What determines the internationalisation of corporate technology?

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Abstract

Based on empirical data at an aggregate level it has been argued that the propensity to internationalise corporate technological activity is higher among firms originating from smaller countries and in less research-intensive industries. However, more disaggregated evidence on the patenting of the world's largest firms suggests a more complex picture.

First, at a disaggregated level there is a great diversity among countries within each industry in the degree of internationalisation of technological activity that is not recorded in global average position. The share of foreign-located activity (through outward investment) depends positively upon the technological strength of each national group of firms in an industry, while the share of foreign-owned activity (through inward investment in a host country) may be deterred by the technological competitiveness of indigenous firms. The degree of internationalisation of technological development depends inversely as well on the extent of localised user-producer interaction in innovation in an industry or in the relevant national innovation system.

Second, the largest firms increasingly use international research networks as a means of corporate technological diversification. Thus, when technologically leading groups invest in innovation abroad they tend to switch towards the foreign development of complementary and supporting technologies outside the primary field of their own industry, which tends to remain relatively more concentrated at home. Likewise, while foreign-owned firms in the same industry may be deterred by the intensity of competition in the home centre of a leading national group, strong foreign-owned firms in other industries may pursue their diversification strategies by developing locally the primary technology of that centre (which is not primary for their own industry).

Hence, we present a more general framework that takes into account the relative technological strengths of national groups of firms, and the role of corporate technological diversification through international networks in each industry. We show how this more comprehensive framework allows us to explain more fully cross-country variations around average industry positions (and cross-sectoral variations in average country positions) in the degree of internationalisation of technological development established by the world's largest firms.

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1. Introduction

Innovation has been increasingly internationalised during recent decades, and while internationalisation is not itself a new phenomenon the number of large firms involved, and the importance of the technological activity that is carried out abroad has greatly increased (Bartlett and Ghoshal, 1989; Dunning, 1993; Cantwell, 1995). The largest US and especially European companies have made a major contribution to this process. The pursuit of international competitiveness at a country level follows historically defined trajectories, as part of different national and regional systems of innovation (Lundvall, 1988; Nelson, 1993; Cantwell, 2000).

At the firm level, the internationalisation of technological activities encourages the creation and diffusion of innovation by tapping into locally-specific resources and effectively deploying individually localised exchanges with indigenous firm capabilities in various sites (Pearce, 1989, 1999; Kuemmerle, 1998, 1999a, 1999b; Zander, 1998, 1999; Cantwell and Janne 1999a; Dunning and Wymbs, 1999). The world's largest firms in recent years have moved from employing international R&D as a means of better exploiting established competencies in accordance with the conditions of local markets and production conditions, towards the creation of local centres of excellence with differentiated but complementary sources of expertise. The geographical dispersion of research facilitates the multi-technological development of firms, and becomes positively associated with corporate technological diversification (Zander, 1997; Breschi, et.al.1998; Cantwell and Piscitello, 1999). Consequently, firms pursue their technological diversification partly through the internationalisation of the process of competence creation, complementing their domestic activity with suitably locally differentiated foreign-located lines of development (Cantwell and Piscitello, 1999, 2000).

2. Development of an analytical framework

In this context, we begin from but then explore how to go beyond two background propositions on the determinant of the international section of corporate technological activity which can be found in the literature (see in particular Patel and Pavitt, 1988). While these propositions may be useful starting points for explaining cross-country and cross-industry variations in the degree of internationalisation they are insufficient. In showing that there are two further factors which also determine differences in the extent of technological internationalisation between countries and industries, we present a more general and comprehensive framework for the analysis of the international location of innovative activity in large firms.

The two background propositions with which we start are as follows. First is the supposition that large firms from small countries tend to be more highly internationalised in their technological development strategies, while large country multinational corporations (MNCs) tend to be less internationalised. The reason is that the constraints of small country size compel large firms originating from such economies to become internationalised more rapidly. Taken alone this proposition is an over-generalisation and may be misleading, since for example British firms have been highly internationalised for a long time while Swedish firms have been little internationalised until relatively recently. More importantly for our argument, the cross-national group pattern in the degree of internationalisation within each industry varies from one industry to another.

To explain the foundation for the second proposition, while firms develop a wide range of technologies to support a narrower range of products (Pavitt, Robson and Townsend, 1989; Granstrand, Patel and Pavitt, 1997), the geographical dispersion of production in multinational firms exceeds that of technological activity (Cantwell and Hodson, 1991). We might infer from this that technology is internationalised more in support of the geographical spread of production and markets, than the other way round, and indeed until recently this has been largely true (Cantwell, 1995; Cantwell and Piscitello, 2000). So historically when the internationalisation of technology followed the internationalisation of production, which in turn was motivated by a search for markets or resources, foreign-located research tended to be greatest where it was needed to adapt products to locally differentiated markets (like in food products) or to adapt resource extraction to local conditions (like mining), and not in research-intensive industries.

