

MERIT-Infonomics Research Memorandum series

*The International dimension of
innovation*

Rajneesh Narula & Antonello Zanfei

2003-009



*MERIT – Maastricht Economic Research
Institute on Innovation and Technology*

PO Box 616
6200 MD Maastricht
The Netherlands
T: +31 43 3883875
F: +31 43 3884905

<http://meritbbs.unimaas.nl>
e-mail: secr-merit@merit.unimaas.nl

International Institute of Infonomics

c/o Maastricht University
PO Box 616
6200 MD Maastricht
The Netherlands
T: +31 43 388 3875
F: +31 45 388 4905

<http://www.infonomics.nl>
e-mail: secr@infonomics.nl

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Rajneesh Narula and Antonello Zanfei

Version May 7 2003

Forthcoming in, **Jan Fagerberg, David Mowery, and Richard R. Nelson (editors), *Handbook of Innovation*, Oxford University Press 2004.**

Abstract: This paper undertakes a brief evaluation of the trends in the internationalization of innovative activities. We provide a taxonomy of R&D internationalization strategies, and discuss the main relevant theoretical and empirical issues, before discussing the centripetal and centrifugal forces underlying the nature and evolution of cross border innovation. We address the issue of international technology partnering as a key strategy that is complementary to the internationalisation of innovative activities through internal means, before raising important policy dimensions that derive from these debates.

Keywords: R&D internationalization, globalisation, multinationals, alliances, technology policy

JEL codes: F23, O32

1. Introduction

Economic globalisation is generally accepted to imply the growing interdependence of locations and economic units across countries and regions. Technological change and the growing significance of multinational enterprises (MNEs) are often cited as the primary driving forces of this process, and in this paper we attempt to evaluate – albeit tentatively – the changing extent and significance of MNEs as conduits for cross-border knowledge flows. It is important to note that MNEs and foreign direct investment (FDI) are not the only vehicles through which innovation develops and diffuses across national borders (Archibugi and Michie 1995). Other modalities by which international knowledge flows occur include trade, licensing, international alliances and joint venturing, and cross- patenting activities.

However, to a great extent, the MNE plays a pivotal role in these other modalities, as it has come to dominate the generation, adoption and diffusion of technology. Indeed, the rapid growth of the MNE is regarded as one of the most significant indicators of globalisation (Narula 2003). Nonetheless, it is important to acknowledge that the internationalization of

R&D has occurred not just through the establishment of physical facilities that are part of existing MNE hierarchical organizations. There are other means by which technological spillovers can be acquired which represent ‘non-internal’ solutions, such as through strategic technology partnering (STP), or technology outsourcing. However, as this chapter will discuss, these non-internal R&D activities are often complementary to ‘internal’ overseas R&D activities, rather than a substitute for them.

This chapter will begin by undertaking a brief evaluation of the trends in the internationalization of innovative activities. Section 3 provides a taxonomy of R&D internationalization strategies, and discusses the main relevant theoretical and empirical issues. Section 4 presents a discussion on the centripetal and centrifugal forces underlying the nature and evolution of cross border innovation. Section 5 will address the issue of international technology partnering as a key strategy that is complementary to the internationalisation of innovative activities through internal means, while section 6 raises important policy dimensions that derive from these debates.

2. Trends in the internationalization of innovative activities.

The growth of international innovative activities to some extent reflects the growth and spread of the MNE and the importance of FDI since the Second World War. FDI stocks as a percentage of GDP¹ stood at 21.46% in 2001, up from just 6.79% in 1982 (Table 1). Furthermore, MNEs engage in considerable intra- and inter-firm trade, and (as Table 1 indicates) about a third of world trade is undertaken by MNEs. The contribution of MNEs to global production and commercialisation of goods and services appears to be even greater if one considers total sales of foreign affiliates, which have grown three times as fast as exports of foreign affiliates and even faster as compared to world trade. The primary source of outbound FDI continues to be the industrialised countries. About 88% of outward FDI stocks emanated from the developed countries in 2001. The EU as a block accounted for the largest share of outward FDI, with Netherlands, UK, France and Germany accounting for fully 41.3% of all outward FDI stock from the developed world. Around 68% of inward FDI is

¹ Strictly speaking, the two numbers are not comparable, because GDP is a flow figure. Nonetheless, it is generally accepted that FDI stock is a monotonic function of value added, so the change in this ratio gives a general idea of how the significance of FDI activities has changed.

directed towards Triad countries. Although there has been an increase in the share of inward FDI to developing countries, this increase is almost entirely due to a small group of developing countries which primarily includes the Asian NICs and China.

Table 1 about here

Some of the largest firms engaged in FDI are also key actors in the generation and diffusion of innovation. To illustrate, over a third of the top 100 MNEs listed by UNCTAD (2002) are active in the most R&D-intensive industries, such as electronics and electrical equipment, pharmaceuticals, chemicals. Furthermore, large MNEs play a dominant role in the innovative activities of their home countries and control or own a large part of the world's stock of advanced technologies. For instance, five US MNEs (General Motors, Ford Motors, IBM, Lucent Technologies and Hewlett-Packard) account for 20 per cent of the US R&D expenditure in the manufacturing sector (Science and Engineering indicators, 2000). Siemens, Bayer and Hoechst performed 18 per cent of the total manufacturing R&D expenditures in Germany in 1994 (Kumar, 1998). In 1997 three multinational companies (Shell, Glaxo Wellcome and Smithkline Beecham) accounted for more than the 30 per cent of the overall UK R&D investment in manufacturing (R&D Scoreboard DTI, 2000). These same MNEs undertake a growing share of their total production activities in host locations.

Table 2 about here

More generally, significant differences emerge when considering the relevance of international R&D across both host and home countries. As far as recipient countries are concerned, R&D expenditures represent varying shares of total R&D expenditures by all firms in industrialized and in developing areas (see table 2 for some details).

By country of origin, the internationalization of innovative activities reflects markedly different national propensities to organize R&D across borders. Cantwell (1995) suggests that countries such as Switzerland, UK and the Netherlands which have historically been home to large MNEs (and thus have always had a high level of international technological activity) have seen remarkable increases in international R&D especially after the Second World War. Another group includes countries (such as France and Germany) which have few large MNEs, and have seen a gradual increase in their international innovative activity over the last 80 years. A third group is characterised by countries whose technological activity is as much

internationalised today as it was in the early decades of the 20th century (having actually experienced a dip, only returning to their pre-war levels relatively recently). This group includes the large US MNEs which have a relatively low proportion of their R&D and patenting activity abroad; and Swedish MNEs, which have historically tended to seek technology internationally, and show much higher shares. See Table 3 for a historical perspective of internationalisation of innovative activities over the 1920-1990 period.

