# Multinational Enterprises and Globalization of R&D: A Study of U.S-based Firms

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*Abstract*: This paper examines patterns and determinants of overseas R&D expenditure of US-based manufacturing MNEs using a new panel dataset over the period 1990-2001. It is found that inter-country differences in R&D intensity of operation of US MNE affiliates are fundamentally determined by the domestic market size, overall R&D capability and cost of hiring R&D personnel. The impact of domestic market orientation of affiliates on R&D propensity varies among countries depending on their stage of global economic integration. Intellectual property protection seems to matter largely for mature economies with complementary endowments. 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. Nor is there a statistically significant relationship between the size of the capital stock of MNEs and R&D intensity of their operation across countries. Overall, our findings serve as a caution against paying too much attention by host country governments on turning MNEs affiliates into technology creators as part of their foreign direct investment policy.

*Key words*: R&D, multinational enterprises, foreign direct investment
*JEL Codes*: F21, O19, O31, O32

# Multinational Enterprises and the Globalization of R&D: A Study of U.S-based Firms[*]

## 1. Introduction

Multinational enterprises (MNEs) play a pivotal role in the generation of technology and its transmission across countries. The potential contribution of MNE affiliates to indigenous 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 methods by which an MNE affiliate provides technology to host countries - importing technology produced elsewhere within global operational network of the MNE (technology transmission) and developing new technology locally though R&D (technology generation). The host-country governments generally attach much greater importance to technology generation over technology transmission, in the hope that R&D activities undertaken within the national boundaries may have important externalities that lay the foundation of national scientific and technology activity. This expectation reflects in strong competition among countries to attract R&D-intensive FDI through investment promotion campaigns and by offering generous R&D-related tax concessions and high-quality infrastructure at subsidised prices.

In spite of this policy emphasis, there are no systematic, up-to-date empirical analyses of the determinants of international location of R&D activity by MNEs and the role of government policy in influencing the process to their national advantage. The few available

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empirical studies on this subject are not only much dated, but also, based as they were on data for a single or a few intermittent years, have failed to account for the inherent dynamics of the phenomenon under study.[1] This paper aims to fill this gap by examining patterns and determinants of the international location of R&D activity by foreign affiliates of US-based MNEs using a rich new panel data set for the period 1990-2001. To the best of our knowledge, ours is the first analysis of the patterns and determinants of R&D activity of US-based MNEs using data spanning the entire decade of the 1990s, a period characterized by significant changes in international production. 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.

The paper is organised 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 and data for 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.

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[1] Most of the existing econometric analyses of overseas R&D of MNEs have specifically focused on change in propensity to locate R&D overseas at the industry or firm level, ignoring the geographic dimension. (For surveys of this literature see Caves 1996, Golberman 1997 and Kumar 2001). So far, three studies have examined inter-country distribution of overseas R&D activities of US MNEs using data compiled from the *Benchmark Survey of US Direct Investment Abroad* conducted by the US Bureau of Economic Analysis. These are, Kumar 1996 (based on pooled country-level 1977, 1982, 1989), Kumar 2001 (pooled country level data for 1982, 1989, and 1994), and Hines 1995 (country-level data for 1989). Similar studies for other countries are, Kumar 2001 (Japanese MNEs, pooled country- and industry-level data for 1982, 1989 and 1994), Odagiri and Yasuda 1996 (Japanese MNEs, firm-level data for 1990), Zejan 1990 (Swedish MNEs, country and firm-level data 1978), and Fors 1998 (Swedish MNEs, pooled industry- and firm-level data for 1978 and 1990).

## 2. Theoretical Framework

The R&D location decision of the MNE is governed by both 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 1996, 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 product design, marketing and other related key functions. There is also the need of better motivation of R&D efforts towards objectives set by the top management. Because of these reasons, dispersion of resources for executing parallel projects at plant level could be wasteful and reduce productivity of the overall R&D effort of the MNE (Barba Navareti and Venables 2004, pp. 25-26).

The above factors are generally expected to have a domineering impact on the MNE's decision to keep R&D fundamentally a headquarter function. However, two 'centrifugal' forces necessitating 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 with 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 (Serapio and Dalton 1999, 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 1996, Ch. 6; Dunning 1994, 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. Thus, the compositional difference between headquarter R&D operations and overseas R&D operations of MNEs is likely to have narrowed overtime with the new emphasis on knowledge-seeking overseas R&D.

Even if there are compelling reasons to decentralize R&D globally, the MNE's decision to undertake R&D in a given host country also 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. 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).

## 3. Trends and Patterns of R&D Internationalization

Data on R&D expenditure of US majority-owned multinational enterprises are set out in Table 1. The dollar value of overseas R&D activities of US MNEs increased rapidly from almost US$ 600 million in 1966 to around US$ 10 billion in 1990 and to over US$ 20 billion in 2001. 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. In spite of rapid globalization of MNE operations in the 1990s, the conventional wisdom about the dominant role played by *centripetal factors* in the MNE R&D decision (Section 2) still seems to hold.

