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Technology and Long-run Economic Growth in Asia

**The International Allocation of R&D Activity by US
Multinationals: The East Asian Experience in
Comparative Perspective**

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Abstract: This paper examines patterns and determinants of overseas R&D expenditure of MNEs, with emphasis on the East Asian experience, using a new panel dataset relating to US-based manufacturing MNEs 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.

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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 through 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 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.

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 1966, p 117).

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).

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, here are two ‘centrifugal’ forces that 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 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 Levinthal 1989, OECD 1994).

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 to the decentralization of R&D by MNEs, particularly those in R&D intensive industries such as pharmaceuticals, consumer chemicals, professional and scientific equipment and office equipment (Ronstadt 1997, Chap. 8; Pearce 1999; Fors and Sevansson 1994, Birkinshaw and Morrison 1995, Vernon 2000, pp. 13-20). 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 ecological 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 (Lal 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. 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, 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.

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 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 per cent) 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, the ratio of R&D expenditure to total sales. 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 GDP, geographic distance (measured by great circle distance between Washington DC and the capital city of the given host country), and domestic market orientation of MNE affiliates (measured by the percentage of domestic sales in total sales turnover of affiliates).

A positive relationship is hypothesised between real GDP and R&D 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. Distance 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. Distance 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). For these reasons, we assume a positive relationship between distance and R&D 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. 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 their 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 the ‘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 manpower 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 profitability 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 process 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, durable consumer goods tend to have more complex configurations than other goods, and we expect more R&D to be needed to modify or adapt them to local markets. Ideally, one should work with country-level data disaggregated by industry. Unfortunately, it is not possible because industry-level R&D data of the BEA are plagued by missing values (see below). As the second-best alternative, we

use output share of chemicals, and electronic and electrical industries (*CHEM and ELEC*) as control variables. There is case-study evidence that these two industries generally have the greatest degree of R&D intensity in global operations of MNEs (Belitz *et al.* 2000, Braunerhjelm 2000, Ronstadt 1977, Pearce 1989, Fors 1998). Products of these industries generally tend to have more complex configurations than other goods, necessitating more R&D effort to modify or adapt them to markets abroad. These are also industries characterised by rapid technological advances and thus induce knowledge-seeking overseas R&D effort by MNEs.

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 may 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*.

Ideally, we should have included country dummy variables to control for country-specific fixed effects. This, however, is not possible because of we have only four observations for each country. Instead, we consider three country groups – developed countries (mature industrial countries, ICs) defined to cover OECD Europe, North America, Japan, Australia and New Zealand; the newly industrialized countries in East Asia (NICs) (Hong Kong, Korea, Taiwan and Singapore); and other developing economies (ODCs) to capture fixed effects associated with the stage of development (with ICs as the controlled group).² These two country group dummies (NIE and ODC) will also be interacted with the other explanatory variables in alternative regression runs to test whether the hypothesized

² 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.

relationship between R&D intensity and each of these variables is sensitive to the stage of development of countries.

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

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

$$\begin{aligned}
 R\&D_{it} = \alpha + \beta_1 GDP_{it} + \beta_2 DMS_{it} + \beta_3 DIST_i + \beta_4 TECH_{it} + \beta_5 RDPN_{it} \\
 &+ \beta_6 TPWG_{it} + \beta_7 TINS_{it} + \beta_8 IRR_{it} + \beta_{13} KUSF + \beta_9 CHEM_{it} + \beta_{10} ELEC_{it} \\
 &+ \theta_1 NIC_i + \theta_2 ODC_i + \theta_3 CRIS_i + \gamma TIME_t + \mu
 \end{aligned}$$

Where, R&D 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
$DMS (- \text{ or } +)$	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)

<i>CHEM</i> (+)	Share of chemical products in total affiliate output
<i>ELEC</i> (+)	Share of electrical and electronic goods in total affiliate output
<i>ODC</i>	Dummy variable for developing countries other than NICs
<i>NIC</i>	Dummy variable for newly industrialized countries in East Asia
<i>CRIS</i>	Financial crisis dummy (for Thailand, Indonesia, Malaysia and the Philippines)
<i>TIME</i>	A vector of time dummy variables (which takes unity in the specific time period and zero otherwise) to capture time-specific ‘fixed’ effects
α	A constant term,
μ	A stochastic error term, representing the omitted other influences on bilateral trade.

