reported as Equation 2.[15] There is reason to suspect the results for TINS and IPR could have been affected

[14] The external instruments used are the one-period lags of the endogenous variables and potentially endogenous explanatory variables.

by the high correlation of these variables with *RDNP* and *TPWG* (Table 7). However, this suspicion is not borne out from a comparison between Equations 1 and 3; the results for TINS and IPR are remarkably insensitive to the deletion of RDNP and TPWG.

The coefficient on *GDP* is significant at the one per cent level supporting the hypothesis that, other things remaining unchanged, domestic market size is a key determinant of R&D intensity of MNE affiliates. One per cent change in market size is associated with 0.28 per cent change in R&D across countries.

As we anticipated *a priori*, the result for *DMS* is mixed. For the entire country sample, its coefficient is statistically significant with the negative sign, suggesting that greater domestic market orientation is *negatively* related with R&D intensity. However, the coefficient of the interaction dummy *DODC*DMS* is positive and statistically significant; suggesting that one percent increase in domestic market orientation is associated with 1.1 per cent increase in *RDS* among other developing countries (that is, developing countries excluding NICs). By contrast, the interaction dummy for NICs (*DNIC*DMS)* was found to be statistically insignificant. These contrasting results confirm the view that, given the similarities of demand patterns between the host country and that of the major (mostly developed country) markets and the virtual absence of trade barriers to trade, greater export orientation provides impetus for increase in R&D effort for MNE affiliates located in developed countries. This finding is consistent the inference of Doh et al. (2005) that R&D is becoming a truly global activity. However, given peculiarities in domestic demand patterns related to low income levels and presumably also because of remaining barriers to integrate into the global economy, there seems to be some need for undertaking product adaptation-type R&D in ODCs.

The coefficient of *RDPN* is statistically significant with the expected (positive) sign, providing support for the hypothesis that the availability of R&D personnel is a significant influence on the R&D location decision of MNEs. The results for *TPWG* corroborate this inference; the wage rate of technical personnel has a strong negative relationship with R&D intensity of MNE operations. This result, however, needs to be qualified for the poor quality of the data series (the wage of non-production workers) used to represent the cost of hiring

[15] This specification choice is amply supported by the standard variable deletion (F) test; the joint test for zero restriction on the coefficients of the two variables yielded, F (2, 154) = 1.23.

technical personnel. Perhaps the estimated coefficient provides a possible *lower bound* because normally the wages of R&D personnel are generally higher and increase at a faster rate compared to wages of non-production workers in general.

The coefficient on *RDP* is statistically significant with the expected (positive) sign, supporting the hypothesis that the industry composition does matter in explaining inter-country differences in the degree of R&D intensity of MNE affiliates. We also re-estimated Equation 2 after deleting *RPI* and found that individual regression coefficients attached to the other variables are remarkably resilient to its inclusion/exclusion.[16] At the same time, the deletion of *RDP* from Equation 2 was not supported by the standard variable deletion *F*-test.[17] The upshot is that industry composition is an important determinant of the overall R&D intensity of MNE operation in a given country over and above the other variables considered here.

Despite attaining the theoretically expected sign, the coefficient of *TECH* is marginal significant (at the 10 per cent level). When two alternatives of *TECH*, technology sophistication index and quality of scientific research institutes, are used, their corresponding coefficient is insignificant as well. There is no evidence to suggest that the relative importance of a given country in global operation of US MNEs as measured by the size of the stock of capital (*FUSF*) is important in explaining R&D intensity of affiliates operating in that country. Contrary to the popular belief that underpins investment promotion campaigns in many host countries, the coefficient of *IPR* is not a statistically significant.

The results for *TINS* casts doubt on the effectiveness of financial incentives as a policy tool for promoting R&D activities by MNE affiliates in host countries.[18] A plausible explanation seems to be that, as the MNEs have access to intra-firm trade and other means to minimize the actual tax burden, tax incentives are not an important consideration for MNEs in their R&D location decisions when allowed for the other relevant variables (Clausing 2001, Mansfield

[16] This alternative estimate is available from the authors on request.

[17] The test for zero restriction on the coefficients of *RDP* in Equation 2 is F (1, 154) = 8.37, which is significant at the one percent level.