How does the degree of internationalisation 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 (Globerman 1997, p. 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, p. 161).

Manufacturing accounts for the lion share (over four fifths) of both total and overseas R&D expenditure of US MNEs (Table 1). However, 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 over 90 per cent in 2001), in contrast to a persistent decline in this share in total overseas R&D expenditure (from 88 per cent 83 percent) during this period. 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.

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 brought together with data on the percentage distribution of the total capital stock and sales.

The developed countries have remained 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 by the dawn of the new millennium. 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 end of the decade. The R&D share of Canada has remained virtually unchanged at 10 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 1999-2001, developed countries accounted for 87 per cent of total overseas R&D expenditure, compared to a share of 73 per cent in total FDI stock and 76 per cent in total sales turnover. By contrast, developing countries accounted for 26 per cent of FDI stock and 24 per cent of total sales turnover, but their share in total R&D expenditure stood at 13 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 (1.70 per cent in 1999-01) is more than double that of developing countries (0.8 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 1.1 per cent respectively) compared to countries in Latin America (0.4 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 of 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-sale ratio of MNE affiliates in China increased from a mere 0.4 per cent in the early 1990s to over 2.0 per cent in 1999-2001, a figure comparable to that of many developed countries. R&D intensity of MNE affiliates in Korea, Singapore and Taiwan has also increased over the years, approaching the average developed-country level. Malaysia and the Philippines have also recorded some notable increases, but they still lag behind the four NIC. Among the other developing countries, R&D-sales ratios of China, India and Brazil are notably high (notwithstanding some decline in the Indian ratio between 1990-02 and 1999-01), 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 1990-2000. 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 US MNEs is small, US MNE affiliates accounts 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 host developing country R&D expenditure for the period 1990-99 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.

## 4. Determinants of R&D Intensity: The Model and Data

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 more formal examination of what forces shape inter-country differences in R&D intensity. The analysis is based on a panel data set for 42 countries constructed at three-year frequency over the period 1990-2001. In this section, we first focus on model formulation, followed by a brief discussion on the data before presenting the results.

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 Section 2. They are discussed below under four main categories.

*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 hypothesised between *GDP* and *RDS* intensity simply because 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, P. 94). Here 'search' refers to acts performed in identifying potential exchange patterns and these acts become more important 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 a '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 1999). Fore these reasons, we assume a positive relationship between *DIST* and *RDS* intensity.

At first blush, R&D activities of affiliates should depend positively on the extent to which the home market is served by their 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 less than the technological gap between the latter and the parent company.

*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 total R&D expenditure net of R&D expenditure in agriculture, defence and various tertiary-sector activities. The latter components are deducted because they are not directly related to innovatory activities of private agents. The number of patents taken out in the US is a good proxy for innovative activities of a country because 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 standardised 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, pp. 8-9).

*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 taxes on royalties payment for imported technology are tax deductible in the host country (Hines 1995). 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 innovators will not fully exploit their capabilities, even when the other preconditions are met, unless they can appropriate returns to their innovations (Maskus 1998 and 2000).

*Other variables*

As discussed, R&D intensity in a given country is potentially influenced by the nature of industry mix because the production processes of some industries are 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. Unfortunately, it is not possible because 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', *RPI*) as an additional control variable.[2] The proposed index is defined by the formula

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

where, $\alpha_i$ 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. Since the index is intended to compare only patterns of output across countries, it should not be influenced by 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

[2] We are grateful to Kyoji Fukao for suggesting this index.

the output composition of MNE affiliates operation in the 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 the 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 reason 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*) to capture possible differences in the degree of R&D intensity associated with the stage of development (with DICs as the controlled group).[3] *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.

Time dummy variables (*TIME*) are included to capture time-specific fixed effects, with the first sub-period (1990-92) as the base dummy. Finally, 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 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.

[3] 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.

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

$$RDS_{it} = \alpha + \beta_1 GDP_{it} + \beta_2 DMS_{it} + \beta_3 DIST_i + \beta_4 TECH_{it} + \beta_5 RDPN_{it}$$
$$+ \beta_6 TPWG_{it} + \beta_7 TINS_{it} + \beta_8 IRR_{it} + \beta_{13} KUSF_{it} + \beta_9 RBI_{it}$$
$$+ \theta_1 DNIC_{\mathrm{i}} + \theta_2 DODC_i + \theta_3 CRIS_i + \Upsilon TIME_t + \mu$$

Where, *RDS* is research and development intensity (Research and Development expenditure as a percentage of sales turnover), and subscripts *i* and *t* denote countries and time 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) |
| *RPI* (+) | 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 |
| *CRIS*(?) | Financial crisis dummy (for 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 |
| α | A constant term, |
| μ | A stochastic error term, representing other omitted influences. |

*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 relates to majority-owned, non-bank affiliates of US-headquartered corporations, as tracked by the BEA. The BEA started reporting data on R&D on an annual basis with effect from 1990 and the latest year for with data was available was 2001.[4] Therefore, our data set covers the twelve-year period from 1990 to 2001. 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 years consecutive years within the period 1990-2001.[5] By doing so, were able to construct a panel data set arranged at three-year intervals[6] for 42 countries (See Appendix). The use of three-year averages 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 are reported in the Appendix.