***Table 3 about here ***

In general, firms from EU countries have shown a higher tendency to adopt international research strategies relative to companies from US and Japan, as shown in Table 4. In the period 1969-95, the share of total patents of EU firms attributable to foreign affiliates grew from an already high 26.3% to 32.5% (with an acceleration in recent years). European firms tend to concentrate a considerable share of their international R&D activities in the US (over 50% on average, with German, British and Swiss firms showing the highest concentration of their foreign activities in the US). The foreign patenting activity of US firms also increased over the same period but remained below 10%². It is worth highlighting that although US foreign R&D activities are relatively low compared to EU firms, they are much larger than Japanese companies, who undertake approximately 1% of their patenting activity abroad (having declined from 2.1% at the beginning of the period).

Table 4 about here

Overall, the internationalisation of innovation has been increasing, with a few relevant exceptions (most notably Japan). Using USPTO data, Patel (1996) showed that firms of most nationalities within the Triad³ expanded the proportion of inventive activities executed abroad. The overall importance of R&D activities of foreign affiliates has been generally growing in most host economies over the 1990's, although with significant diversities across countries: it is especially high in the case of some countries (UK, Ireland, Spain, Hungary and Canada), and lowest in Japan, with other countries (including the US, France and Sweden) in

² Although the degree of R&D internationalisation of US firms is below average, it more than doubled between the mid 60's and the end of the 80's (Creamer 1976, Pearce 1990).

³ Except for those originating from Canada.

intermediate position. Broadly speaking, trends in R&D internationalization have suggested a increasing decentralization, that is by and large associated with the degree to which the firms are multinational and the extent of cross-border rationalisation of their value added activities (Dunning 1994).

It remains that innovation is not a highly globalised phenomenon, as most R&D and patenting activities are still largely concentrated in the MNEs' home countries, and in a few host countries. Indeed, only one firm out of the top 30 firms active in high tech industries as recorded by the World Investment Report in 2001 originates from the LDCs; and well over 90% of the R&D expenditures of most MNEs tends to be located within the Triad⁴. The international dispersion of innovative activity is intermediated by industry level effects (e.g., Lall 1979, Patel 1996), and there is considerable inertia in the internationalisation of R&D. That is, firms have not internationalised their innovative activity proportionally to the growth in their overall production activities (Patel and Pavitt 2000, Narula 2002a). A large proportion of even the most internationalised MNEs tend to concentrate their more 'strategic' activities, such as R&D and headquarters functions that tend to stay at home (Benito *et al* 2003). Thus, the R&D activities undertaken abroad are associated with adapting and modifying existing assets in response to demand conditions, and tend to demonstrate a low level of R&D intensity.

This relatively low – but increasing - degree of internationalisation is associated *inter alia* with the complex nature of systems of innovation, and the embeddedness of the MNE's activities in the home environment (see e.g., Narula 2002a), the need for internal cohesion within the MNE (Blanc and Sierra 1999, Zanfei 2000), and the high quality of local infrastructures and appropriability regimes that R&D activities tend to require (Dunning 1994, UNCTAD 2001).

3. Overseas innovative activities of MNEs: theoretical and empirical issues

The internationalisation of R&D is most often considered as a special case in the more general theories that explain the location of international production. R&D can be said to internationalise for broadly the same motives as traditional elements of the value added chain,

⁴ Even where MNEs do engage in R&D in developing countries (e.g., industries where demand considerations and regional variations are especially significant, such as food products and consumer goods), these tend to agglomerate in just a few locations such as China, India, Malaysia, Brazil, South Africa and the Asian NICs.

although not at the same rate, nor to the same extent. Two primary types of R&D activity have been identified in the economic literature.

First, firms internationalise their R&D because of the need to improve the way in which existing assets are utilised. That is, firms may seek to promote the use of their technological assets in conjunction with, or in response to, specific foreign locational conditions. This has been dubbed as asset-exploiting R&D (Dunning and Narula 1995) or home-base exploiting (HBE) activity (Kuemmerle 1996). Locational conditions may require some level of modification to the product or processes in order to make them more appropriate to local conditions, or in some cases, to create peripheral products. In such activities, the technological advantages of the firm primarily reflect those of the home country.

Countries with a higher involvement in foreign production also demonstrate a higher proclivity towards foreign-located R&D. The level of foreign R&D in any given host location is however also dependent on the kinds of value adding activity undertaken there. In general, the more embedded the foreign subsidiary, and the greater the intensity of the value-adding activity, the greater the amount of R&D activity in the host location. Such activities lead to a duplication of the MNE's home base activities, since the host location is acting as a substitute for activities it may have wished, *ceteris paribus*, to undertake at home (Zander 1999), but find that it can undertake these more efficiently elsewhere.

HBE strategies by and large correspond to how classic contributions in the economics of MNEs viewed the organization of innovative activities. Referring mainly to the US based multinationals, Vernon (1966), Kindleberger (1969), Stopford and Wells (1972) theorised a quasi-colonial relationship between the parent company and foreign subsidiaries, wherein the latter replicated the former's activities abroad, with strategic decisions - including R&D and innovation strategies - being rigidly centralised. In particular, Vernon emphasised that co-ordinating international innovative activities would be too costly, due to the difficulties of collecting and controlling relevant information across national borders. Host countries and foreign subsidiaries would then play a role almost exclusively in the adoption and diffusion of centrally created technology. This view was supported mainly by US economists and based on US evidence from the early post-war period, but it was very influential for the development of studies on the economics of MNEs and the internationalisation of firms in general.

The second broad classification is that of strategic asset-seeking activity (Dunning and Narula 1995) or home-base augmenting (HBA) activity (Kuemmerle 1996). In such kinds of

investments, firms aim to improve their existing assets, or to acquire (and internalise) or create completely new technological assets through foreign-located R&D facilities. The assumption in such cases is that the foreign location provides access to complementary location-specific advantages that are not as easily available in the home base. In many cases the location advantages sought are associated with the presence of other firms. The investing firm may seek to acquire access to the technological assets of other firms, either through spillovers (in which case the firm seeks benefits that derive from economies of agglomeration), by direct acquisition (through M&A), through R&D alliances, or by arms-length acquisition. HBA motives and technology sourcing have been partially incorporated in formal models of the FDI decision⁵.

Indeed, the increasing attention to HBA strategies in economics and international business literature goes hand in hand with the emergence of a new perspective on the role played by local contexts in the cross-border generation and diffusion of innovation. Considering local contexts more as sources of competencies and of technological opportunities, and less as constraints to the action of multinational enterprises, marks a fundamental departure from the conventional approach to international business. In his seminal contribution, Hedlund (1986 pp.20-21) probably caught the essence of this new way of theorising the role of local contexts: "The main idea is that the foundations of competitive advantage no longer reside in any one country, but in many. New ideas and products may come up in many different countries and later be exploited on a global scale". Later, Kogut (1989 p.388) expressed a similar, complementary view: "What is distinctive in the international context, besides larger market size, is the variance in country environments and the ability to profit through the system-wide management of this variance".