[18] The data series on TINS captures the state of tax incentives for R&D circa 1999/2000 (See Appendix Table A-1. However, this does not seem to be a serious problem because in most changes in effective tax incentives occurred in the 1980s. For instance, see United Nations 1996, Bloom *et al*. 2002, Figures 1 and 2.

1986). The coefficient on *DIST* has the expected positive sign suggesting that geographical distance still matters for the overseas R&D location decision of MNEs, but this relationship is not statistically significant. The coefficients of the intercept dummies for China and Ireland are significant but with the negative sign. This suggests that once controlled for the other relevant variables, the average level of R&D intensity of US MNE affiliates in these countries is lower (rather than higher) than the average level of the countries covered in the analysis. As can be seen from Equations 4 and 5 in the Table, the results are remarkably robust to the exclusion of these two countries from the data coverage.

Finally, how do our findings compare with those of the previous studies? Our results confirm the findings of Kumar (1996 and 2001) and Doh *et al*. (2005) that MNEs prefer to locate their R&D activities in countries that are able to offer, among other things, large markets and technical resources. However, in contrast to Kumar (1996 and 2001) we find that there is no unique relationship between the nature of market orientation of MNE affiliates and R&D intensity. There is a positive relationship between these two variables only for developing countries that are still at early stage of joining the process of economic globalization. For developed countries and dynamic NICs in Asia, the relationship is negative, implying that greater export-orientation is associated with more, rather than less, R&D intensity. Thus, there is no case for supporting domestic-market oriented policies on grounds that they promote local R&D activities by MNEs in developing countries. Our findings are consistent with those of Doh et al. 2005, 121) who found that 'substantial portion of R&D undertaken in US foreign affiliates is becoming a truly global activity''.

No previous study has examined the impact of R&D tax incentives on R&D intensity of MNE affiliates using data encompassing both developed and developing host countries. However, our results relating to this variable run counter to that of and Hines and Jaffe (2001) for affiliates of US-based MNEs in developed countries and Bloom and Griffith (2001) for UK-based MNEs. These authors have uncovered a statistically significant positive effect of tax incentives on the distribution of inventive activity between the home country and overseas locations of MNEs. We suspect that these results suffer from a serious omitted variable bias; failure to appropriately control for other relevant explanatory variables may have biased the results against the null hypothesis. Both studies have controlled for only one arbitrary selected relevant variable (Hines and Jaffe 2001: R&D intensity of the host country; Bloom and Griffith

2001: domestic real output) in testing the link between internationalization of R&D and tax incentives). Interestingly, our data set permits us to replicate their results through similar (arbitrary) variable choice. For instance, truncating our model to retain *TECH* (our measure of the R&D intensity of the host country) as the only control variable yields:[19]

$$\begin{array}{lccc} R\&D & = -1.55 & +0.21TECH & +0.26TINS \\ & (-5.92)*** & (7.85)*** & (3.52)*** \\ & \bar{R}^2 = 0.47 & F = 93.02 & \end{array}$$

When *GDP* (our measure of real output) is used in place of *TECH*:

$$\begin{array}{lccc} R\&D & = -5.89 & +0.31GDP & +0.47TINS \\ & (-10.13)*** & (5.89)*** & (7.06.)*** \\ & \bar{R}^2 = 0.41 & F = 73.35 & \end{array}$$

Both equations provide strong statistical support for the hypothesis that tax incentives are a significant determinant of inter-country differences in R&D intensity of US MNE affiliates. However, the (arbitrary) truncation of the model in each case is not supported by the standard variable deletion (F) test conducted against our full model (Table 5).