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[4] For details on this database see Hansen et al. (2001), Appendix.

[5] In cases where the reported amount is greater than zero but less than $500,000, we set the level of investment at $250,000.

[6] That is, an observation is a country's performance average over a three-year period, yielding four observations (averages for 1990-92, 1993-95, 1996-98 and 1999-2001) 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 168 observations on R&D only 17 observations have been 'approximated' in this way.

## 5. Determinants of R&D Intensity: Regression Results

We used the random effect estimator as our preferred estimation technique. The alternative fixed effect estimator is not appropriate because our model contains a number of time-invariant variables (DIST, IPR, TINS, DODC, DNIC) which are central to our analysis. A major limitation of the random effect estimator compared to its fixed effect counterpart is that it can yield inconsistent and biased estimates if the unobserved fixed effects arecorrelated with the remaining component of the error term. However, this is unlikely to be a serious problem in our case the number of because N (the number of explanatory variables) is larger than T (the number of 'within' observations) (Wooldrige 2002, Chapter 10). The random effect estimator also has the added advantage of taking caring of the serial correlation problem.

The results are reported in Table 5. Summary statistics for the data used in the estimation are presented in Table 6 to facilitate interpretation of the results. All variables, other than the two ordered qualitative variables (IPR and TINS) and the dummy variables, have been used in natural logarithms in estimation. In experimental runs, we interacted the two country group dummies, *DNIC* and *DODC*, with other explanatory variables 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 two interaction terms — *DODC**DMS* and (*DODC*+ *DNIC*)**IPR* — turned out to be statistically significant.[7] The estimate of the full model is reported as Equation 1. In this Equation, the coefficients on two variables (*KUSF* and *TINS*) are statistically insignificant (with t-ratios of less than 1) with the unexpected (negative) sign. The final equation estimated after deleting these variables (our 'preferred model') is reported as Equation 2.[8]

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[7] As we will discuss below, this is much in line with our expectations (as discussed under model specification).

[8] This specification choice is amply supported by the standard variable deletion (F) test; the joint test for zero restriction on the coefficients of the four variables yielded, $F(4, 152) = 1.097$.

Since there was some evidence of heteroscadasticity, t-ratios of regression coefficients were computed from standard errors estimated using the White's heteroscadasticity consistent covariance matrix estimator (White, 1980). An examination of the squired multiple correction coefficient of each explanatory variable on the other explanatory variables (last column, Table 6) suggests that multicollinearity does not cause problems in interpreting the individual regression coefficients. For all explanatory variables except *TECH*, the squired multiple correction coefficient is smaller in magnitude compared to the $R^2$ of the parent regressions. The relatively high intercorrelation of *TECH* does not seem to cause problem because that variable has ample variability (a coefficient variation of over 2.86, the highest among all explanatory variables) (Goldberger 1991, Chapter 23).

For the purpose of comparison, OLS estimates of the two equations are reported in Appendix Table A-3. Also reported in the table are the random-effects and fixed-effect estimates obtained after deleting the time invariant explanatory variables. The random effects (Table 5) and OLS estimates (Table A-3) are remarkably similar, suggesting that unobserved effects are relatively unimportant in our model. Fixed effects and random effects estimates of the model after deleting the time invariant parameters are also closely comparable. However, the hypothesis that the fixed-effects estimator in better than the random effects estimator is rejected by the Hausman test (Hausman 1978). The following discussion focuses solely on the results reported in table 5.

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 0.48 per cent increase in *RDS* among other developing countries (that is, developing countries excluding NICs). As already noted, 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. The NICs, given their heavy export orientation, seems to exhibit a similar relationship between these two variables. By contrast, given some peculiarities in domestic demand patterns and presumably also because of remaining barriers to integrate in the global economy, there seems to be some need for undertaking product adaptation-type R&D in ODCs. In sum, the link between the nature of market orientation and R&D intensity varies across countries, depending on the stage of development and global market integration of the countries under study.

There is strong statistical support for the hypothesis that R&D intensity of domestic manufacturing in the host country is a strong attraction for MNEs to undertake R&D activities in those countries. The coefficient on *TECH* is significant at the one per cent level. It suggests that one per cent increase in the national technology effort is associated with 0.15 per cent increase in R&D intensity of MNE affiliates.