Data

The data on the dependent variable and four explanatory variables (*DMS*, *CHEM*, *ELEC*, *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.³ The data relates to majority-owned, non-bank affiliates of US-headquartered corporations, as tracked by the US Bureau of Economic Analysis (BEA). The BEA started reporting data on R&D on an annual basis with effect from 1990 and the latest year for which data was available was 2001. Therefore, our data set covers a 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 standard industry classification) for those countries in which there are sufficient number of US firms with sizable activities. It is not possible however to construct 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,

³ For details on this database see Hansen et al. (2001), Appendix.

with a view to achieving a minimum time series dimension and a reasonable country coverage, we limited the sample coverage only to those countries for which there are no missing values for more than two years consecutive years (1990-92, 1993-95, 1996-98 and 1999-2001) within the period 1990-2001.⁴ By doing so we were able to construct a pooled time series data set arranged at three-year intervals⁵ 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.

5. Determinants of R&D Intensity: Regression Results

The model is estimated using ordinary least squares (OLS).⁶ All variables, other than the two ordered qualitative variables (IPR and TINS) and the dummy variables, are used in natural logarithms in estimation. 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.

In experimental runs, we interacted the two country group dummies, *NIC* and *ODC*, 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 three interaction terms — *ODC*DMS* and *ODC*ELEC*, *(ODC+ NIC)*IPR* — turned

⁴ In cases where the reported amount is greater than zero but less than \$500,000, we set the level of investment at \$250,000.

⁵ That is, each data point is a three-year average. 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.

⁶ It is not possible to use a fixed-effect estimator because some of the data series are time-invariant, either because of the nature of data availability or because the very nature of the data series (See Table A-2).

out to be statistically significant.⁷ The estimate of the complete model is reported as Equation 1 in Table 5. 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 Since there was some evidence of heteroscedasticity, t-ratios of regression coefficients have been computed from standard errors estimated using the White’s heteroscedasticity consistent covariance matrix estimator (White, 1980).⁹

The Equations pass the standard *F* test for the overall statistically significant, Ramsey’s regression specification error (RESE) test for functional form choice, and Jarque-Bera (JB) test for normality. An examination of the squared multiple correlation 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 squared multiple correlation coefficient is smaller in magnitude compared to the R^2 of the parent regressions (Equations 1 and 2 in Table 5). 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).

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. The coefficient on *DIST* is positive with a t-ratio above unity (but not statistically significant), providing mild statistical support for the

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, $F(4, 152) = 1.097$.

proposition that, notwithstanding the ‘death of distance’ in terms of communication, geographical distance still matters for the overseas R&D location decision of MNEs.

As we anticipated *a priori*, the result for *DMS* is mixed. For the entire country sample, its coefficient is negative, suggesting that greater domestic market orientation is *negatively* related with R&D intensity. However, the coefficient of *ODC* (developing countries other than NICs) is positive and statistically significant; suggesting that one percent increase in domestic market orientation is associated with 0.14 per cent increase in R&D among these countries. (As already noted, the interaction dummy for NICs (*NIC*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. The coefficient on *DIST* is positive as hypothesized, but not statistically significant. Thus, the evidence on the importance of distance in determining R&D intensity of MNE operation is at best inconclusive.

There is strong statistical support for the hypothesis that domestic R&D intensity of the host countries 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

⁹ The Breusch-Pagan test for heteroscedasticity: Equation 1: $\chi^2(19) = 18.5$; Equation 2: $\chi^2(17) = 18.2$

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 *CHEM* and *ELEC* indicate that industry composition of international production does matter in explaining R&D intensity of MNE affiliates in a given host country. One percent increase in the share of chemical products in the total product mix of affiliates is associated with 0.19 per cent increase in overall R&D intensity of their local operations. For all countries in the sample, the share of electrical and electronic goods in total production is positively associated with R&D intensity. However, for ODCs the relationship is perverse as we anticipated. The interaction term is not statistically significant for NIC, suggesting that they are not different from developed countries in terms of the nature of the relationship under study. This result presumably points to an important difference between ODCs, and developed countries and NICs in terms of the nature of MNE involvement in these industries.