Interestingly our failure to uncover a statistically significant effect of R&D tax incentives on R&D effort is consistent with the following remarks on this issue by an eminent practitioner in this field:

> In 20 years, I have never had a single corporate executive ….tell me that they have done a dime's worth of research that they otherwise would have done as a result of R&D credit. They spend a lot of time and effort reallocating costs so that they can take advantage of the credit, but they don't actually do any more research (Gleckman 2006)[20]

6. Conclusion

We have examined patterns and determinants of overseas R&D activity by MNEs using a new panel dataset relating to US-based MNEs over the period 1990-2004. It is found that domestic market size, geographic distance, overall R&D capability of the country and cost of R&D personnel are key determinants of the R&D intensity of operation of US MNE affiliates. There is also evidence that, contrary to the conventional wisdom, the impact of domestic market

[19] The following two equations are OLS estimates.
[20] We are indebted to Russell Thompson for drawing our attention to this reference.

orientation of affiliates on R&D propensity varies among countries depending on their stage of development. The degree of domestic market orientation has a positive impact on R&D intensity only in developing countries other than the East Asian NICs. For the latter countries and developed countries the two variables are negatively related, suggesting that greater export-orientation is associated with greater (*not* less) R&D intensity. There is also evidence that, once controlled for the other relevant variables, the industry composition does matter in explaining inter-country variations in R&D intensity. R&D related tax incentives do not seem important in explaining inter-country differences in R&D intensity when appropriately controlled for other relevant variables. Intellectual property protection seems to matter for mature economies with complementary endowments.

Overall, our findings cast doubts on the ability of host governments to entice MNEs affiliates become technology creators within their national borders as part of their foreign direct investment policy. MNEs' decision to undertake R&D activities in a given country seems largely endogenous to its overall growth and development process. Excessive concern about where R&D is performed runs the risk of downplay the more important role of MNEs as a conduit of technology transfer. Even if MNE affiliates generate little or no technology locally, they are potentially well placed to play an important role in improving local innovative capabilities through technology transfer.

In our examination of the determinants of R&D intensity, we have been able to bring to bear considerably richer data than have been used in prior research. However, the results need to be qualified for two major limitations of the data set. First, a two-dimensional panel dataset (arranged by country and time), while being a significant improvement over pure cross country data set, still fails to capture industry specificity of R&D intensity. Unlike in previous studies, we have controlled for industry specificity by including a R&D potential index of output mix, but this is admittedly a crude way of tackling a more complex issue. Second, we have used a perception-based index to measure R&D tax incentives, which is probably not consistently reported across nations. There is certainly a need to check the robustness of the results using a statutory measure of tax incentives. Finally, it is important to be cautious when generalizing from our findings, which are specific to overseas operations of US-based MNEs. In particular, given the large domestic economy and the R&D resource base, US-MNEs may have a lesser

tendency to internationalize R&D in aggregate or in specific industries overseas compared to MNEs based in a small country like Sweden.

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Table 1: R&D Internationalization of US MNEs during 1966-2003

	All sectors			Manufacturing			Manufacturing share (%)	
	Total	Foreign affiliates		Total	Foreign affiliates		Total	Foreign affiliates
	$ mn	$ mn	%	$ mn	$ mn	%		
1966	9.0	0.6	6.6	8.1	0.5	6.5	90.5	89.2
1977	21.0	2.1	9.9	---	---	---	---	---
1982	60.2	3.9	6.4	---	---	---	---	---
1989	89.3	7.0	7.9	78.9	5.7	7.2	88.4	81.1
1990	74.8	10.2	13.6	64.4	8.5	13.1	86.1	83.1
1991	76.8	9.4	12.2	67.0	8.1	12.1	87.3	86.1
1992	83.2	11.1	13.3	73.4	9.3	12.7	88.2	84.3
1993	84.2	11.0	13.0	74.2	9.0	12.2	88.2	82.4
1994	103.2	12.1	11.7	90.6	10.1	11.2	87.8	83.9
1995	110.2	12.6	11.4	97.2	10.8	11.1	88.2	85.8
1996	114.6	14.0	12.3	102.2	12.2	11.9	89.2	86.9
1997	121.4	14.6	12.0	107.3	12.5	11.7	88.4	85.7
1998	128.4	14.7	11.4	113.6	12.8	11.3	88.4	87.4
1999	144.4	18.1	12.6	121.2	16.4	13.5	83.9	90.3
2000	155.9	20.5	13.1	128.2	18.5	14.4	82.2	90.2
2001	162.7	19.7	12.1	132.5	17.4	13.1	81.4	88.2
2002	158.0	21.1	13.3	128.8	18.7	14.5	81.5	89.0
2003	162.2	22.3	13.8	132.6	19.9	15.0	81.7	89.1
2004	169.4	27.5	16.3	137.5	23.3	16.9	81.2	84.6

Note: --- data not available.
Source : Compiled from, U.S. Department of Commerce (1975, 1981, 1985, 1992) and Computer files of *U.S. Direct Investment Abroad*, Bureau of Economic Analysis, US Department of Commerce.