Among the variables included to capture the domestic investment climate, the coefficient on *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 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.

*IPR* has a statistically significant (at the ten per cent level) coefficient with the expected positive sign, but its interaction term with developing countries yield a negative coefficient of virtually the same magnitude. This finding is consistent with the view that international property protection is a positive tool for promoting R&D activities only in countries with appropriate complementary endowments and policies ( Maskus 2002).

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.[9] 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 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.

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, total foreign direct investment and R&D activities does seem to go hand in hand.

The coefficient on *RPI* is statistically significant with the expected (positive) sign, supporting the hypothesis that the industry composition does matter in explaining inter-

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[9] 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.

country differences in the degree of R&D intensity of MNE affiliates. We also re-estimated Equation 2 (our preferred equation) after deleting *RPI* and found that individual regression coefficients attached to the other variables are remarkably resilient to its inclusion/exclusion.[10] At the same time, the deletion of RPI from Equation 2 was not supported by the standard variable deletion *F*-test.[11] 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.

Finally, how do our findings compare with those of the previous studies? Our results confirm the finds of Kumar (1996 and 2001) 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, 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. For developed countries and NICs in Asia, the relationship is negative, implying that greater export-orientation is associated with more, rather than less, R&D intensity. The relationship depends very much on the stage of development of a given country. 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. Unlike Kumar (1996 and 2001) we find some statistical support for the view that intellectual property protection can play a positive role in promoting innovatory activities, depending of course on the presence of appropriate complementary endowments and policies.

Our results on the impact of tax incentives on R&D activities run counter to that of Hines (1995) and Hines and Jaffe (2001) relating to US-based MNEs and Bloom and Griffith (2001) relating to UK-based MNEs. These 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 the failure to appropriately control for relevant

[10] This alternative estimate is available from the authors on request.
[11] The test for zero restriction on the coefficients of RPI performed on Equation 2 is, $F(1, 151) = 8.37$, which is significant at the one percent level.

explanatory variables may have biased the results of these studies against the null hypothesis of their experiments. Both studies have controlled for only one relevant variable (Hines: R&D intensity of the host country; Bloom and Griffith: domestic real output) in testing the link between internationalisation 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:[12]

$$R\&D = -1.27 \quad + 0.20TECH \quad + 0.18TINS$$
$$(4.84)^{**} \quad (7.56)^{***} \quad (2.49)^{**}$$
$$\overline{R}^2 = 0.47 \quad F = 75.00$$

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

$$R\&D = -5.32 \quad + 0.28GDP \quad + 0.39TINS$$
$$(9.19)^{***} \quad (5.44)^{***} \quad (5.90)^{**}$$
$$\overline{R}^2 = 0.39 \quad F = 55.85$$

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 (Equation 1 in Table 5).[13]

## 5. 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 1990-2001. It is found that

[12] The following two equations are OLS estimates.

[13] The results of the variable deletion (F) test for the two equations are F (16,147) = 7.02 and F (16,147) = 12.71 respectively.

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 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 serve as a caution against governments paying too much attention on turning MNEs affiliates into technology creators 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 as to where R&D is performed may tend to downplay the more important role of MNEs as a conduit of technology transfer. Even if MNE affiliates generate little or no technology locally, they can still play an important role in improving local innovative capabilities through technology transfer.

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**Table 1: R&D Internationalization of US MNEs during 1966-2001**

| | All sectors | | | Manufacturing | | | Manufacturing share (%) | |
|---|---|---|---|---|---|---|---|---|
| | Total | Foreign affiliates | | Total | Foreign affiliates | | Total | Foreign affiliates |
| | $ bn | $ bn | % | $ bn | $ bn | % | | |
| 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 | 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 | 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 | 151.3 | 19.8 | 13.1 | 125.0 | 17.8 | 14.3 | 82.6 | 90.2 |
| 2001 | 162.7 | 19.7 | 12.1 | 132.5 | 17.4 | 13.1 | 81.4 | 88.2 |