There are several reasons why such HBA R&D activities would be hard to achieve from the home base, and would then require localised access to foreign based knowledge. When the knowledge relevant for innovative activities is located in a certain geographical area and it is very "sticky", the R&D activity should take place at that site. Foreign affiliates engaged in HBA activities are attracted to these technological clusters in order to benefit from the external economies and knowledge spillovers generated by the concentration of production and innovation activities. Among the reasons for such sticky knowledge, the

⁵ Fosfuri and Motta (1999) and Siotis (1999) show that a technological laggard may choose to enter a foreign market by FDI because there are positive spillover effects associated with locational proximity to a technological leader in the foreign country. Where the beneficial knowledge spillover effect is sufficiently strong, Fosfuri and Motta show that it may even pay the laggard firm to run its foreign subsidiary at a loss to incorporate the benefits of advanced technology in all the markets in which it operates.

argument of the tacit nature of knowledge often stands out. The tacit nature of technology implies that even where knowledge is available through markets (technology markets generally tend to be under-developed or non-existent), it still needs to be modified to be efficiently integrated within the acquiring firm's portfolio of technologies. In addition, the tacit nature of knowledge associated with production and innovation activity in these sectors implies that "physical" or geographical proximity is important for transmitting it (Blanc and Sierra, 1999). While the marginal cost of transmitting codified knowledge across geographic space does not depend on distance, the marginal cost of transmitting tacit knowledge increases with distance. This leads to the clustering of innovation activities, in particular at the early stage of an industry life cycle where tacit knowledge plays an important role (Audretsch and Feldman, 1996).

The discussion on HBE vs. HBA activities thus bears important similarities to the debate on the local nature of technological spillovers in the economics literature (e.g., Jaffe *et al.*, 1993, Jaffe and Trajtenberg, 1996, 1998, Jaffe *et al.*, 1998). The issue here is whether or not knowledge spillovers between firms, or from (semi-) public knowledge institutes to firms, depend on geographical distance (on this issue see also Asheim's chapter in this book). If knowledge spillovers are indeed localized, one may expect that local knowledge bases tend to differ with regard to focus and quality. The only efficient way for a firm to tap into a local knowledge base would then be to be physically present in such a local environment, which is indeed what we have defined as HBA activities.

In general, HBE activities are primarily associated with demand-based activities, with the internalisation of technological spillovers as a secondary issue. HBA activities, on the other hand, while often reported as a much smaller phenomenon in terms of international R&D expenditure (Patel and Vega 1999, Gerybadze and Reger 1999, Niosi 1999), are primarily undertaken with the intention to acquire and internalise technological spillovers that are host location-specific. HBE activity, broadly speaking, represents an extension of R&D work undertaken at home, while HBA activity represents a diversification into new scientific problems, issues or areas.

A rather extensive literature has recently suggested that asset seeking (HBA) internationalisation of R&D has significantly gained momentum over the past two decades as a result of several factors ranging from: a) the increasing costs and complexity of technological development, leading to a growing need to expand technology sourcing and interaction with different and geographically dispersed actors endowed with complementary bits of knowledge; b) the higher pace of innovative activities in a number of industries,

spurring firms to search for application abilities which are mainly location specific; (c) the growing pressures from host governments on MNEs which have led them to an increase in the access to, and use of, local resources as a key condition to gain access to foreign markets.

While the conceptual differences are clear, in reality it is quite hard to find appropriate indicators of the motivations underlying investment decisions. Until recently, empirical studies had largely reflected the widely accepted view that the role played by foreign R&D units be predominantly determined by market or demand-side factors. Pioneering studies by Mansfield et al (1979), Lall (1979), and Warrant (1991) tended to make the assumption of demand-based motivation⁶. More recent works have focused their attention on technology sourcing motives for R&D investments. A number of contributions have used case studies and interviews to managers of foreign R&D units to identify the orientation of their activity. Detailed analyses carried out by Miller (1994), Odagiri and Yasuda (1996), and Florida (1997) have highlighted that technology sourcing strategies play an important role in a number of manufacturing industries in North America, Europe and Asia⁷. In some cases market oriented R&D units are found to evolve into technology oriented ones, as shown by Rondstadt (1978 p.22) in his seminal investigation of R&D investment abroad by seven US-based multinationals. In other circumstances, foreign R&D units experienced no major shift in their characters, as observed by Kuemmerle (1999 p.185) with reference to R&D labs of 32 MNEs active in 5 different countries in the electronics and pharmaceutical industries.

Several studies using different multivariate techniques attempt to identify the relative importance of HBA vs. HBE orientation. Using patent citations to explore all prior art referenced in each patent granted to 22 US-based subsidiaries of MNEs active in the semiconductor industry, Almeida (1996) found that foreign firms not only learnt more from local sources, but they did so to a greater extent than their domestic counterparts. This study also found that, with the significant exception of subsidiaries of Japanese MNEs, foreign firms locate their technological activities overseas in areas of home country disadvantage (measured in terms of Revealed Technological Advantages). Using a similar methodology,

⁶ The study carried out by Mansfield et. al (1979) on a sample of 55 major US manufacturing firms in 1970-74, found that a firm's percentage of sales from foreign subsidiaries has a highly significant effect on its percentage of R&D expenditures carried out overseas (p.190). The inquiry carried out by Warrant (1991) on R&D units of the 150 largest multinationals from the Triad.

⁷ Miller (1994 p.37) studied the factors affecting the location of R&D facilities of 20 automobile firms in North America, Europe and Asia, and found that an important motivation is to establish "surveillance outposts" to follow competitors' engineering and styling activities. In their study of 254 Japanese manufacturing firms, Odagiri and Yasuda (1996 p.1074) note that R&D units are often set up in Europe and in the US to be kept informed of the latest technological developments. Similar results are obtained by Florida (1997 p.90) analyzing 186 foreign affiliated laboratories in the US.

Cantwell and Noonan (2002) described technology sourcing activities of foreign firms located in Germany between 1975 and 1995, and found that MNE subsidiaries source a relatively high proportion of knowledge (especially new, edge-cutting technology) from this host country, and that few citations lead back to patents of the parent firms. This altogether would give support to the idea that foreign owned technological activities undertaken in Germany are largely HBA. A more comprehensive assessment of the relative importance of HBA vs. HBE motives was carried out by Patel and Vega (1999) through their study of US patenting activities by 220 multinationals originating from the Triad and active mostly in high technology fields (computers, pharmaceuticals, telecommunications, image and sound materials). By comparing the RTA of the company at home and the advantage of the location, they show that in a large majority of cases, firms tend to locate their technology abroad in the core areas where they are strong at home. They interpret this as evidence of the fact that adapting products and processes and materials to suit foreign markets and providing technical support to off-shore manufacturing plants remain major factors underlying the internationalization of technology. This result is by and large confirmed by an extensive survey carried out by Pearce (1999) through interviews to managers of foreign-based labs of multinational enterprises. Expanding on Patel and Vega's methodology with reference to a large sample of firms with patenting activities in Europe, Le Bas and Sierra (2002) find that while firms rarely internationalise their R&D to compensate their technological weaknesses (hence undergoing purely technology seeking activities), there is nevertheless a high recourse to HBA strategies. These would in fact occur when both the foreign and the domestic firms are endowed with technological advantages, paving the way to what the authors describe as dynamic learning through the interaction with local contexts. They also highlight that this circumstance is one which has grown in relative importance between the late 1980's and the second half of the 1990's (see Box 1 for details on the methodology used to measure alternative international R&D strategies)