Table 2: Industry Distribution of R&D Expenditure of selected countries, 1990-2004

	All Countries		Developed Countries[1]		NICs[2]		Other Developing Countries	
	1990-92	2002-04	1990-92	2002-04	1990-92	2002-04	1990-92	2002-04
All Industries	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Petroleum	2.7	0.0	0.3	0.0	0.5	0.0	1.5	0.1
Manufacturing	84.5	89.2	83.1	88.8	89.6	93.1	95.5	91.7
Food products	2.2	2.1	1.8	1.9	0.0	0.3	6.5	5.8
Chemical products	23.4	24.5	24.1	26.4	3.3	3.7	29.0	13.1
Primary and fabricated metals	1.0	0.8	1.0	0.9	0.0	0.1	1.1	0.3
Industrial machinery and equipment	18.4	3.2	15.2	3.4	11.0	1.1	5.4	2.9
Electronics	7.3	21.1	4.8	18.3	11.0	61.4	5.5	28.9
Automotives	22.7	23.7	19.4	26.0	0.0	4.1	4.0	8.3
Other manufacturing	9.4	13.7	6.2	11.9	1.8	22.5	13.8	32.4
Wholesale trade	6.3	2.0	5.4	2.1	3.3	0.9	4.2	1.4
Finance insurance and real estate	0.1	0.0	0.1	0.0	0.0	0.0	0.3	0.0
Services	6.2	8.7	6.1	9.0	6.9	6.0	0.7	6.6
Other industries	0.3	0.1	0.1	0.1	0.0	0.0	1.2	0.3
Total Expenditure ($mil)	10,222	22,439	9,528	19,879	245	1,062	295	1,498

Notes:

1. OECD Europe, North America, Japan, Australia and New Zealand.
2. Hong Kong, Korea Republic, Singapore, and Taiwan
3. Twenty-four countries with data available are Turkey, Argentina, Brazil, Chile, Colombia, Mexico, Panama, Ecuador, Venezuela, China, the Philippines, Indonesia, Malaysia, Thailand, India, Egypt, Nigeria, South Africa, Costa Rica, Honduras, Peru, Dominican Republic, Saudi Arabia and United Arab Emirates.

Source: Compiled from computer files of *US Direct Investment Abroad*, Bureau of Economic Analysis, US Department of Commerce

Table 3: Overseas Affiliates of US Manufacturing MNEs: FDI Stock, Sales, R&D Expenditure and R&D-Sales Ratio by Country/Region (%)

	FDI Stock		Sales		R&D Expenditure		R&D-Sales ratio	
	1990-92	2002-04	1990-92	2002-04	1990-92	2002-04	1990-92	2002-04
Developed Countries	84.09	76.15	84.95	75.72	94.22	86.54	1.61	1.74
Europe	57.74	48.97	61.43	53.26	76.86	63.55	1.82	1.82
Austria	0.49	0.49	0.46	0.40	0.10	0.34	0.30	1.33
Belgium	3.36	2.08	3.26	2.66	3.83	2.08	1.71	1.20
Denmark	0.27	0.55	0.26	0.27	0.16	0.26	0.91	1.50
Finland	0.09	0.25	0.08	0.26	0.01	0.42	0.21	2.50
France	7.55	5.02	7.88	6.53	8.48	8.23	1.56	1.92
Germany	15.47	4.71	16.31	9.27	28.74	18.00	2.56	2.96
Greece	0.09	0.04	0.11	0.15	0.02	0.04	0.30	0.44
Ireland	1.51	4.85	1.94	4.87	6.92	2.49	5.18	0.78
Italy	4.20	4.24	4.96	3.69	3.85	2.80	1.13	1.16
Netherlands	4.50	6.42	5.05	3.92	3.71	2.06	1.07	0.80
Norway	0.06	0.19	0.08	0.54	0.04	0.16	0.73	0.46
Portugal	0.24	0.16	0.30	0.27	0.06	0.07	0.30	0.40
Spain	3.48	2.53	3.82	3.01	1.88	1.53	0.72	0.78
Sweden	0.51	0.32	0.70	2.08	1.08	6.66	2.25	4.88
Switzerland	0.94	2.45	0.81	0.86	0.70	1.26	1.26	2.23
United Kingdom	14.73	11.81	15.26	11.70	17.03	18.27	1.62	2.38
Canada	17.79	19.63	16.04	15.11	10.31	11.34	0.93	1.14
Japan	4.65	3.58	4.40	4.50	5.27	7.18	1.74	2.43
Australia	3.78	2.86	2.93	2.22	1.75	1.79	0.87	1.23
New Zealand	0.13	0.16	0.16	0.27	0.03	0.06	0.32	0.35
Israel	0.24	0.95	0.15	0.36	0.23	2.62	2.26	11.02