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, 1990-2001**

| | All Countries | | Developed Countries[1] | | NICs[2] | | Other Developing Countries | |
|---|---|---|---|---|---|---|---|---|
| | 1990-92 | 1999-01 | 1990-92 | 1999-01 | 1990-92 | 1999-01 | 1990-92 | 1999-01 |
| All Industries | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Petroleum | 2.7 | 1.7 | 0.3 | 5.8 | 0.5 | 25.9 | 1.5 | 7.9 |
| Manufacturing | 84.5 | 89.6 | 83.1 | 87.6 | 89.6 | 72.8 | 95.5 | 88.4 |
| Food products | 2.2 | 1.7 | 1.8 | 1.5 | 0.0 | 0.1 | 6.5 | 4.3 |
| Chemical products | 23.4 | 22.7 | 24.1 | 23.2 | 3.3 | 2.5 | 29.0 | 15.5 |
| Primary and fabricated metals | 1.0 | 0.8 | 1.0 | 1.0 | 0.0 | 0.1 | 1.1 | 0.4 |
| Industrial machinery and equipment | 18.4 | 3.9 | 15.2 | 4.5 | 11.0 | 1.2 | 5.4 | 3.8 |
| Electronics | 7.3 | 26.4 | 4.8 | 20.7 | 11.0 | 64.5 | 5.5 | 8.7 |
| Automotives | 22.7 | 28.0 | 19.4 | 29.0 | 0.0 | 0.3 | 4.0 | 15.0 |
| Other manufacturing | 9.4 | 6.0 | 6.2 | 7.7 | 1.8 | 4.1 | 13.8 | 40.6 |
| Wholesale trade | 6.3 | 3.1 | 5.4 | 2.5 | 3.3 | 0.6 | 4.2 | 1.9 |
| Finance insurance and real estate | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 |
| Services | 6.2 | 5.2 | 6.1 | 4.0 | 6.9 | 0.5 | 0.7 | 1.4 |
| Other industries | 0.3 | 0.3 | 0.1 | 0.1 | 0.0 | 0.1 | 1.2 | 0.4 |
| Total Expenditure ($mil) | 10,222 | 19,201 | 9,528 | 14,971 | 245 | 1,122 | 295 | 1,096 |

*Notes*:

1. OECD Europe, North America, Japan, Australia and New Zealand.
2. Hong Kong, Korea Republic, Singapore, and Taiwan
3. Twenty-our countries for with data are available (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 Ration by Country/Region (%)**