In ODCs, MNE affiliates in these industries are engaged mostly in labour intensive components and final-good assembly activities (vertical specialisation) which predominantly involves the use of standard (diffused) technology. By contrast, in developed countries and NICs (particularly in the former) affiliates are engaged in activities involving considerable local technology development and adaptation ((Hanson et al. 2000). As already noted, these industries are the magnet for ‘knowledge seeking’ FDI in developed countries.

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.¹⁰ 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).

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.

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,

¹⁰ 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.

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), Hines and Jaffe (2001) and Bloom and Griffith (2001). By examining internationalisation of R&D activities of US-based and UK-based MNEs respectively, these authors have found that a statistically significant positive effect of tax incentives on the distribution of inventive activity between the home country and overseas locations of MNEs. Our findings are of course not strictly comparable with that of these studies because of the differences in the particular measure of tax incentives used and other methodological differences. However, we suspect that the failure to appropriately control for relevant 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:

$$R \& D = -1.27 + 0.20TECH + 0.18TINV$$

$$(4.84)** \quad (7.56)*** \quad (2.49)**$$

$$\bar{R}^2 = 0.47 \quad F = 75.00 \quad NORM = 1.98 \quad RESET = 7.93$$

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

$$R \& D = -5.32 + 0.28GDP + 0.39TINV$$

$$(9.19)^{***} \quad (5.44)^{***} \quad (5.90)^{**}$$

$$\bar{R}^2 = 0.39 \quad F = 55.85 \quad NORM = 3.44 \quad RESET = 1.12$$

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 6).¹¹

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 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 by and large for mature economies with complementary endowments.

¹¹ 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.

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
	\$ mn	\$ mn	%	\$ mn	\$ mn	%		
1966	8,976	590	6.6	8,124	526	6.5	90.5	89.2
1977	21,028	2,075	9.9	---	---	---	---	---
1982	60,171	3,851	6.4	---	---	---	---	---
1989	89,275	7,048	7.9	78,931	5,713	7.2	88.4	81.1
1990	74,823	10,187	13.6	64,440	8,468	13.1	86.1	83.1
1991	76,762	9,396	12.2	67,044	8,092	12.1	87.3	86.1
1992	83,191	11,084	13.3	73,366	9,345	12.7	88.2	84.3
1993	84,157	10,951	13	74,207	9,019	12.2	88.2	82.4
1994	103,205	12,097	11.7	90,587	10,147	11.2	87.8	83.9
1995	110,249	12,582	11.4	97,205	10,791	11.1	88.2	85.8
1996	114,590	14,039	12.3	102,178	12,205	11.9	89.2	86.9
1997	121,393	14,593	12.0	107,296	12,505	11.7	88.4	85.7
1998	128,441	14,664	11.4	113,589	12,819	11.3	88.4	87.4
1999	144,435	18,144	12.6	121,230	16,388	13.5	83.9	90.3
2000	151,334	19,758	13.1	125,011	17,822	14.3	82.6	90.2

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		NIEs ²		Other Developing Countries	
	1990-92	1999-2001	1990-92	1999-2001	1990-92	1999-2001	1990-92	1999-2001
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-four countries for which 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

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)		

Table 4: Percentage Share of R&D Expenditure of US MNE Affiliates in Total R&D Expenditure in Host Countries (1990-2000 annual 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: Regression Results*