Developing countries	15.91	23.85	15.05	24.28	5.78	13.46	0.56	0.85
Asian NICs	2.76	7.24	3.88	5.41	2.54	4.83	0.95	1.36
Hong Kong	0.28	0.73	0.76	0.63	0.26	0.99	0.49	2.40
Korea, Republic of	0.61	1.86	0.35	0.85	0.09	0.92	0.35	1.66
Singapore	1.06	3.59	1.89	3.25	1.76	2.59	1.35	1.22
Taiwan	0.82	1.06	0.87	0.69	0.44	0.98	0.74	2.17
Other Asia	1.38	4.41	1.68	6.25	0.32	4.10	0.27	1.00
China	0.10	1.71	0.06	2.65	0.02	2.70	0.41	1.56
Indonesia	0.06	n.a.	0.08	0.14	0.04	0.02	0.80	0.20
Malaysia	0.56	0.88	0.67	1.81	0.09	1.34	0.20	1.13
Philippines	0.29	0.61	0.36	0.48	0.09	0.23	0.34	0.73
Thailand	0.34	0.87	0.46	0.81	0.05	0.10	0.15	0.18
India	0.04	0.35	0.05	0.41	0.03	0.15	1.09	0.58
Latin America	11.45	11.25	9.08	11.62	2.72	2.54	0.43	0.33
Argentina	0.64	0.45	0.62	0.81	0.15	0.11	0.36	0.20
Brazil	6.32	2.74	3.86	2.97	1.66	1.53	0.62	0.79
Chile	0.62	0.46	0.15	0.16	0.02	0.02	0.18	0.20
Colombia	0.21	0.28	0.30	0.24	0.05	0.02	0.22	0.15
Ecuador	0.05	0.02	0.04	0.06	0.01	0.00	0.21	0.00
Mexico	3.25	4.68	3.58	5.80	0.67	0.93	0.27	0.24
Panama	0.02	0.09	0.05	0.02	0.01	0.00	0.18	0.18
Peru	0.04	0.05	0.04	0.05	0.01	0.00	0.35	0.07
Venezuela	0.30	0.80	0.44	0.40	0.15	0.10	0.48	0.40
South Africa	0.14	0.33	0.25	0.47	0.14	0.11	0.79	0.35
Turkey	0.19	0.20	0.16	0.30	0.06	0.06	0.53	0.32
All countries	100	100	100	100.00	100	100.0	1.45	1.53
(US$ billion)	(179.0)	(374.4)	(600.0)	(1,343.5)	(8.6)	(20.5)		

Source: Compiled from U.S. Department of Commerce (1975, 1981, 1992) and Bureau of Economic Analysis, U.S. Department of Commerce, computer files of *U.S. Direct Investment Abroad.*

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Table 4: Percentage Share of R&D Expenditure of US MNE Affiliates in Total R&D Expenditure in Host Countries (1990-2004 annul average)