| | FDI Stock | | Sales | | R&D Expenditure | | R&D-Sales ratio | |
|---|---|---|---|---|---|---|---|---|
| | 1990-92 | 1999-01 | 1990-92 | 1999-01 | 1990-92 | 1999-01 | 1990-92 | 1999-01 |
| | | | | | | | | |
| Developed Countries | 84.09 | 73.19 | 84.95 | 76.16 | 94.22 | 87.23 | 1.61 | 1.70 |
| Europe | 57.74 | 48.14 | 61.43 | 53.49 | 76.86 | 66.63 | 1.82 | 1.81 |
| Austria | 0.49 | 0.66 | 0.46 | 0.55 | 0.10 | 0.49 | 0.30 | 1.32 |
| Belgium | 3.36 | 2.72 | 3.26 | 2.58 | 3.83 | 1.79 | 1.71 | 1.03 |
| Denmark | 0.27 | 0.35 | 0.26 | 0.28 | 0.16 | 0.35 | 0.91 | 1.87 |
| Finland | 0.09 | 0.22 | 0.08 | 0.23 | 0.01 | 0.42 | 0.21 | 2.75 |
| France | 7.55 | 5.23 | 7.88 | 6.41 | 8.48 | 8.22 | 1.56 | 1.91 |
| Germany | 15.47 | 9.20 | 16.31 | 10.94 | 28.74 | 18.91 | 2.56 | 2.57 |
| Greece | 0.09 | 0.09 | 0.11 | 0.14 | 0.02 | 0.04 | 0.30 | 0.45 |
| Ireland | 1.51 | 3.03 | 1.94 | 4.21 | 6.92 | 1.90 | 5.18 | 0.67 |
| Italy | 4.20 | 3.10 | 4.96 | 3.85 | 3.85 | 2.90 | 1.13 | 1.12 |
| Netherlands | 4.50 | 3.45 | 5.05 | 4.06 | 3.71 | 2.13 | 1.07 | 0.78 |
| Norway | 0.06 | 0.23 | 0.08 | 0.48 | 0.04 | 0.09 | 0.73 | 0.29 |
| Portugal | 0.24 | 0.24 | 0.30 | 0.34 | 0.06 | 0.09 | 0.30 | 0.41 |
| Spain | 3.48 | 2.48 | 3.82 | 2.86 | 1.88 | 1.03 | 0.72 | 0.54 |
| Sweden | 0.51 | 1.22 | 0.70 | 1.77 | 1.08 | 6.10 | 2.25 | 5.13 |
| Switzerland | 0.94 | 0.60 | 0.81 | 0.96 | 0.70 | 0.87 | 1.26 | 1.34 |
| United Kingdom | 14.73 | 14.63 | 15.26 | 13.44 | 17.03 | 19.36 | 1.62 | 2.14 |
| Canada | 17.79 | 17.11 | 16.04 | 15.50 | 10.31 | 10.85 | 0.93 | 1.04 |
| Japan | 4.65 | 4.32 | 4.40 | 4.78 | 5.27 | 8.03 | 1.74 | 2.50 |
| Australia | 3.78 | 3.08 | 2.93 | 2.13 | 1.75 | 1.66 | 0.87 | 1.16 |
| New Zealand | 0.13 | 0.54 | 0.16 | 0.26 | 0.03 | 0.05 | 0.32 | 0.29 |
| Israel | 0.24 | 0.69 | 0.15 | 0.37 | 0.23 | 1.92 | 2.26 | 7.69 |
| | | | | | | | | |
| Developing countries | 15.91 | 26.81 | 15.05 | 23.84 | 5.78 | 12.77 | 0.56 | 0.80 |
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Asian NICs | 2.76 | 5.37 | 3.88 | 6.01 | 2.54 | 5.63 | 0.95 | 1.39 |
| Hong Kong | 0.28 | 0.33 | 0.76 | 0.79 | 0.26 | 0.22 | 0.49 | 0.41 |
| Korea, Republic of | 0.61 | 1.16 | 0.35 | 0.69 | 0.09 | 0.73 | 0.35 | 1.59 |
| Singapore | 1.06 | 3.12 | 1.89 | 3.79 | 1.76 | 3.90 | 1.35 | 1.53 |
| Taiwan | 0.82 | 0.75 | 0.87 | 0.75 | 0.44 | 0.78 | 0.74 | 1.54 |
| Other Asia | 1.38 | 6.74 | 1.68 | 5.22 | 0.32 | 3.97 | 0.27 | 1.13 |
| China | 0.10 | 2.61 | 0.06 | 1.75 | 0.02 | 2.40 | 0.41 | 2.04 |
| Indonesia | 0.06 | 0.20 | 0.08 | 0.12 | 0.04 | 0.01 | 0.80 | 0.15 |
| Malaysia | 0.56 | 1.35 | 0.67 | 1.65 | 0.09 | 1.13 | 0.20 | 1.02 |
| Philippines | 0.29 | 0.67 | 0.36 | 0.53 | 0.09 | 0.24 | 0.34 | 0.66 |
| Thailand | 0.34 | 1.34 | 0.46 | 0.89 | 0.05 | 0.07 | 0.15 | 0.12 |
| India | 0.04 | 0.57 | 0.05 | 0.29 | 0.03 | 0.12 | 1.09 | 0.63 |
| Latin America | 11.45 | 14.07 | 9.08 | 11.88 | 2.72 | 3.01 | 0.43 | 0.38 |
| Argentina | 0.64 | 1.53 | 0.62 | 1.13 | 0.15 | 0.19 | 0.36 | 0.25 |
| Brazil | 6.32 | 4.85 | 3.86 | 3.20 | 1.66 | 1.44 | 0.62 | 0.67 |
| Chile | 0.62 | 0.19 | 0.15 | 0.18 | 0.02 | 0.01 | 0.18 | 0.08 |
| Colombia | 0.21 | 0.27 | 0.30 | 0.26 | 0.05 | 0.04 | 0.22 | 0.24 |
| Ecuador | 0.05 | 0.05 | 0.04 | 0.05 | 0.01 | 0.00 | 0.21 | 0.08 |
| Mexico | 3.25 | 6.42 | 3.58 | 6.42 | 0.67 | 1.19 | 0.27 | 0.28 |
| Panama | 0.02 | 0.05 | 0.05 | 0.07 | 0.01 | 0.00 | 0.18 | 0.06 |
| Peru | 0.04 | 0.06 | 0.04 | 0.06 | 0.01 | 0.00 | 0.35 | 0.08 |
| Venezuela | 0.30 | 0.65 | 0.44 | 0.50 | 0.15 | 0.12 | 0.48 | 0.36 |
| South Africa | 0.14 | 0.31 | 0.25 | 0.45 | 0.14 | 0.11 | 0.79 | 0.37 |
| Turkey | 0.19 | 0.32 | 0.16 | 0.28 | 0.06 | 0.05 | 0.53 | 0.26 |
| All countries | 100 | 100 | 100 | 100 | 100 | 100 | 1.45 | 1.49 |
| (US$ billion) | (46.8) | (83.0) | (198.0) | (372.0) | (2.9) | (5.5) | | |

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 (1990-2000 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 |
| | | Asian NICs | 0.3 |
| Developed countries | 3.4 | Hong Kong | 0.1 |
| | | Korea, Republic of | 0.3 |
| Europe | 4.9 | Singapore | 11.4 |
| Austria | 1.2 | Taiwan | 1.4 |
| Belgium | 7.5 | Other Asia | 2.8 |
| Denmark | 1.1 | China | 16.2 |
| France | 3.2 | Indonesia | 3.9 |
| Germany | 5.5 | Malaysia | 21.9 |
| Greece | 0.6 | Thailand | 2.5 |
| Ireland | 43.8 | India | 0.3 |
| Italy | 3 | Philippines | 11.9 |
| Netherlands | 4.6 | Latin America | 4.1 |
| Norway | 0.3 | Argentina | 2.3 |
| Portugal | 3 | Brazil | 3.9 |
| Spain | 4.5 | Chile | 0.8 |
| Sweden | 3.6 | Colombia | 2.4 |
| Switzerland | 1.5 | Ecuador | 3.1 |
| United Kingdom | 8.7 | Egypt | 0.7 |
| Israel | 2.4 | Mexico | 10.6 |
| Canada | 12.1 | Panama | 2 |
| Japan | 0.6 | Peru | 34 |
| Australia | 4.1 | Venezuela | 6 |
| New Zealand | 1.4 | 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 GLS Estimates [*]**