Box 1 – Disentangling international R&D strategies

Le Bas and Sierra (2002) selected the 345 MNEs with the greatest patenting activity in Europe in 1988-1990 and in 1994-1996. Altogether these firms account for 47.1 and 45.6% of all patents registered by the European Patent Office (EPO) in the two periods. US firms amounted to 37.1% of the total, Japanese firms to 22.6% and European firms (German, French, British and Swiss MNEs in particular) to 38%. Less than 3% originate from other countries, mainly Canada and Korea. The authors classify the sample MNEs according to the RTAs based on their European patenting activities and compare these with the host country's RTAs in the same technological fields. Denoting as P_{ij} the number of patents granted in technological field j to firm (or country) i , the RTA index is calculated as follows:

$$RTA_{ij} = (P_{ij} / \sum_i P_{ij}) / (\sum_j P_{ij} / \sum_{ij} P_{ij})$$

Drawing on Patel and Vega (1999, p. 152), Le Bas and Sierra (2002) construct two types of RTA index. First, *homeRTA*, is an indicator of a firm's relative strength or weakness in a particular technological field in its home country, i.e. in the country of the headquarters. For each particular technological field, *homeRTA* is defined as the firm's share in that field of European patents due to inventions in its home country, relative to its overall share of all European patents due to inventions in the same country. Second, *hostRTA*, is an indicator of the host country's relative strength or weakness in a particular technological field. For each particular technological field, *hostRTA* is defined as the host country's share of all European patenting in that field, divided by its share of all European patents in all fields. In all cases an $RTA > 1$ signals a relative advantage of the country (firm). Based on these definitions four R&D strategies are identified:

Corporate technological activities in the home country	Technological activities in the host country	
	Strong	Weak
Weak	Type 1: technology-seeking HomeRTA < 1 HostRTA > 1	Type 2: home-base-exploiting HomeRTA < 1 HostRTA < 1
Strong	Type 3: home-base-augmenting HomeRTA > 1 HostRTA > 1 (Learning-oriented FDI in R&D)	Type 4: market-seeking HomeRTA > 1 HostRTA < 1 (Efficiency-oriented FDI in R&D)

Source: adapted from Patel and Vega (1999, p. 152).

Using EPO data to calculate home and host RTAs, Le Bas and Sierra find that a great majority of cases MNEs located their activities abroad in technological areas or fields where they were strong at home (strategies 3 and 4), while purely technology seeking activities (corresponding to strategy 1, i.e. a technological disadvantage at home and a technological advantage in the host location) were the least likely to occur. Moreover they emphasise that this does not mean that most R&D foreign investment decisions are HBE. In fact the most frequent strategy is one characterized by the circumstance in which not only foreign R&D activities are active in technologies wherein the company has a relative advantage at home (Home RTA > 1), but also the location is relatively strong, i.e. the host country has a revealed technological advantage as well (Host RTA > 1). This case would correspond to the essence of HBA orientation of R&D FDI, and reflects what the authors identify as dynamic learning, because the interaction with local contexts is most likely to produce knowledge improvements over time.

Evolution of multinationals' strategies (percentage share): comparisons between 1988–1990 and 1994–1996		
	1994–1996	1988–1990
Strategy 1	13.1	12.8
Strategy 2	30.1	31.0
Strategy 3	47.4	45.4
Strategy 4	9.5	10.8
Total	100	100

Source: Le Bas and Sierra (2002 p.606)

4. The contrary forces for centralisation vs internationalisation

Empirical work on the internationalisation of innovative activities has taken two distinct approaches. The first approach has focused on the nature of HBE and HBA as an intra-firm

process. That is, the foreign-located R&D seeks to adapt and use technologies associated with the parent company; or to integrate the MNEs' knowledge base with assets it gains access to in the foreign location. These studies have generally been based on surveys using firm level data (Florida, 1997, Kuemmerle, 1999, Dalton and Serapio, 1999, Castellani and Zanfei 2003b). This 'narrow' or 'micro' view of innovative activities can be contrasted with a 'systemic' or 'macro' view which has measured HBE vs. HBA as being *implicitly* associated with the technological resources of the *entire* home location as compared with those of the *entire* host location (see e.g., Dunning and Narula 1995, Driffield and Love 2001, Criscuolo *et al* 2002).

Both views can indeed be useful to single out the contrary forces pushing in the direction of centralising *vs.* internationalising innovative activities. An MNE's knowledge base is not simply a function of its own activities in the home location, but also of its home location's innovation system. Nor is access to foreign knowledge only the result of interactions between MNE's own competencies and those of a single local counterpart: the entire innovation systems of both the home and the host locations are at stake here. There are complex interdependencies between economic actors in any given location, and because the MNE parent is often highly embedded in its home location, these linkages determine its knowledge base and the efficiency with which it can leverage its technological assets. Economic actors include both non-firm organisations as well as suppliers, who are often inextricably linked to the MNE and its innovatory activity.

Having emphasised these interdependencies, we can single out at least four broad sets of factors underlying the tensions towards centralisation and internationalisation of innovative activities. As we shall see, these forces are active at both the macro and micro levels of analysis identified above. Let us discuss them in some details:

a) The costs of integrating activities in local contexts. When firms engage in R&D in a foreign location to avail themselves of complementary assets that are location specific (and include those that are firm-specific or institution-specific, which the laboratory in question seeks to use through collaboration), they are essentially aiming to explicitly internalise several aspects of the systems of innovation of the host location. However, developing and maintaining strong linkages with external networks of local counterparts is expensive and time consuming, and is tempered by a high level of integration with the innovation system in the home location. Such linkages are both formal and informal, and will probably have taken years – if not decades – to create and sustain. Frequently, the most significant issues are the

'know-who'. Government funding institutions, suppliers, university professors, private research teams, informal networks of like-minded researchers take considerable effort to create, and once developed, have a low marginal cost of maintaining. Even where the host location is potentially superior to the home location - and where previous experience exists in terms of other value adding activities - the high costs of becoming familiar with, and integrating into a new location may be prohibitive. Firms are constrained by resource limitations, and that some minimum threshold size of R&D activities exists in every distinct location. As such, to maintain more than one facility with a threshold level of researchers must mean that the new (host) location must offer significantly superior spillover opportunities, or provide access to complementary resources that are simply not available anywhere else, and which cannot be acquired by less risky means more efficiently.

b) Local technological opportunities and constraints. As we have noted, the high costs associated with integrating into the host location's systems of innovation – in contrast to the low marginal cost of maintaining its embeddedness in its home location's innovation system – may create an 'inertia' whereby firms are reluctant to expand internationally (Narula 2002a). However, these costs must be tempered by supply-side considerations, the development of these technologies benefits from diversity and heterogeneity in the knowledge base, which might come from competitors, from interaction with customers and from other complementary technologies. A single national innovation system is often unable to offer the full range of interrelated technological assets required for this diversification strategy (see Box 2 on the interactions between innovation systems and R&D internationalization strategies). The point we are trying to raise is that the complex centripetal and centrifugal forces underlay the kinds of R&D activities a firm undertakes, and where these are located. It is rare that firms undertake either HBA or HBE overseas in exclusion of the other.