Country/country group	US Affiliates' share in total domestic R&D expenditure	Country/country group	US Affiliates' share in total domestic R&D expenditure
All countries	3.3	Developing countries	1.7
Developed countries	3.4	Asian NICs	0.3
Europe	4.9	Hong Kong	0.1
Austria	1.2	Korea, Republic of	0.3
Belgium	7.5	Singapore	11.4
Denmark	1.1	Taiwan	1.4
France	3.2	Other Asia	2.8
Germany	5.5	China	16.2
Greece	0.6	Indonesia	3.9
Ireland	43.8	Malaysia	21.9
Italy	3.0	Thailand	2.5
Netherlands	4.6	India	0.3
Norway	0.3	Philippines	11.9
Portugal	3.0	Latin America	4.1
Spain	4.5	Argentina	2.3
Sweden	3.6	Brazil	3.9
Switzerland	1.5	Chile	0.8
United Kingdom	8.7	Colombia	2.4
Israel	2.4	Ecuador	3.1
Canada	12.1	Egypt	0.7
Japan	0.6	Mexico	10.6
Australia	4.1	Panama	2.0
New Zealand	1.4	Peru	34.0
		Venezuela	6.0
		South Africa	1.9

Source : Computed using data for Research and Development Expenditure is from World Development Indicator(CD ROM), World Bank except for Taiwan. Data for Taiwan is from *Taiwan Statistical Data Book* 2001, Council for Economic Planning and Development, Taipei.

Table 5: Determinants of R&D Intensity: Random-Effect IV Estimates *

		Equation 1	Equation 2	Equation 3	Equation 4	Equation 5
α	Constant term	1.54	-3.11	-3.54	+0.98	-2.68
		(0.47)	(1.65)*	(1.53)***	(0.31)	(1.45)*
GDP	Real gross domestic product	+0.51	+0.38	+0.35	0.50	+1.21
		(3.89)***	(5.10)***	(3.45)***	(3.78)***	(3.82)***
DMS	Domestic market share of total	-2.55	-1.48	-1.56	-2.33	-1.21
	Sales	(3.63)***	(4.87)***	(3.12)***	(3.42)***	(3.82)***
DIST	Distance	+0.08	+0.09	+0.28	+0.06	0.07
		(0.47)	(0..75)	(2.03)**	(0.35)	(0.59)
TECH	Technology index	+0.09	+0.12	+0.12	+0.05	+ 0.13
		(1.60)*	(1.87)**	(1.55)**	(0.48)	(1.96)**
RDPN	R&D personnel per million	+0.79	+0.51		+0.79	+0.43
	Population	(4.98)***	(5.55)***		(5.13)***	(4.35)***
TPWG	Wages of technical personnel	-0.42	-0.85		-1.51	-1.00
		(2.43)**	(4.12)**		(3.94)***	(4.70)***
TINS	Tax incentives for firm-level	-0.41		+0.01	-0.40	
	R&D	(0.40)		(0.05)	(0.34)	
IPR	Intellectual property protection	-0.10		+0.04	-0.03	
		(0.65)		(0.31)	(0.23)	
KUSF	Stock of fixed capital of US	+0.09	+0.02	-0.01	0.09	+0.01
	MNEs	(1.15)	(0.39)	(0.08)	(1.18)	(0.16)
R&DP	R&D potential of output	+0.59	+ 0.60	+0.64	0.53	+0.61
	Composition	(3.47)***	(3.87)***	(3.84)**	(3.28)***	(4.03)***
Dummy variables						
DODC	Developing country dummy	-11.71	-7.18	-7.05	-10.96	-6.76
		(3.19)***	(4.13)***	(3.12)***	(3.49)***	(3.99)***
DNIC	Newly industrialized country	-0.85	-0.61	-0.50	-0.78	-0.74
	dummy	(2.16)**	(2.64)**	(1.70)*	(2.01)**	(3.13)***
*DODC*DMS*	Interaction term of *ODC* and *DMS*	+2.66	+1.60	+1.57	+2.49	+1.54
		(3.65)***	(3.94)***	(3.03)***	(3.48)***	(3.91)***
CRIS	Financial crisis dummy	-0.80	-0.88	-0.72	-0.83	-0.82
		(2.32)**	(2.40) **	(2.05)**	(2.57)**	(2.53)**
DIRL	Ireland dummy	-2.71	-1.63	-1.63		
		(2.82)***	(3.27)***	(2.27)**		
DCHN	China dummy	-1.82	-1.12	-1.21		
		(2.48)**	(2.47)**	(2.44)**		
	R-sq: Overall	0.62	0.68	0.61	0.64	0.70
	within	0.23	0.27	0.12	0.27	0.29
	Between	0.75	0.81	0.78	0.76	0.71
	Wald test, X^2	170.73**	325.52***	214.16***	171.07***	341.91***
	Observations	168	168	168	160	160
	Number of groups	42	42	42	40	40
	Sargan-Hansen statistic X^2 (1)	4.80**	2.81**	1.95**	3.06**	2.19**