| | | Equation 1 | Equation 3 | Equation 2 |
|---|---|---|---|---|
| α | Constant term | -5.34 (2.39)** | -1.90 (1.10) | -6.25 (3.05)*** |
| *GDP* | Real gross domestic product | +0.26 (3.07)*** | +0.28 (4.36)*** | +0.21 (3.01)*** |
| *DMS* | Domestic market share of total Sales | -0.73 (3.76)*** | -0.78 (4.51)*** | -0.64 (3.66)*** |
| *DIST* | Distance | +0.07 (0.46) | +0.06 (0..48) | +0.12 (0.88) |
| *TECH* | Technology index | +0.13 (1.65)** | +0.10 (1.25)* | +0.12 (1.52)* |
| *RDPN* | R&D personnel per million Population | +0.21 (2.01)** | +0.19 (1.97)** | +0.19 (1.96)** |
| *TPWG* | Wages of technical personnel | -0.50 (2.36)** | -0.43 (2.28)** | -0.45 (2.33)*** |
| *TINS* | Tax incentives for firm-level R&D | -0.12 (0.97) | | |
| *IPR* | Intellectual property protection | +0.18 (2.04)** | +0.13 (1.48)* | +0.18 (2.03)** |
| *KUSF* | Stock of fixed capital of US MNEs | -0.05 (0.73) | | |
| *RPI* | R&D potential of output Composition | +0.87 (4.08)*** | | +0.85 (4.01)** |
| Dummy variable | | | | |
| *DODC* | Developing country dummy | -3.24 (2.09)** | -3.89 (2.54)** | -3.30 (2.18)*** |
| *DNIC* | Newly industrialized country dummy | +.63 (0.79) | +0.44 (0.56) | +0.65 (0.83) |
| *DODC*DMS* | Interaction term of *DC* and *DMS* | +0.96 (3.01)*** | +1.08 (3.40)*** | +0.99 (3.16)*** |
| *(DODC+DNIC)*IPR* | Joint interaction term of ODC and NIC, and IPR | -0.19 (1.56)* | -0.15 (1.32)* | -0.20 (1.72)** |
| *CRIS* | Financial crisis dummy | -0.51 (2.17)** | -1.90 (1.10) | -0.52 (2.24)** |
| | *R-sq:* Overall<br>within<br>Between | 0.69<br>0.30<br>0.81 | 0.68<br>0.19<br>0.81 | 0.69<br>0.29<br>0.80 |
| | *Wald test*, $X^2$ | 179.06*** | 169.18*** | 183.56*** |
| | Observations | 168 | 168 | 168 |

*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.

*NORM* Jarque-Bera test for normality of the error term.

*RESET* Ramsey's regression specification error test

\# Null-hypothesis is not rejected at the 5 per cent level.

**Table 6: Summary Data on Variables Used in the Regression Analysis***

| | Maximum | Minimum | Mean | Std. Deviation | Coef. of Variation | $R^2$ |
|---|---|---|---|---|---|---|
| *R&D* | 2.04 | -2.75 | -0.41 | 0.96 | 2.35 | --- |
| *GDP* | 15.54 | 8.91 | 12.27 | 1.23 | 0.10 | 0.32 |
| *DMS* | 4.57 | 2.23 | 4.07 | 0.46 | 0.11 | 0.35 |
| *TECH* | 4.46 | -4.61 | 0.92 | 2.66 | 2.89 | 0.80 |
| *RDPN* | 8.65 | 3.61 | 6.73 | 1.35 | 0.20 | 0.69 |
| *DIST* | 9.70 | 6.61 | 8.92 | 0.58 | 0.06 | 0.05 |
| *TPWG* | 4.44 | 1.70 | 3.36 | 0.70 | 0.21 | 0.67 |
| *KUSF* | 12.35 | 5.70 | 8.76 | 1.45 | 0.16 | 0.31 |
| *RPI* | 4.07 | 1.38 | 2.99 | 0.61 | 0.20 | 0.14 |
| *IPR* | 8.68 | 1.61 | 5.76 | 1.76 | 0.31 | 0.56 |
| *TINS* | 5.63 | 1.68 | 3.69 | 0.96 | 0.26 | 0.47 |

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

$R^2$ Squired multiple correlation coefficient of each explanatory variable with respect to all other explanatory variables.
--- Not applicable