Box 2 - How the inertia of innovation systems affects the internationalisation of R&D

Innovation systems are built upon a relationship of trust, iteration and interaction between firms and the knowledge infrastructure, within the framework of institutions based on experience and familiarity of each other over relatively long periods of time. In engaging in foreign operations in new locations, firms which already face opportunities and constraints created by their home innovations systems gradually become embedded in the host environment. The self-reinforcing interaction between firms and infrastructure perpetuates the use of a specific technology or technologies, or production of specific products, and/or through specific processes. Increased specialisation often results in a systemic lock-in, because of structural inertia (Hannan and Freeman 1984). Institutions develop that support and reinforce the interwoven relationship between firms and the knowledge infrastructure through positive feedback, resulting in positive lock-in. When SI cannot respond to a technological

discontinuity, or a radical innovation that has occurred elsewhere, there is a mismatch between what home locations can provide and what firms require, this is known as sub-optimal lock-in. In general, national innovation systems and industrial and technological specialisation of countries change only very gradually, and – especially in newer, rapidly evolving sectors - much more slowly than the technological needs of firms. In other words, there may be *systemic* inertia. Firms have three options open to them (Narula 2002a). Firms may seek either to import and acquire the technology they need from abroad, or venture abroad and seek to internalise aspects of other countries' innovation systems, thereby utilising a 'exit' strategy. There are costs associated with an exit strategy. For instance, it must suffer the costs of entry in another location (in terms of effort, capital and time), and firms may minimise this through a cooperative strategy with a local firm. Developing alternative linkages and becoming embedded in a non-domestic SI takes considerable time and effort. They can also use a 'voice' strategy which is to seek to modify the home-country innovation system. For instance, establishing a collective R&D facility, or by political lobbying. Firms are inclined towards voice strategies, because it may have lower costs, especially where demand forces are not powerful, or where the weakness of the SI is only a small part of their overall portfolio. But voice strategies have costs, and are not necessarily realistic for SMEs, which have limited resources and political clout. Such firms cannot afford an 'exit' strategy either, and end up utilising a 'loyalty' strategy, relying instead on institutions to evolve, or seeking to free-ride on the voice strategy of industry collectives, or larger firms.

It is axiomatic that HBA activities will be located where opportunities for internalising spillovers are highest, and this implies seeking proximity to 'technology leaders' (Cantwell 1995), and given that firms tend to concentrate their more strategic R&D activities in their home location, this high level of competence is often reflected in the associated system of innovation. Thus, HBA activities have been hypothesized to occur in locations that exhibit a technological or comparative advantage, relative to other locations, and particularly relative to the home location of the MNE seeking these assets (Dunning and Narula 1995, Patel and Vega 1999, Bas and Sierra 2002). It is worth noting that technology leaders are not always synonymous with industry leaders: firms - particularly in technology intensive sectors – increasingly need to have multiple technological competences (see e.g., Granstrand 1998, Granstrand *et al* 1997).

Whenever products are multi-technology based, one firm may be marginally ahead in one technology, and its competitor in another; but on a macro-level, both may have equally 'powerful' innovation systems (Criscuolo et al 2002). Even within any given technology (and in particular for highly dynamic sectors), there are several technological paradigms at play: as firms base products on the current dominant design, yet they pursue the long-term intention of replacing the current technology with a new dominant design. This implies that technology leadership can change rather rapidly. This is another reason that firms may engage in both HBA and HBE activities simultaneously.

c) Firm size and market structure. An important structural trait that determines efficient internalisation is the size of the firm. Smaller firms are constrained by their limited resources: the expansion of R&D activities- both at home and in overseas locations - requires considerable resources both in terms of capital investment, and managerial resources which these firms simply do not have. *Ceteris paribus*, large firms have more money and resources to use in overseas activity. On the other hand, large firms are also more likely to have more linkages with the domestic science base, and tend to have a well-developed network of supplier firms at home. Small firms are generally in the role of supplier firm, and as such form part of the network of some larger firm, and are thus also bound to their home location (or the location of their main customers) (Narula 2002b). Internationalisation of supplier firms often occurs in tandem with the internationalisation of their primary customer, especially where the customer is large and dominant in terms of their market, as has been observed with regards Japanese auto manufacturers and their network of supplier firms as the auto manufacturers have relocated production to the US and Europe (Florida 1997). However, even when such strong customer - supplier links are not the case, small firms are constrained by limited resources. R&D is a costly and slow affair, and the long-term horizon that such investments need makes overseas R&D facilities an expensive and risky option that is hard to justify for SMEs. Indeed, Belderbos (2000) find that there is a non-linear relationship between firm size and overseas R&D, with medium-sized Japanese firms showing a higher propensity (in relative terms) to internationalise R&D than small or large sized firms.

There are also considerable industry-specific differences which encourage or discourage centralisation. It is axiomatic that the industrial structure of countries is path dependent, and technological specialisation changes only very gradually over time (Cantwell 1989, Zander 1995). As Teece (1986) has argued, the maturity of the technology, and its characteristics, determines the extent to which the innovation process can be internalised. Obviously, every technological trajectory of each individual firm is unique, since the innovation process is path-dependent on previous innovation. In other words, there are cognitive limits on what firms can and cannot do. Most mature technologies evolve slowly and demonstrate minor but consistent innovations over time, and can be regarded as post-paradigmatic. The technology is to a great extent codifiable, widely disseminated, and the property rights well-defined. Innovation is rarely patentable in these technologies, where applications development account for most innovatory activity. Competition shifts towards price, economies of scale, and downstream activities in order to add value, as the original product is priced as a commodity. These sectors tend to have a low R&D intensity. These are generally process industries which

do not require to be tailored to customer the same extent, or as quickly (Lall 1979). Under these circumstances, constant and close interaction with customers is not an important determinant of R&D: profits of firms are highly dependent on the costs of inputs, and proximity to the source of these inputs is often more significant than that of customers. On the other extreme, rapidity of technological change in 'newer' technologies or engineering industries, require a closer interaction between production and R&D (Lall 1979). Technology has a higher tacit, uncodifiable element, and this requires a closer coordination between users and producers of innovation.

d) Organisational issues. Another micro-level determinant is associated with the difficulties of managing cross-border R&D activities. It is not sufficient for the foreign affiliate to internalise spillovers if it cannot make these available to the rest of the MNE – there needs to be internal proximity between overseas R&D and the rest of the MNE (Blanc and Sierra 1999). Allowing for differences in the motivation to conduct overseas R&D (which may themselves derive from simple firm- and industry-specific differences), geographical proximity to host locations is important in determining the location of R&D, in both the case of supply and demand-driven R&D activity. A dispersion of R&D activities across the globe requires extensive coordination between them – and particularly with headquarters- if they are to function in an efficient manner with regards to the collection and dissemination of information. This acts as a centripetal force on R&D, and accounts for a tendency of firms to locate R&D (or at least the most strategically significant elements) closer to headquarters.