Thus, the second background proposition is that less research-intensive industries tend to be relatively more internationalised in their technological activity (in terms of foreign research shares) than are highly research-intensive industries. However, taken alone this is (also) an over-generalisation that may be misleading. To the extent it is true it may reflect the fact that the types of technology different industries develop abroad are to a greater extent than at home those outside the primary technologies of their own industry, while their primary activities remain more heavily concentrated at home. High research-intensive industries develop abroad technologies in some low research-intensive areas (e.g. chemicals and pharmaceuticals firms in mechanical engineering technologies), while low research-intensive industries develop some high research-intensive technologies abroad (eg. in new materials and IT). In any event, chemicals, pharmaceuticals, petrochemicals and office equipment (computing) are all research-intensive industries that have on average a substantial internationalisation of technological endeavour among large firms. More importantly again for our purposes, the ranking from highly internationalised industries down to the least internationalised is not uniform if we compare the cross-industry distribution for the firms of different nationalities of origin. So rather than explaining why on average food and pharmaceuticals are highly internationalised industries while aircraft is not, we need to be able to explain why the food firms of some home countries of origin are highly internationalised in their technological efforts, but the food companies of other countries are not.

To clarify the nature of the supplementary arguments that are necessary to build upon but qualify and go beyond the received wisdoms that technological development tends to be more internationalised on average in firms from smaller countries and in less research-intensive industries, we develop a new framework that embraces elements of these existing contentions. Yet at the same time our approach provides a more comprehensive explanation of the complex variations across countries and industries in the degree of internationalisation of technological activity that is observed in practice among large firms. Our framework introduces two new components in order to establish more precisely the determinants of the internationalisation of corporate innovative effort.

Figure 1 here

First, national groups of large industrial firms have unique and distinctive international technological profiles that reflect the path-dependent and historically bounded competencies that were originally developed in their home country (Cantwell, 2000). In industries in which national groups of firms are strongest as technological leaders the extent of internationalisation of technology development will be relatively high (Cantwell, 1989). However, such multinational firms utilise their international networks for innovation in large part to promote their own comparative technological diversification (Cantwell and Piscitello, 2000). The investment that they conduct abroad tends to be more oriented towards general technological systems, relevant to most industries, which are either core to the current technological paradigm (such as information and communication technology or new materials) or carried forward from past paradigms (such as mechanical devices and instruments), while they tend to retain at home a higher proportion of technological development in the primary fields for their own respective industries. Conversely, from the perspective of inward investment, in the industries in the host country is technologically strongest, the vibrant local presence of strong indigenous companies tends to deter foreign-owned firms of the same industry from conducting substantial levels of local development in the primary technologies of the industry in question. At the same time, the strongest firms of other industries might be attracted to locate development of the relevant technologies in such a centre of excellence, which lines of development for them would represent diversification from the primary technologies of their own industries. Since they are in another industry, they are not direct competitors of the local leaders.

In other words, the intensity of technological competition influences cross-sectoral patterns of international expansion. Competitive strengths in an industry on the part of a national group of firms encourage outward investment in foreign-located technological development but discourage the inward investment of foreign-owned companies in the same industry. However, the foreign-owned firms of other industries (which are not major competitors in output markets) may be attracted to source technology from a centre of excellence in the primary field of development in which local firms lead. Likewise, while the leading local companies tend to retain at home much of their development of their own primary technologies (given local expertise), what they locate abroad will be geared towards the foreign development of related or complementary fields.

Thus, in general in the case of an area in which local firms are strong we expect to observe roughly the pattern illustrated in Figure 1 in terms of the degree of internationalisation of technological activity at the level of the industry, and at the level of the equivalent technological field. First, we expect outward investment in innovation to exceed inward investment, given the balance of corporate strengths. However, second, while in the case of outward investment the internationalisation of the industry will tend to exceed that in the corresponding technological field (since strong domestically owned firms diversify abroad), within inward investment the pattern tends to be the other way round (since foreign-owned firms in the same industry are those most deterred by the presence of dominant local companies).

Figure 2 here

However, to bring in now the second new component of our framework, an essentially reverse trend may be observed in industries and countries in which the basis of strong local technological competitiveness is a tight interrelatedness of companies in the industry with downstream local user firms or upstream supplier firms as the sources of innovation and as a crucial feedback to in-house innovation. This type of relationship places great importance on mutual trust and locally-specific knowledge creation because it demands a commitment of substantial resources and "has a cumulative and continuous property with a time dimension" (Lee, pp. 47-48) that induces national industrial groups to remain local in their innovative orientation (Lundvall, 1985, 1988). Hence, the more that the production of a national industrial group is aimed at local intermediate good markets, or depends upon locally-specific suppliers of innovative equipment or other inputs, the less internationalised they will tend to be in their research strategy.