# 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 | 1990-2001 |
| *DMS* | Domestic market share of total sales | - do - | - do - |
| *CHEM* | Percentage of chemical products in total affiliate output | - do - | - do - |
| *RPI* | 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 | 1990-2001 |
| *TPWG* | Wages of technical personnel | U.S. Department of Commence, Bureau of Economic Analysis, *Benchmark Survey of US Investment Abroad* 1994. | 1996 (?) |
| *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*, | 2000 and 2001 (average) |
| *IPR* | Index of Intellectual property protection (ranges from 1 (least binding) to 10 (most stringent)) | World Economic Forum, *Global Competitiveness Report* | 1990-2001 |

**Table A-2**
**Country Coverage**

| Industrial Countries | Developing countries | |
|---|---|---|
| Europe | Asian NICs | South Africa |
| Austria | Hong Kong | Turkey |
| Belgium | Korea, Republic of | |
| Denmark | Singapore | |
| Finland | Taiwan | |
| France | Other Asia | |
| Germany | China | |
| Greece | Indonesia | |
| Ireland | Malaysia | |
| Italy | Philippines | |
| Netherlands | Thailand | |
| Norway | India | |
| Portugal | Latin America | |
| Spain | Argentina | |
| Sweden | Brazil | |
| Switzerland | Chile | |
| United Kingdom | Colombia | |
| Canada | Ecuador | |
| Japan | Mexico | |
| Australia | Panama | |
| New Zealand | Peru | |
| Israel | Venezuela | |

**Table A-3: Determinants of R&D Intensity: Alternative Regression Results[1]**

| | | OLS | OLS | Fixed effects[2] | Random effects[2] |
|---|---|---|---|---|---|
| | | Equation 1 | Equation 2 | Equation 3 | Equation 4 |
| α | Constant term | -3.98 (2.30)** | -4.65 (2.90)*** | -10.95 (7.26)*** | -7.80 (5.61)*** |
| *GDP* | Real gross domestic product | +0.26 (3.71)*** | +0.22 (4.67)*** | 0.33 (2.56)** | +0.21 (2.60)*** |
| *DMS* | Domestic market share of total Sales | -0.74 (3.86)*** | -0.66 (3.69)*** | -0.69 (2.33)** | -0.48 (2.84)*** |
| *DIST* | Distance | +0.08 (1.08) | +0.12 (1.85)** | | |
| *TECH* | Technology index | +0.16 (2.15)** | +0.15 (1.96)** | | |
| *RDPN* | R&D personnel per million Population | +0.19 (1.90)** | +0.17 (2.19)** | +0.23 (1.34) | +0.24 (2.40)** |
| *TPWG* | Wages of technical personnel | -0.50 (3.04)*** | -0.47 (3.17)*** | | |
| *TINS* | Tax incentives for firm-level R&D | -0.08 (0.93) | | | |
| *IPR* | Intellectual property protection | +0.14 (1.58)* | +0.15 (1.77)** | +0.30 (2.51)** | +0.15 (2.54)** |
| *KUSF* | Stock of fixed capital of US MNEs | -0.04 (0.84) | | -0.02 (0.14) | -0.06 (0.99) |
| *RPI* | R&D potential of output Composition | +0.64 (2.62*** | +0.62 (2.56)** | +1.17 (5.02)*** | 1.01 (4.81)*** |
| Dummy variables | | | | | |
| *ODC* | Developing-country dummy | -4.12 (2.78)*** | -4.17 (2.92)*** | | |
| *NIC* | Newly industrialized country dummy | +.33 (0.50) | +0.33 (0.52) | | |
| *ODC*DMS* | Interaction term of *DC* and *DMS* | +1.12 (3.70)*** | +1.14 (4.70)*** | +0.70 (1.27) | +0.06 (0.88) |
| *(ODC+NIC)*IPR* | Joint interaction term of ODC and NIC, and IPR | -0.11 (1.37)* | -0.10 (1.40)* | -23 (1.41)* | -0.05 (1.48)* |
| *CRIS* | Financial crisis dummy | -0.53 (2.01)** | -0.55 (2.06)** | | |
| | *R-sq:* Overall<br>Within<br>Between | 0.66 | 0.67 | 0.10<br>0.29<br>0.08 | 0.60<br>0.27<br>0.70 |
| | *F-Statistic* | 19.33*** | 21.75*** | 4.29*** | 21.57*** |
| | *Wald,* $X^2$ | --- | --- | --- | 128.01*** |
| | *Observation* | 168 | 168 | 168 | 168 |

*Notes*:

1 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: *** 1 per cent, ** 5 per cent; and * 10 per cent. --- Not applicable.

2 The hypothesis that fixed effects estimator is better than the random effect estimator is rejected by the Hausman test (Hausman 1978) ($X^2$ (2,11) = 6.56)..