Complex linkages, both within the firm, and between external networks and internal networks, require complex coordination if they are to provide optimal benefits (Zanfei 2000). Such networks are not only difficult to manage, but also require considerable resources (both managerial and financial). It is no surprise, therefore, that external technology development is primarily the domain of larger firms with greater resources, and more experience in trans-national activity (Castellani and Zanfei 2003b).

Large firms tend to engage in both HBA and HBE activities, because large MNEs may have several semi-autonomous sister affiliates in the same location, which may operate in similar technological areas. In addition, any given subsidiary has a need for a variety of technologies, and any given host location may possess a relative technological advantage in one area, but be relatively disadvantaged in another. Lastly, MNEs tend to also engage in production activities (whether in the same or another physical facility) in the host location, and this prompts a certain level of HBE activity. Thus, an MNE in a given location may not

only be seeking to internalise spillovers from non-related firms, but may also be engaging in intra-firm knowledge transfers within the same multinational group (Criscuolo et al 2002).

5. Innovation through international strategic technology partnering

The previous sections have discussed the growing international dimension of R&D, concentrating on the intra-MNE aspect of this development. However, it is important to note that not all innovatory activity is undertaken within hierarchies. Over the last 2 decades there has been a concurrent rapid growth in non-internal R&D activities through cooperative agreements.

The facilitating role of globalisation has expanded firms' use of external resources to reduce, *inter alia*, innovation time spans, costs and risks, and acquire greater flexibility in their operations (Hagedoorn 1993). The increased knowledge content of products in general, the cross-fertilisation of previously distinct technological areas and the multiple technological competences of firms have been facilitated by the improved enforceability of contracts and declining transaction costs resulting from the diffusion of ICTs and from the developments associated with globalisation. These developments have made it easier for firms of all sizes to monitor, identify and establish collaborative ventures than previously had been the case. In other words, hierarchical control and full internalisation is no longer always a first-best option to MNEs, especially where innovatory activities are concerned (Narula 1999).

These 'non-internalised' means of innovation include a wide variety of organisational modes, including strategic technology partnering, outsourcing and networks. We limit our discussion here to our understanding of international strategic technology partnering (STP), which represents a particular subset of cooperative agreements. STP refers to inter-firm cooperative agreements where R&D is at least part of the collaborative effort, and which are intended to affect the long-term product-market positioning of at least one partner (Hagedoorn 1993). Declining transaction costs provide only a partial explanation for the growth in cooperation. In general, economisation motives are crucial to understanding quasi-external, vertical solutions such as outsourcing and customer-supplier networks (which tend to involve lower levels of joint activity). Technology partnering, on the other hand, are most often horizontal agreements which tend to reflect a more complex strategic intent, and require closer collaboration (Narula and Hagedoorn 1999, Narula 2001). 'Strategic' suggests that such agreements are aimed at long-term profit optimising objectives by attempting to enhance the

value of the firm's assets. STP has grown rapidly over the years⁸. As Hagedoorn (2002) notes, in the early 1970s there were less than 30 agreements per year. By the end of the 1990s this number had risen to about 500 agreements per year. There has also been a gradual shift over time: in the mid 1970s, the share of equity agreements was about 70%, and by the end of the 1990s the percentage of equity agreements in the total had declined to less than 10%.

International STP has also grown considerably, although as a percentage of all STP it has been seen to be rather steady, oscillating around 60% of all agreements, although the figure has declined in the 1990s to about 50% (Hagedoorn 2002). However, there is considerable variation by sector. Medium tech sectors show a higher propensity for international agreements than high tech and low tech sectors. On a further sectoral breakdown, information technology has a lower than average propensity for international alliances, while chemicals has a higher than average propensity.

On a country-level, 70% of all STP since the 1960s have at least one US partner (Hagedoorn 2002), although the importance of North America has increased quite fast. The share of intra-North American alliances has increased from 19.3% of total STP in the 1970s, to almost 42% in the 1990s, while intra-European STP and intra-Asian STP have declined from 26.8% to 11.3% and 6.4% to 2.5% respectively over the same periods. On the other hand, trans-Atlantic STP (between Europe and North America) have become relatively more important, increasing from 18.5% to 25.2% of the total between the 1970s and 1990s. Europe-Asia agreements and North America-Asia STP have both fallen. This is partly attributed to the fact that the MERIT-CATI database upon which these results are based has a relative bias towards high tech sectors, with particularly strong focus on new materials, biotechnology and information technologies. The last two are sectors in which US firms have a technological dominance. In general, STP patterns demonstrate industry-wide rather than national trends which suggests that the same process of learning about the mechanics of alliance formation and management apply to all firms regardless of nationality. It also highlights the need of firms, again regardless of nationality, to partner with the most appropriate firms regardless of national origin (Narula and Hagedoorn 1999). Given that most of the EU firms in the biotechnology and information technology sector do not enjoy a significant competitive

⁸ STP –like other forms of innovative activity -is a phenomenon that is hard to analyse in quantitative terms. Part of the problem has to do with the difficulties of monitoring and evaluating alliances, since it is difficult to accurately estimate the importance of individual agreements, both ex ante and ex post. Even where firms can place a value on an agreement, they have no incentive to make such information available, either to each other, or to the public.

advantage, it follows that a majority of STP by these companies are with Japanese and US firms (Narula 1999).

STP tends to be highly correlated with large firms with ample resources in technology intensive sectors. It is no surprise, therefore, that STP tends to be dominated by MNEs from the Triad, indeed, more so than R&D activities in general. Developed country firms participate in 99% of STP agreements (Hagedoorn 2002). While there has been a growth in R&D and manufacturing outsourcing agreements with developing country firms over the last two decades, the share of these firms in STP has remained around the 5-6% mark since the 1980s (Narula and Sadowski 2002). Well over 90% of these involve at least one Triad firm. Furthermore, firms from the East Asian NICs and Eastern Europe account for the bulk of the non-Triad partners. Indeed, when one examines the industry and country distribution of STP involving developing country firms, these largely reflect the industrial structure of their economies (Narula and Sadowski 2002). In other words, partners generally originate from countries characterised by comparable development levels. Thus, it appears that these alliances have little to do with technological catching-up or with the transfer of mature technology. Co-operation is most frequently the way to keep up with the technological frontier: by associating complementary resources and competencies, it makes it possible to explore and exploit new technological opportunities.