		Equation 1	Equation 2
α	Constant term	-1.68 (1.19)	-2.45 (1.82)**
<i>GDP</i>	Real gross domestic product	+0.35 (4.66)***	+0.29 (5.65)***
<i>DMS</i>	Domestic market share of total sales	-0.79 (3.57)***	-0.69 (6.11)***
<i>DIST</i>	Distance	+0.02 (0.32)	+0.06 (1.14)
<i>TECH</i>	Technology index	+0.14 (1.94)**	+0.13 (1.75)**
<i>RDPN</i>	R&D personnel per million population	+0.19 (1.84)**	+0.17 (2.17)**
<i>TPWG</i>	Wages of technical personnel	-0.56 (3.16)***	-0.51 (3.36)***
<i>TINS</i>	Tax incentives for firm-level R&D	-0.08 (0.84)	
<i>IPR</i>	Intellectual property protection	+0.11 (1.50)*	+0.11 (1.38)*
<i>KUSF</i>	Stock of fixed capital of US MNEs	-0.05 (1.00)	
<i>CHEM</i>	Share of chemical products in total affiliate output	+ 0.15 (1.30)*	0.15 (1.36)*
<i>ELEC</i>	Share of electrical and electronic products in total affiliate output	+ 0.12 (2.02)**	+0.13 (1.56)*
Dummy variable			
<i>ODC</i>	Developing-country dummy	-2.98 (1.76)**	-3.14 (1.91)**
<i>NIC</i>	Newly industrialized country dummy	-0.05 (0.072)	-0.05 (0.06)
<i>ODC*DMS</i>	Interaction term of <i>DC</i> and <i>DMS</i>	0.87 (2.44)**	0.91 (2.64)***
<i>(ODC+NIC)*IPR</i>	Joint interaction term of <i>ODC</i> and <i>NIC</i> , and <i>IPR</i>	-0.10 (1.10)	-0.11 (1.20)
<i>ODC*ELEC</i>	Interaction term of <i>ODC</i> and <i>ELEL</i>	-0.18 (2.02)**	-0.17 (1.84)**
<i>CRIS</i>	Financial crisis dummy	-0.64 (2.07)**	-0.67 (2.16)**
	\bar{R}^2	0.66	0.66
	<i>F-Statistic</i>	17.01***	18.86***
	<i>JB test, X²(2)</i>	0.84 [#]	0.75 [#]
	<i>RESE test, X²(1)</i>	3.04 [#]	2.23 [#]

Notes:

* All variables (except *ODC*, *NIC*, and *TINS* and *IPR*) are in logarithms. The *t*-ratios based on White's heteroscedasticity 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
<i>R&D</i>	2.04	-2.75	-0.41	0.96	2.35	---
<i>GDP</i>	15.54	8.91	12.27	1.23	0.1	0.32
<i>DMS</i>	4.57	2.23	4.07	0.46	0.11	0.35
<i>TECH</i>	4.46	-4.61	0.92	2.66	2.89	0.8
<i>RDPN</i>	8.65	3.61	6.73	1.35	0.2	0.69
<i>DIST</i>	9.7	6.61	8.92	0.58	0.06	0.05
<i>TPWG</i>	4.44	1.7	3.36	0.7	0.21	0.67
<i>KUSF</i>	12.35	5.7	8.76	1.45	0.16	0.31
<i>CHEM</i>	4.07	1.38	2.99	0.61	0.2	0.14
<i>ELEC</i>	4.41	-4.61	1.87	1.84	0.98	0.31
<i>IPR</i>	8.68	1.61	5.76	1.76	0.31	0.56
<i>TINS</i>	5.63	1.68	3.69	0.96	0.26	0.47

Notes:

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

R² Squared 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
<i>R&D</i>	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 (US BEA)	1990-2001
<i>DMS</i>	Domestic market share of total sales	- do -	- do -
<i>CHEM</i>	Percentage of chemical products in total affiliate output	- do -	- do -
<i>ELEC</i>	Percentage of electrical and electronic products in total affiliate output	- do -	- do -
<i>KUSF</i>	Stock of fixed capital of US MNEs (at the beginning of the 3-year period)	- do -	- do -
<i>GDP</i>	Real gross domestic product	World Development Indicator Database, world Bank	- do-
<i>DIST</i>	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	
<i>TECH</i>	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	Lal (2002)	Circa 1999
<i>RDPN</i>	R&D personnel per million population	UNESCO Statistical Yearbook, Geneva: United Nations	1990-2001
<i>TPWG</i>	Wages of technical personnel	US BEA, Benchmark Survey of US Investment Abroad, 1997	1996 (?)
<i>TINS</i>	Index of tax incentives for firm-level R&D (ranges from 1 (no incentives) to 7 (incentives most prevalent))	Global Competitiveness Report, World Economic Forum	2000 and 2001 (average)
<i>IPR</i>	Index of Intellectual property protection (ranges from 1 (least binding) to 10 (most stringent))	Global Competitiveness Report, World Economic Forum	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	