We might expect this argument to apply in an industry such as metals, or machine tools, yet the same inward-looking approach to innovation may also be relevant to other industries with a strong indigenous advantage linked to inter-company and inter-industry interrelatedness. This is particularly likely to apply in the case of Japan, where a closely knit network of firms (such as in the form of Keiretsu) supports a broad dispersion of development across complementary technological fields (Scher, 1997). For example, we have a variety of industries in Japan such as the chemical, the computer, the electrical equipment, etc. whose technological development relies for support upon, and in turn helps to support competence development in a focus industry, most notably motor vehicles. In this case the chemical, computer, and electrical equipment industries can be regarded as to a greater extent than usual intermediate-good oriented and much of their technological effort is directed to the innovative support of the car industry. Of course, this does not mean that these industries provide only for the local market or that in some later stage of their development they will not become more international in their innovative activity. Instead, the Japanese chemical industry is, for example, among the leading national groups in paints.[1]

However, in general in a case in which the technological strength of local firms depends upon a tight localised inter-industry coupling of user-producer interaction in innovation, we expect to observe roughly the pattern illustrated in Figure 2, distinguishing again between the level of the focus industry and the level of the equivalent technological field. First, we expect outward investment in innovation to be low, quite likely to the extent that it is even weaker than inward investment. Yet in this case both outward and inward internationalisation in the industry will tend to be lower than in the corresponding technological field (since the firms of related industries may be better able to diversify into this field abroad or to tap into local excellence, while

[1] Kansai Paints and Nippon Paints Co., Ltd. are according to *Chemical Week* magazine among the leading top ten Paints and Coating firms (forth and sixth respectively), ranked by 1994 sales (*Encyclopedia of Global Industries*,

within the industry local firms would find it difficult to establish similar linkages or to operate more independently elsewhere, and foreign-owned firms find the inter-knit structure of the local industry a barrier to entry).

3. Data and methodology

Already in the 1960s work conducted by Schmookler (1966) and Scherer (1965) related firm size, and the volume of investment to the determinants of the rate and direction of inventive activity as measured by corporate patenting. Growing recognition since then of the importance of technology and technological change for the competitiveness and growth of both firms and countries led to a continuous effort in the exploration of the causal relationships between patenting activity and measured economic variables. There is almost unanimous agreement about the importance of patent statistics, although there is considerable debate among scholars about the essence of what exactly is being measured. A brief examination follows, to explain how we use corporate patent statistics in what follows.

Patents are an indirect measure of (the composition of) advances in knowledge inputs into the technological learning processes of firms. They provide a good proxy measure of the cross-sectoral distribution of technological activity for large firms (Cantwell, 1993), which tend to have a high propensity to patent (Mansfield, 1986). The database used for the study consists of patents granted in the US to the largest world firms. The data presented here are patents granted to 792 of the world's largest industrial firms, derived from the listings of Fortune 500 (Dunning and Pearce, 1985).

1996).

Of these 792 companies 730 had an active patenting presence during the period 1969-1995. Moreover, 54 companies were added to these. They include (mainly for recent years, but occasionally historically) enterprises that occupied a prominent position in the US patent records, some of which are firms that were omitted from Fortune's listing for classification reasons (e.g. RCA and AT&T were classified in the service sector).

Patents granted in the US are a rich, historically consistent and often unique source of information. The patent record includes the name(s) of inventors, details about the time of application and granting of the patent, and the name of the firm to which the patent has been assigned (from which we can infer the name and location of the parent company, following a consolidation process as described below), as well as the location of residence of the first-named inventor, which as a general rule reflects the location of the research facilities that have led to the invention. Moreover, each patent document provides a historically consistent classification of the type of technology associated with each invention provided by the examiners of the US Patent and Trademark Office, who continuously update the US patent class system by reclassifying all earlier patents accordingly. Inventions have to satisfy three criteria in order to be entitled to a patent: novelty, non-obviousness and usefulness. The US system is referred to as the first-to-invent system, in contrast to the EC and the Japanese, which are first-to-file systems.

The year 1984 is used as the base year in the consolidation process. In other words firms were consolidated in their 1984 form with respect to patents granted between 1969 and 1984, but post-1984 acquisitions have been taken into account. To identify the corporate groups, companies have been grouped according to their country of origin (home country of the parent company) and allocated to the industry of their primary output, according to the product distribution of their sales. As stated already, each patent granted to the world’s largest firms has been classified into a type of technological activity. This classification scheme collects together appropriate classes and sub-classes from the US patent class system. Usually patents are assigned to several technological fields, but here the primary classification is used in all cases. For the purposes of our study patents have been aggregated into six periods (dividing 1969-1995 into six). An extensive literature discusses the advantages and disadvantages of the use of patent data as a comparable indicator of technological activity (Pavitt, 1988; Griliches, 1990; Archibugi, 1992). These comprehensive accounts aim to raise caution as to the potential problems of interpretation of these data and state the limitations of the method rather than undermining its significance.

Although a detailed analysis is beyond the scope and scale of this paper one point that is significant to what follows is worth reiterating here. Small and medium-sized firms tend to have a relatively low propensity to patent their inventions. However, we only deal with the largest and most technologically advanced firms whose propensity to patent is high. This study focuses on patenting activity by the largest firms originating from the US or from selected European countries arranged by their nationality of ownership and examines the extent of internationalisation of their research facilities, and also looks at the patenting of all the world's largest firms which is sourced from research located in the equivalent set of host countries (the US and certain European countries).