The increasing recourse to agreements is all the more interesting since the majority of them associates potential competitors acting in the same - or at least interconnected - markets (Jacquemin et al. 1986, Morris-Hegert 1987). At the same time, they are concentrated in high technology industries, and often cover R&D activities. This can be interpreted as a sign of the fact that technology acquisition and exchange is at least as important an objective as benefiting from wider markets.

Even smaller technology-based MNEs are nowadays involved in a web of such agreements, and their growing significance raises numerous conundrums (Narula 2002b, Powell, Chapter x, this volume). Firms – regardless of size – must maintain the appropriate breadth of technological competences, and to do this they must maintain complex international internal and external networks. Such networks are not only difficult to manage, but also require considerable resources (both managerial and financial). SMEs strongly need to rely on non-internal sources, as they often experience wider gaps in terms of competencies and development abilities than their larger counterparts (Zanfei 1994) and must be more skilful at managing their portfolio of technological assets, but have limited resources (Narula 2002b).. Managing a web of different types of agreements across borders is not without its

price, and highlights the role of transaction-type ownership advantages in the success of the MNE. A dispersion of activities across the globe also requires extensive coordination between them – and particularly with headquarters- if they are to function in an efficient manner with regards to the collection and dissemination of information. Indeed, the management of intangible assets is central advantage of the MNE. Thus, if one is to understand developments in internationalization of R&D it is crucial to understand STP as a central and primary feature of the cross-border R&D activities of firms, and whether this represents a substitute or a complement to internal R&D. The substitution vs. complementarity issue can be examined from at least two points of view which we shall examine below.

a) Interdependencies between multinational expansion and international technology partnering. Two streams of literature have addressed this issue with diverging outcomes. First, drawing from transaction cost literature, several works on international market entry strategies have highlighted that multinational experience, obtained through an extensive and long lasting presence in foreign markets, is a fundamental means to reduce the *uncertainty* MNEs have to deal with when carrying out their operations abroad. This will affect the choice among different foreign market penetration modes. In fact, in the absence of multinational experience, cooperative ventures would be considered to be more effective market entry tools than hierarchical control strategies, being more flexible and less commitment intensive means to gather information on host economies. As MNEs accumulate greater experience of foreign markets, the information gathering advantages of collaboration will be gradually reduced, and the risks of commitment intensive strategies will be perceived to be lower. As a result, it will be more likely that the organisational costs of cooperation, in terms of shirking and conflicts of interest between partners, will exceed the benefits deriving from this strategy (Gomez-Casseres, 1989; Gatignon and Anderson, 1988; Hennart and Larimo, 1998). In summary, multinational experience is supposed to impact negatively on collaborative ventures and positively on equity based, commitment intensive linkages. We shall refer to this as the “entry mode hypothesis”. The entry mode hypothesis (and related literature) is largely - but not exclusively- consistent with the view that multinational experience helps facilitate the exploitation of MNEs’ ownership advantages in foreign markets. In other words, the MNE because of uncertainty in host economies, MNEs are better off utilising their own assets as a means to penetrate these markets. One may venture to say that this emphasis on exploitation of MNE’s own assets - rather than on the exploration of, and access to, external resources - leads several of these contributions to understate the role of cooperative linkage modes.

By contrast, a second stream of literature, focusing mainly on the evolution of high technology industries, has highlighted an important motive for entering inter-firm linkages, i.e. the need to explore and rapidly exploit new opportunities, either new businesses or new technological developments. The idea is that strategic alliances can be thought of as "an attractive organisational form for an environment characterised by rapid innovation and geographical organisational dispersion in the sources of know how" (Teece, 1992 p.20). In other words, the need for a timely and effective knowledge access may well overcome short term, static (transaction and organisational) cost minimisation. From this perspective, the role of multinational experience can also be re-considered. In fact, consistently with a more general view of complementarity between internal and external competence accumulation, multinational experience – which is associated to the establishment and activity of foreign subsidiaries over time - can be identified as a fundamental asset increasing a firm's capacity to *search for and absorb external knowledge* (Cantwell 1995, Castellani and Zanfei 2003b). This view appears to be consistent with a number of studies on high technology industries which highlight the mutually reinforcing nature of intra-firm and inter-firm networks, through which generic as well as applications and market oriented knowledge assets can be searched for and accessed. Several works provide evidence on the complementarity between intra-firm networks and inter-firm collaborative ventures in biotechnology (Arora and Gambardella 1990), software (Malerba and Torrisi 1992), semiconductors (Steinmueller 1992), and electronics industries (Zanfei 1993, Ernst 1997). The relevant implication for our purposes is that multinational experience can be expected to expand the *exploration potential* and hence lead to a greater recourse to international collaborative ventures especially for technology sourcing purposes.

b) Interdependencies between internal R&D and international technology partnering. Considerable research effort has been exerted towards understanding how much a firm can substitute STP for in-house R&D. The attempt to understand the reasons behind a firm's choice between non-internal and internal technological development is not new. The work of Teece (1986) presents a pioneering analysis of this issue, which builds on Abernathy and Utterback (1978), Dosi (1982) among others, and further developed by Pisano (1990), Henderson and Clark (1990), Nagarajan and Mitchell (1998), Veugelers and Cassiman (1998), Gambardella and Torrisi (1998), Nooteboom (1999), Narula (2001) and Brusoni *et al* (2001). Beyond a certain point, different forms of R&D organisation act as complements to one another, rather than as substitutes for traditional hierarchical modes. The excessive use of

non-internal means entails considerable risks and costs. As a general rule, firms find it extremely costly and difficult to access competencies from other firms or locations in fields which are unrelated to their own capabilities, and with which they have little initial familiarity; while the internalisation advantages of in-house combinations of activities derive (inter alia) from the technological coherence of these activities (Teece *et al.*, 1994). This is essentially due to the need for 'absorptive capacity' when the firm acquires knowledge from its external environment or one knowledge-creating part of the firm interacts with another, and which requires the recipient to have some innovative potential of its own to be able to learn and effectively adapt the technologies to which it may wish to have access. Thus, STP tends to develop in areas in which partner companies share some complementary capabilities, and these alliances create a greater degree of interaction between the partners' respective paths of learning and innovation (Mowery *et al* 1998, Cantwell and Colombo, 2000, Santangelo 2000). However, the extent and form of interaction between learning activities depend upon the organisational form of cooperation. This varies considerably by industry. Equity agreements are preferred in relatively mature sectors, while non-equity agreements are utilised in high-tech sectors (Hagedoorn and Narula 1996). Non-equity forms of agreements tend to be more efficient for undertaking activity in more research-intensive industries, and where technological change is rapid since they promote negotiation and can lead to more intensive cooperation than equity forms. However, where firms seek to learn and transfer tacit knowledge back to the parent firm, such as market-specific knowledge when entering a new market, or are engaged in production as well as research, equity forms of agreement may be more appropriate.

6. Conclusions and Policy issues

This chapter has discussed the internationalisation of innovative activities, and highlighted that it has been driven by a myriad of factors, the most recurrent of which are the need to respond to different demand and market conditions across locations, and the need for the MNE to respond effectively to these by adapting their existing product and process technologies through foreign-located 'home-base exploiting' (HBE) R&D.