Notes: All variables (except ODC, NIC,and TINS and IPR) are in logarithms. The *t*-ratios based on White's heteroscadasticity adjusted standard errors are given in brackets, with statistical significance (one-tailed test) denoted as: *** 1per cent, ** 5 per cent; and * 10 per cent. # Null-hypothesis is not rejected at the 5 per cent level.

Table 6: Summary Data on Variables Used in the Regression Analysis[1]

	Maximum	Minimum	Mean	Std. Deviation	Coef. Of Variation
R&D	2.40	-6.91	-0.40	1.08	-2.67
GDP	15.50	8.91	12.29	1.22	0.10
DMS	4.57	2.23	4.07	0.44	0.11
TECH	4.46	-4.61	0.92	2.66	2.88
RDPN	8.96	3.61	6.80	1.36	0.20
DIST	9.70	6.61	8.92	0.58	0.06
TPWG	4.72	1.70	3.45	0.71	0.20
KUSF	12.30	4.49	8.62	1.49	0.17
RPI	6.42	3.85	4.85	0.40	0.08
IPR	4.67	0.33	3.24	1.08	0.33
TINS	5.80	1.60	3.69	0.96	0.26

Notes: All variables other than IPR and TINS are in natural logarithms.

Table 7: Correlation Matrix of Variables Used in the Regression Analysis

	RD	*GDP*	*DMS*	*DIST*	*TECH*	*RDNP*	*TPWG*	*TINS*	*IPR*	*KUSF*
GDP	0.52									
DMS	-0.28	0.14								
DIST	0.05	0.02	-0.06							
TECH	0.66	0.46	-0.33	-0.03						
RDNP	0.68	0.47	-0.20	-0.01	0.87					
TPWG	0.44	0.39	-0.09	-0.27	0.75	0.75				
TINS	0.56	0.43	-0.47	0.12	0.64	0.63	0.31			
IPR	0.58	0.37	-0.36	0.05	0.81	0.72	0.56	0.59		
KUSF	0.37	0.56	-0.18	-0.23	0.42	0.30	0.30	0.31	0.44	
RDP	0.18	0.10	-0.05	-0.03	-0.06	0.01	0.09	0.05	-0.18	0.01

Appendix

Table A-1: Variable Definition and Data Sources

Variable		Source	Time coverage
R&D	Research and development expenditure as a presentation of total sale turnover	Compiled from the electronic data files of the *Annual Survey of US Investment Abroad*, the Bureau of Economic Analysis http;//www.bea.doc.gov./bea/uguide.htm#_1_23	1990-2004
DMS	Domestic market share of total sales	- do -	- do -
CHEM	Percentage of chemical products in total affiliate output	- do -	- do -
R&DP	Index of R&D potential – a composite index of R&D potential of output composition	- do -	- do -
KUSF	Stock of fixed capital of US MNEs (at the beginning of the 3-year period)	- do -	- do -
GDP	Real gross domestic product	Word Development Indicator Database, World Bank (http://www.worldbank.org)	- do-
DIST	Great-circle distance between the capital city of the given country to Washington DC	The Western Cotton Research Laboratory database, US Department of Agriculture www.wcrl.ars.usda.gov/cec/java/lat-long.htm	Not applicable
TECH	Technology effort index – a composite index of productive-enterprise R&D expenditure and the number of patents registered in the USA, both normalized by mid-year population	Lall (2002)	Circa 1999
RDPN	R&D personnel per million population	UNESCO Statistical Yearbook, Geneva: United Nations	1990-2004
TPWG	Wages of technical personnel	U.S. Department of Commence, Bureau of Economic Analysis, *Benchmark Survey of US Investment Abroad* 1994.	1996 -2004
TINS	Index of tax incentives for firm-level R&D (ranges from 1 (no incentives) to 7 (incentives most prevalent))	World Economic Forum, *Global Competitiveness Report*,	1995-2004
IPR	Index of Intellectual property protection (ranges from 0 (weakest) to 5 (strongest))	Ginarte and Park (1997) and Park (2008)	1985-2005