The revealed technological advantage (RTA) index is a proxy measure of technological specialisation across different fields of technological activity. In this paper the profile of technological specialisation across fields of innovative activity of a national group of firms in a specific industry (such as chemicals and pharmaceuticals), is measured by the RTA index. RTA is defined as the share of US patents granted to the group of firms in question in some given technological field, relative to that group's share of US patents in all technological fields granted to firms in the industry.

$$RTA_{ij} = (P_{ij}/\Sigma_j P_{ij})(\Sigma_i P_{ij} / \Sigma_i \Sigma_j P_{ij}),$$

where: P is the number of US patents

i is the national group of firms

j is the technological sector

The index gives values around unity. The greater the value, the more a group of firms has a comparative technological advantage in the field of activity in question. The index controls for inter-sectoral and inter-country variations in the propensity to patent (Cantwell, 1993, 2000). An equivalent index is also used to portray the pattern of technological specialisation of national group of firms as a whole (not restricted to a particular industry) relative to all other large firms in the world, either across industries or across technological fields. We use this form of the index to establish the profile of national technological strengths and weaknesses - that is, the industries in which the largest firms originating from a given country are technological leaders.

4. Revisiting the general cross-country and cross-industry pattern of internationalisation

In Tables 1-5 we examine the internationalisation of research through the US patenting activity of the largest industrial firms of the most internationalised countries, by distinguishing between patents that are attributable to research outside the home country and those due to research located in the home country of the parent company. It soon becomes evident that the use of aggregate data at a global level provides only a partial picture of the degree of internationalisation that characterises the firms of particular countries or particular industries.

Table 1 here

Table 1 sketches the overall picture of the extent of internationalisation of technological activity in the world's largest firms. It examines the share of their US patenting from research in foreign locations organised by the nationality of the parent firm through the period 1969-1995. In the world total a mild upward trend is observed. This tendency becomes much more obvious once Japanese-owned firms are excluded, and moreover a slight acceleration in the internationalisation process can be observed during the more recent periods. However, when including the Japanese-owned companies the absolute values of the world total percentages may be misleading. The relatively low degree of internationalisation of the largest US and the Japanese firms drives down the global average, such that the latter provides only weaker recognition of the more highly international orientation of European firms, because of the dominant share of US patenting accounted for by US-owned and Japanese-owned national groups[2].

However, the largest US firms experienced an upward trend in their foreign research share. In fact, US companies saw a total increase of 43% in patenting from international sources between the first and the last period. Still, their general level of patenting had in 1991-95 not yet recovered the peak attained in the 1969-72 period (patenting by US-owned companies from their domestically-located R&D in 1969-72 was 94,309 as against 94,115 in 1991-95). On the other hand, Japanese-owned firms show a very low level of overall patenting activity from international sources and there are a number of reasons that may account for this. First, the substantial strength of domestic technological activity, which has outstripped the significance of their by now quite considerable foreign research activity. Second, there is evidence that Japanese firms are more likely to locate their basic research in laboratories abroad than in Japan (Papanastassiou and Pearce, 1995; Pearce and Papanastassiou, 1996) to take advantage of the local scientific expertise, but which may feed into downstream research and technological capability at home. In addition, the relatively recent establishment of research laboratories, for instance in Europe especially in the chemical and pharmaceutical industries, might be expected in due time to bear fruit and increase

[2] Half of the US corporate patents granted to the world's largest firms are assigned to US-owned companies, and about one-sixth are due to Japanese-owned large firms.

foreign research output in the form of patenting once the investment matures (Penner-Hahn and Shaver, 1999). We emphasise a further possible explanation below, which as argued already in section 2 has to do with the interlocking vertically integrated structure of production and technology linkages domestically in the largest Japanese companies.

Two other interesting cases are the Italian and Canadian groups. The largest Italian firms (of which only 11 are large enough to qualify for inclusion), followed a rather individualistic course with a lot of ups and downs in their foreign share, but in the 1990s saw a clear increase in internationalisation (moving up to 16.47%), in common with all other national groups. The trend in Canadian-owned companies, after a drop in the 1970s and 1980s, turned upwards and an increase in international research activity was observed in the last two periods (which is not just a relative rise in the foreign ratio but a reflection of an increased overall level of activity in absolute terms).

The category of “Others” in Table 1 shows after the first two periods a growth in international research activity (in the period 1978-82 the foreign share is 22.38%) but then the tendency reverses to reach the lowest point in the last period, a mere 8.73%. This is mainly due to a compositional change away from Austrian and Finish companies towards Korean firms, which spectacularly increased the level of their research activity, but achieved this almost exclusively through research at home, as is common in the earliest stages of corporate growth and which reflects as well a close-knit local industrial structure (Lee, 1998) similar to that of Japan (Samsung’s foreign share in 1991-95 was 3.4%, while in the same period the share of the Lucky Group remained at only 1.6%).

The impression of the internationalisation of research activity by large firms is greatly enhanced when the largest European-owned firms are considered separately. The average rate of internationalisation is about thirty percent of total technological development located abroad, while most of the foreign-located research activity of the largest European-owned companies has been hosted outside Europe in the US, particularly for UK-owned, German-owned, and Swiss-owned firms (Cantwell and Janne, 2000). In other words, the explanation for the higher research share of European owned firms is not merely that more activity spills across borders within Europe due to geographical and cultural proximity and increased European integration.