However, supply factors and the need to gain access to local competencies have become an increasingly important motivation to engage in 'home-base augmenting' (HBA) R&D abroad. This is due, *inter alia*, to the growing tendency for multi-technology products, and the fact that patterns of technological specialisation are distinct across countries, despite the economic

and technological convergence associated with economic globalisation (Archibugi and Pianta 1992, Narula 1996, Zanfei 2000). Other studies have shown that these patterns of technological specialisation are fairly stable over long periods (see Cantwell 1989, Zander 1995) and change only very gradually.

As a result, there is a growing mismatch between what home locations can provide and what firms require. In general, national innovation systems and industrial and technological specialisation of countries changes only very gradually, and – especially in newer, rapidly evolving sectors - much more slowly than the technological needs of firms. Firms must seek either to import and acquire the technology they need from abroad, or venture abroad and seek to internalise aspects of other countries' innovation systems. There is a third option – that of firms seeking to modify the home-country innovation system – which is expensive, and difficult to sustain in the long run (Narula 2002a). Thus, in addition to proximity to markets and production units, firms also venture abroad to seek new sources of knowledge, which are associated with the innovation system of the host region. The interdependence of markets and the cross-fertilisation of technologies – whether through arms-length means, cooperative agreements or equity based affiliates - means that that few countries have truly 'national' systems. Of course, some innovation systems are more 'national' than others, and the term is indicative rather than definitive (see also chapters by Edquist e by Malerba in this volume for a discussion). Furthermore, firms need a broader portfolio of technological competences than they have in the past.

The internationalisation of R&D raises crucial welfare issues, since it provides opportunities for spillovers between the MNE and its host economy, and in certain circumstances between the MNE affiliate and its home country. From this perspective, there has been some concern in the US with the potential loss of competitiveness of domestic firms and with the impoverishment of the 'national knowledge base' which would be associated with the increasing local R&D presence of foreign-owned MNEs (e.g., Dalton et al, 1999). In other countries and areas of the world, the perception is quite opposite, as local presence of foreign R&D and value added activities is expected to contribute to the upgrading of national technology systems. This perception is based *inter alia* on the existing evidence according to which foreign firms usually outperform domestic ones (see Bellak 2002 for a review). This has provided grounds for policy measures aimed at favouring the presence of foreign firms, based on the belief that they are fundamental vehicles for technology transfer and growth of host economies (cf. e.g. Conyon et al 2002). A few empirical studies seem to provide sound evidence on the existence of positive spillovers of multinational presence in the case of some

emerging economies such as Korea, Taiwan and Singapore (Hobday 2000, Lim 1999), and of some of the EU member states (Barry and Strobl 2002, Castellani and Zanfei 2003a). Generally speaking however, the evidence is mixed: according to a recent survey on econometric studies of productivity spillovers from FDIs, the number of cases in which negative or non significant results are obtained is approximately as high as the opposite cases (Gorg and Strobl 2001). This suggests a cautious approach to this issue, and calls for a refinement of analytical tools. On the one hand, public policy needs to rely on more direct measures of technological spillovers, which are hardly captured by performance indicators like productivity. On the other hand, the channels through which spillovers occur need to be examined more carefully, in order to devise appropriate policy measures.

The flipside of the policy debate is that the internationalisation of R&D may lead to a 'hollowing out' of the home country's innovatory capacity when the domestic innovation system does not meet the needs of firms in certain industries (ETAN 1998). When systems suffer from sub-optimal lock-in, firms seek alternative innovation systems in which to embed themselves, despite the cost and efforts associated with both 'exit' and 'entry' (see Box 2 in section 4 for a discussion on this issue). The danger of hollowing out are very real, especially when the innovation system is specialised around a few products, and/or concentrated around a few large firms. These consequences can be particularly severe for small open economies which tend to be specialised in a few niche sectors and dominated by a few firms. However it is crucial that policy-makers distinguish between hollowing-out as a symptom of sub-optimal lock-in and the internationalisation of innovation to supplement domestic supply limitations (Narula 2003). No country can possibly expect to provide world-class competences in all technological fields. Even the largest, most technologically advanced countries cannot provide strong innovation systems to all their industries, and world-class competences in all technological fields. Some countries have regarded imported technologies as a sign of national weakness, and have sought to maintain and develop in-country competences, often regardless of the cost (Narula 2002a). Relying largely on in-country competences may however lead to a sub-optimal strategy, especially in this age of multi-technology products. In fact, the cross-border flow of ideas is fundamental to firms, and this imperative has increased with growing cross-border competition, and international production.

Table 1. Selected indicators of FDI and international production, 1982-2001 (US \$Billion at current prices and percentage values)

	1982	2001
FDI inflows	59	735
FDI outflows	28	621
FDI inward stock	734	6846
FDI outward stock	552	6582
Sales of foreign affiliates	2541	18517
Gross product of foreign affiliates	594	3495
Total assets of foreign affiliates	1959	24952
Exports of foreign affiliates	670	2600
Employment of foreign affiliates (thousands)	17987	53581
Inward FDI stocks to GDP ratio	6,79%	21,46%
Foreign affiliates' export to total exports	32,20%	34,99%

Source: UNCTAD, based on its FDI/TNC database and UNCTAD estimates.

Table 2. R&D Expenditure of foreign affiliates as a percentage of total R&D expenditures by all firms in selected host economies, 1998 or latest year

Canada	34.2
Finland (1999)	14.9
France	16.4
Japan	1.7
Netherlands	21.8
Spain (1999)	32.8
UK (1999)	31.2
US	14.9
Czech Republic (1999)	6.4
Hungary	78.5
India (1994)	1.6
Turkey	10.1

Source: UNCTAD (2002), table I.10

Table 3. Shares of US patenting of largest nationally owned industrial firms due to research located abroad, 1920-1990

	1920-1939	1940-1968	1969-1990
US	6.81	3.57	6.82
Europe	12.03	26.65	27.13
UK	27.71	41.95	43.17
Germany	4.03	8.68	13.72
Italy	29.03	24.76	14.24
France	3.35	8.19	9.55
Sweden	31.04	13.18	25.51
Netherlands	15.57	29.51	52.97

Source: Cantwell (1995)

Table 4. Share of US patents of the world's largest firms attributable to research in foreign locations by main area of origin of parent firms 1969-1995

Nationality of parent firm	1969-1977	1978-1986	1987-1995
US	5.4	6.9	8.3
Japan	2.1	1.2	1.0
European countries *	26.3	25.6	32.5
Total all countries**	10.3	10.7	11.3
Total all countries excluding Japan	11.1	13.0	16.2

* Germany, UK, Italy, France, Netherlands, Belgium, Luxembourg, Switzerland, Sweden, Denmark, Ireland, Spain, Portugal, Greece, Austria, Norway, Finland

** Total includes all the 784 world's largest firms recorded by the University of Reading database, base year 1984

Source: Cantwell and Janne (2000)

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