Appendix Table A.2: Determinants of R&D Intensity: Alternative Regression Estimates [1]

		Pooled OLS		Random effects	
		Equation 1	Equation 2	Equation 1	Equation 2
α	Constant term	-3.94	-4.49	-4.88	-5.31
		(2.67)***	(2.84)***	(2.84)***	(2.99)***
GDP	Real gross domestic product	+0.30	+0.27	+0.26	+ 0.24
		(4.41)***	(3.15)***	(3.45)***	(3.45)***
DMS	Domestic market share of total	-0.94	-0.82	-0.95	-0.86
	Sales	(5.49)***	(5.53)***	(4.44)***	(4.53)***
DIST	Distance	+0.11	+0.11	+0.14	0.12
		(1.35)	(1.39)	(1.25)**	(1.14)
TECH	Technology index	+0.15	+0.14	+0.09	+0.07
		(2.28)**	(2.11**	(1.60)*	(0.82)
RDPN	R&D personnel per million	+0.40	+0.36	0.54	0.51
	Population	(2.59)***	(2.60)***	(2.81)***	(2.83)***
TPWG	Wages of technical personnel	-0.82	-0.75	-0.75	-0.71
		(3.68)***	(3.67)***	(2.22)**	(2.21)
TINS	Tax incentives for firm-level R&D	-0.10		-0.11	
		(1.14)		(0.95)	
IPR	Intellectual property protection	-0.03		-0.03	
		(0.51)		(0.55)**	
KUSF	Stock of fixed capital of US MNEs	+0.02	+0.03	-0.09	0.08
		(0.43)	(0.44)	(1.07)	(1.03)
RPI	R&D potential of output	+0.67	+ 0.65	+0.57	+0.57
	Composition	(3.73)***	(3.76)***	(3.33)**	(3.37)***
Dummy variables					
DODC	Developing country dummy	-5.58	-5.37	-5.20	-5.02
		(5.06)***	(5.01)***	(3.58)***	(3.56)***
DNIC	Newly industrialized country dummy	-0.67	-0.67	-0.58	-0.59
		(2.96)***	(3.29)**	(1.76)*	(1.89)**
*DODC*DMS*	Interaction term of *DC* and *DMS*	+1.27	+1.23	+1.20	+1.67
		(5.11)***	(5.06)***	(3.73)***	(3.72)***
CRIS	Financial crisis dummy	-0.68	-0.68	-0.65	-0.66
		(2.36)**	(2.40) **	(2.38)**	(2.33)**
DIRL	Ireland dummy	-0.62	-0.55	-0.67	-0.64
		(1.33)*	(1.22)*	(0.84)	(0.83)
DCHN	China dummy	-0.83	-0.76	0.90	-0.88
		(1.67)**	(1.62)**	(1.30)	(1.14)
	R-sq: Overall	0.69	0.68	0.69	0.68
	Within	NA	NA	0.30	0.30
	Between	NA	NA	0.82	0.82
	F	21.58			
	Wald test, X^2	170.73**	325.52***	238.78***	238.68***
	Observations (N)	210	210	210	210
	Number of groups	42	42	42	42
	B-P test, chi(1)[2]	NA	NA	14.22	14.89

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Notes: 1 All variables (except ODC, NIC TINS and IPR) are in logarithms. The *t*-ratios based on heteroscadasticity adjusted (cluster robust) standard errors are given in brackets, with statistical significance (one-tailed test) denoted as: *** 1 per cent, ** 5 per cent; and * 10 per cent. NA: Not applicable.

2. The Breusch-Pagan Lagrangian multiplier test of random effects. The null hypothesis of random effects is rejected at the one percent level.

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