The buoyant internationalisation of European-owned research is consistent with the findings of Table 1 in which the countries of Group A[3] are considered separately. The general level of international activity was much higher (28.41% against 10.04% in 1969-72, and 34.98% against a mere 11.27% for the world total in 1991-95, or even as against the somewhat higher 16.53% excluding Japan). The tendency towards the internationalisation of research is much more distinct.

However, even within Group A, not all national groups present the same highly international profile nor do they follow the same course over time. All nationalities within this group, with the notable exception of Swedish-owned firms, faced a prolonged lethargic period in the trend of internationalisation during the 1970s.

UK-owned firms in particular, started with a relatively high degree of internationalisation (43.08%), then following the general trend, held a fairly stable foreign share in the 1970s but in the mid-1980s saw a renewed increase and by mid-1990s became the most highly internationalised group (55.79%), an overall increase of 12.71% (see also Cantwell and Hodson, 1991).

In sum, the overall picture in Table 1 shows that in line with the first background proposition outlined above, the largest firms which originate from small countries such as Sweden, Switzerland, and especially the Netherlands (as well as Belgium) tend to have a much higher level of patenting from international sources than do those of larger countries. Dutch firms have been consistently highly international since the 1960s (on average over half of their research is performed abroad) and they experienced a noticeable increase in the 1990s (for the Netherlands see Cantwell and Janne, 1999b). Swiss firms reached their peak at the end of 1960s, and after a slight slippage back regained lost ground in the last period (1991-95), and even reduced the difference with the national groups of the Netherlands and the UK. At this general level the UK is the major exception to the proposition of an inverse relationship between the size of a domestic technological system and the internationalisation of that country's largest firms. The high degree of internationalisation which British-owned firms have inherited is linked to the role of Britain as an imperial power with strong overseas interests, and a long-standing liberal economic policy with respect to inward and outward capital movements as well as trade. In contrast, Swedish multinationals remained constrained for longer by the

[3] A functional distinction is made between the national groups under particular investigation here and other nationalities of ownership. Moreover, both the sub-totals of our sample group and the world total without Japanese

needs of the more locally integrated domestic economic and technological system of which they were part, despite the smaller size of their home country - and so they evolved internationally only in a 'tortoise-like' fashion (Zander, 1994).

French and Swedish firms, although still followers in the process, have made giant leaps towards internationalisation (both raised their international activity by approximately 25% over the entire period) and are catching up with the leaders. This results in a much lower dispersion in the rates of internationalisation within Group A in recent years. Swedish-owned companies, in a continuous upward trend towards internationalisation had two dramatic increases, one in the late 1970s (from 19.90% during 1973-77 to 26.20% during 1978-82), and a second in the early 1990s (from 30.60% in the period from 1987-1990 to 42.42% between 1991-1995). The largest French firms were latecomers and the least internationalised of group A at the end of the 1960s (8.16%), and they remained at very low levels and even experienced a slight decline in their foreign research share during the 1970s. However, this changed dramatically in the last two periods at which time French firms even considerably surpassed the German rate of internationalisation (see also Cantwell and Kotecha, 1997). Finally, although the German-owned group has seen a substantial increase in the foreign research share since the mid-1980s (achieving an overall rise of nearly 8%), the largest German companies are still lagging behind as the most centralised national group in our European sub-set (Cantwell and Harding, 1998).

Tables 2.1 and 2.2 here

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owned firms have been calculated. The European countries we focus in this work and label Group A is comprised of the largest national firms from France, Germany, Netherlands, Sweden, Switzerland, and the United Kingdom.

Table 2.1 traces the comparative advantage in innovation of national industrial groups over the 1969-95 period as a whole, in order to be able to apply the framework suggested by Figure 1 and to identify the national origins of the technological leaders in each industry. To start with, smaller countries have a narrower range of industries in which their firms compete successfully as worldwide technological leaders. Table 2.2 gives instead the profile of national competencies in a variety of technological fields. Firms, in general, sustain a wider research in a variety of technological fields to support a narrower range of products. As a result of this the gap between large and small countries in the cross-sectoral dispersion of research is less pronounced than in Table 2.1. Moreover, a technologically competitive industry in most cases presumes a competitive primary technology and vice versa. However, this does not hold for computers in which two different national groups of firms share leadership. US-owned firms lead in the computing industry, while Japanese-owned firms have the strongest technological advantage in the development of the corresponding primary technologies, showing how Japanese firms are strongest in downstream industrial applications of computerised methods. In aircraft and aerospace UK-owned firms have an advantage solely in the technology (unlike US-owned and French-owned firms, that are leaders in the industry and in the technology), which owes to the British motor vehicle component firms whose expertise lies in engines in general.

Table 3 here

Table 3 provides a view over the 1969-95 period as a whole of inter-industry, and cross-national group comparisons of the extent of internationalisation of technological development in the largest firms. From the world total column it is obvious that not all industries are internationalised to the same extent. Among the most internationalised on average are food (22.24%), pharmaceuticals (16.16%), petrochemicals (15.08%), and chemicals (14.21%). With the exception of food these are research-intensive industries which would run contrary to the second background proposition, but it might still be argued that they are internationalised in support of access to markets (pharmaceuticals is a highly regulated industry at the level of product distribution), or natural resource extraction (in the case of oil).

However, there is not an even distribution of international R&D across national groups and industries, which would reflect in a uniform fashion their average contribution to foreign-located innovative activity. In food, as suggested by Figure 1 the leading groups, namely UK-owned (66.42%) and Swiss-owned firms (69.12%) as well as French-owned firms (61.79%), are the national groups responsible for the high foreign share in the world total (22.24%), but in this industry internationalisation is not high for the US-owned (6.53%) or German-owned companies (0.00%). In chemicals (world average ratio 14.21%), the high overall share abroad is primarily due to the high internationalisation of German companies, the world leaders in this industry (20.76%) which is again consistent with the scheme of Figure 1. In pharmaceuticals (world total 16.16%) it is the firms of the US (10.99%), Switzerland (59.36%) and to a lesser degree Germany (17.98%) that sustain an above-average industry foreign share to match their technological prowess (Table 2.1), and in petrochemical products the high overall foreign share is due entirely to the largest British-owned firms (83.90%), once more the technological leaders in this industry. At the other end of the spectrum, the instruments industry is one of the least internationalised according to the world total (a mere 3.37%), but not for Swedish-owned firms (32.13%).

Table 4 here

Table 4 reorganises the same data instead by the type of technological activity rather than the industry of corporate ownership, and this differs from Table 3 by virtue of the ‘multi-technology’ character of production in any industry (Granstrand et. al., 1997). In the chemical and pharmaceutical industry among others for example, mechanical engineering innovations are of great importance for production processes (Pavitt et. al., 1989). Partly as a result of this spread of the development of many technologies across industries, the dispersion of internationalisation of technological sectors in Table 4 is narrower than for the world total of industries in Table 3**.** Hence, the larger number of sectors is around average. Notably above average is pharmaceutical technological activity (18.79%); while, below average are the fields of aircraft and aerospace (2.58%) and motor vehicles (5.57%).

Most of the international innovation in Table 4, as in Table 3, is done by only a handful of national groups. Food, for example, is a technological sector on which stronger German-owned firms in industries other than food have placed the greatest emphasis upon diversifying into abroad (26.97%), while from a leading position in the industry US-owned companies abroad have very low activity (at 4.91%). In pharmaceuticals the foreign share is highest by the relevant national standards for German-owned (26.96%), US-owned (11.32%) and to a lesser degree Swiss-owned firms (54.25%) to which the diversification abroad of the strong German and Swiss chemical majors makes a contribution, while it is very low for French-owned (13.01%) and British-owned companies. The international activity of UK-owned firms in pharmaceuticals (30.65%) is much below the national average, owing to the fact that the UK has become a major international centre for the development of pharmaceutical technology, and so UK-owned firms conduct much of their research at home, one of the few cases in which they come closer to a 'large country' pattern of conserving much of their effort within their domestic base.[4]

Tables 5 and 6 here

Turning to the organisation of these data from the perspective of inward rather than outward investment, the focal point in Tables 5 and 6, we examine the degree of foreign penetration in each of our selection of host countries. In Table 5 the foreign shares of local activity are classified by industry and in Table 6 by the field of technological activity as derived from the US patent class system.

Considering the world as a whole in Table 5 (as in Table 3), foreign penetration is highest in the industrial sectors of food (22.24%), pharmaceuticals (16.16%), petrochemicals (15.08%), chemicals (14.21%), and machinery (12.47%).

[4] An indication of countries' competitiveness is given by the number of start-ups in the dynamic sector of biotechnology: "According to a report by Ernst & Young released today […] Germany has 225 biotech companies, against 270 in the UK. Five years ago, Germany had almost no life science start-ups at all. France, traditionally Europe's second center for biotechnology, is a distant third with 150 companies. Behind it comes Israel, Sweden, Switzerland and the Netherlands." (Financial Times 1999).

Looking more closely, however, host country variations again suggest a more complex picture which reflects the pattern suggested by Figure 1. The foreign penetration of the food industry is much below average in the UK (15.45% as against the national average of 33.73%) in which local firms are technologically strong (Table 2.1). In pharmaceuticals Switzerland, Sweden, France and Germany have low levels of foreign research penetration, in line with Figure 1 in the case of the Swiss and German leaders, while the UK has attracted considerable foreign attention. The UK has an advantage in the development of pharmaceutical technology (Table 2.2) enhanced by a virtuous cycle of interaction between indigenous firms and inward investment from the US (Cantwell, 1987, 1989). The UK pharmaceutical case might be thought of as an exception to Figure 1, since it is a centre of excellence in which strong indigenous company activity does not deter but encourages foreign-owned innovation locally, and indeed encourages indigenous firms to carry out more development in their home base than in other UK industries. It seems that there are only a few cases of such centres of excellence in which inward investment is encouraged and outward investment discouraged in the same industry, but such centres do seem to be exceptional and are difficult to create. In chemicals Switzerland and Germany (whose firms are the leaders - see Table 2.1) together with the Netherlands have witnessed minimal penetration in comparison with the tendency in the world as a whole. Moreover, the two countries of major comparative strength in coal and petroleum product technology - that is the UK and the Netherlands - have both developed strong research bases in petrochemicals at home that have allowed little scope for foreign penetration. Instruments, an industry largely disinclined towards internationalisation (the average for the world total is

3.37%), gains substantial appeal in the case of the larger European countries (France, UK and Germany), in which the local industry has virtually no technological presence, but in which field there are greater efforts by the local firms of other industries (comparing Tables 2.1 and 2.2), so providing a point of attraction without competitive deterrence.

The world total in Table 6 reveals again a quite different view of international activity when considering the type of technological activity (as opposed to the industry) that is sited abroad. As seen already from the identical world total column in Table 4, differences with the equivalent industries shown in Tables 3 and 5 are apparent in petrochemicals and in chemicals that now feature below average, while mechanical engineering is now above average. This suggests that oil companies use their foreign-located development more for mining and the mechanical technologies involved in the extraction of crude oil, rather than to innovate in petrochemicals themselves. A similar pattern, even if to a lesser extent, may apply in other industries. The level of international activity in food is also considerably less as a technological field as opposed to an industry (Cantwell and Santangelo, 1999, 2000). Thus, although in terms of the absolute level of activity firms tend to do most abroad in the same line of innovation as at home (Patel and Vega, 1999), namely in the primary technological field of their own industry - it is after all scarcely surprising that chemical firms develop mainly chemical technology and so on, whether at home or abroad - in relative terms in their foreign-located activity they tend to diversify away from the primary field of their own industry, becoming proportionally more active in the development of complementary and supporting technologies.

In Tables 7, 8, and 9 we add into the story (i) the technological specialisation across fields (primary and other) that characterise national groups of firms in three major industries; (ii) the spatial distribution of such specialisation between home and foreign-located activity; and (iii) the profile of technological specialisation by foreign-owned firms that host countries attract in each of the industries in question.

Tables 7, 8 and 9 here

5. The explanation of variations between national industrial groups of firms

Although national groups of firms have distinctive technological profiles, a comparative analysis of their competitive position, their degree of internationalisation and of foreign-owned inward investment in the equivalent countries reveals some common underlying determinants, which have been illustrated in Figures 1 and 2 above. The most technologically competitive national industrial groups tend to be also as expected the most internationalised in the cross-country distribution of each country of origin. However, the home countries of these leading national groups tend to receive comparatively lower inward investment in technological development in the equivalent industries, as proposed in Figure 1.

UK-owned firms lead in the food industry as well as in the food technological sector (RTA=4.74 and 2.41 in Tables 2.1 & 2.2 respectively), to be followed only at a distance by US-owned and Swiss-owned firms. British-owned firms are also highly internationalised in both the food industry and the food technological field (66.42%

and 61.72% in Tables 3 & 4 respectively). However, foreign-owned firms when considering technology-based investment in the UK, seem overwhelmed by indigenous competitiveness, and have only a modest innovative presence in the country (15.45% and 20.73% in Tables 5 & 6 respectively). Moreover, it is clear that UK-owned food industry firms are more internationalised as a whole than are UK-owned firms in the development of food technology as such (that is, the food firms conduct abroad the development of non-food technologies to a greater extent than at home); while foreign-owned firms are more attracted to the UK to develop food technology than in the food industry itself (it is the firms of other industries that in part source food-related technology from a UK location).

Likewise, Swiss-owned, and in particular German-owned firms are the technological leaders in the chemical industry and technological sector (Tables 2.1 and 2.2). Both national groups have a high degree of internationalisation (41.55% and 20.67% in Table 3). Swiss-owned firms have become just slightly more internationalised in the primary technological sector (43.41% in Table 4) than in the industry (which may be due to the even greater strength of the Swiss pharmaceutical firms, and their emphasis on the development of related chemical technologies abroad), but the German group remains consistent with Figure 1, and is more active internationally in the chemical industry than in chemical technologies (16.24% in Table 4). However, both host countries (Switzerland and Germany) receive minimal attention from foreign-owned research in this industry (3.78% and 6.49% in Table 5), although the local sourcing of chemical technologies by foreign-owned firms of other industries is indeed slightly higher (4.92% and 8.09% in Table 6). This is consistent with the pattern of Table 7.3 which shows that in inward investment in Germany from foreign-owned chemical and pharmaceutical firms, the local operation of the companies concerned are technologically specialised in the mechanical engineering (1.95) and aircraft (2.26) fields, but not in the primary chemical technologies. Foreign-owned chemical firms in Switzerland too are specialised in inward research-based investment in a number of technological sectors, such as mechanical engineering (1.70), metals (1.41), office equipment (1.27) and even food and instrument technologies (1.17), but not in chemical technologies.

Swiss-owned and US-owned firms have the strongest technological base in the pharmaceuticals industry (3.98 and 1.24 respectively in Table 2.1). Swiss-owned companies are very active internationally in this industry (59.36% in Table 3) and also, although to a lesser extent, in the corresponding technological sector (54.25% in Table 4). At the same time Switzerland has little to fear from foreign penetration in either pharmaceutical technologies (4.13% in Table 6), or the even weaker inward innovation from foreign-owned firms in the industry (2.57% in Table 5). As discussed above in the case of chemicals, Table 7.3 shows that foreign-owned chemical and pharmaceutical firms in Switzerland specialise in innovative activity in a number of technologies, but not in pharmaceutical technologies.[5] US-owned firms in the pharmaceutical industry are, with respect to the US average, quite internationalised in both the industry (10.99% in Table 3), and slightly more in the primary technology (11.32% in Table 4). Further, despite the accessibility of the US as a host to foreign-

[5] However, although the sector is subject to small number problems if following the ground rule that it has less than 1,200 patents (Cantwell and Kotecha, 1997; Cantwell and Harding, 1998), metal and mechanical engineering firms (Table 9.3) do a considerable amount of innovation in pharmaceutical technologies in Switzerland (2.77).

owned innovation, much more is accomplished in the technological field than is achieved in the industry itself (9.91 and 15.78% in Tables 5 & 6).

The technological advantage of Swedish-owned firms in machinery is without any serious challenge from other national groups that cluster around average. Swedish-owned firms in this industry are highly internationalised in their organisation of innovation, even if the internationalisation of the technology is just above that of the industry (32.25% and 34.03% in Tables 3 & 4). The relative strength of the development of mechanical technology abroad may be due to the close relationship between the mechanical engineering industry and other industries in Sweden, in particular electrical equipment (RTA of 1.65), but also aircraft and aerospace, food and pharmaceuticals (although the latter sectors are not very important in absolute terms) as Table 9.1 suggests from the perspective of the distribution of technological efforts of the Swedish metal and machinery firms at home. On the other hand, innovation by foreign-owned firms in Sweden is consistent with Figure 1, since although low, innovation in the relevant technology is greater than it is in the industry (1.48 and 7.22% in Tables 5 & 6).

Dutch-owned firms have the strongest position in the electrical equipment industry (3.29 in Table 2.1) and in the development of the primary technologies (2.23 in Table 2.2). Correspondingly, Dutch-owned firms are highly internationalised in both the industry and primary technology (51.93% and 52.96% in Tables 3 & 4), and the Netherlands has a low degree of penetration by foreign-owned research, but one which is higher for the firms of other industries accessing local innovation in electrical technology (4.11% and 6.76% in Tables 5 & 6). To complement the picture, RTA figures in Table 8.3 show clearly how foreign-owned firms in the Netherlands in the same industry do not specialise in the development of electrical technologies (0.90) but invest instead in activity in other technological fields, such as motor vehicles (4.24), chemicals (2.10), and mechanical engineering (1.82) technologies.

In the computing industry and field of technological activity, US-owned firms are without hesitation the industry leaders, and have a high share in foreign-situated research, which is higher in the industry than in the technological sector (11.41% and 7.21% in Tables 3 & 4). However, Tables 5 and 6 show once again an indication of entry deterrence in their own home country. Foreign-owned research in the US industry is very low especially when compared to the high interest in computing technologies (5.32% in Table 6), and suggests the interest of foreign investors from other industries in acquiring US computing technologies. In addition, Table 8.3 indicates that, although inward investment in computing technologies is above average (1.06), foreign-owned electrical equipment and computing firms in the US favour investment in the electrical equipment (1.18) and motor vehicle (1.14) technological sectors.

In motor vehicles German corporate strength is quite prominent as Tables 2.1 and 2.2 show (1.58 and 1.72). The industry, on the whole, is moderately internationalised in terms of innovation and the German-owned national group is consistent with this picture (8.32% and 9.24% in Tables 3 & 4). However, foreign-owned innovation, although low in Germany, is higher than what one would expect for a leading group (8.35% and 7.01% in Tables 5 & 6), which may be due to the relocation of the technological efforts of the UK component companies in Germany at the time when the indigenous UK vehicle industry declined. UK competitiveness on the other hand is exaggerated (1.24 in Table 2.1) because the motor-vehicle industry includes both a relatively weak vehicle assembly industry and the much stronger vehicle and transport component firms. Hence, competitiveness in the most immediate technological field is low (0.65 in Table 2.2), while it is high in the mechanical engineering technological field (1.36 in table 2.1 while the mechanical engineering industry has only average competitiveness 1.01 in Table 2.1). This amalgamation of a weak car industry and much stronger component firms helps to account for the average industry but the somewhat higher technology internationalisation (always in respect to the relevant country and industry average figures: 24.39% and 19.20% in Tables 3 & 4). Inward innovation conducted by foreign-owned firms in the UK shows the same mixed effect (13.18% and 20.79% in Tables 5 & 6), suggesting again that a more disaggregated level of investigation has to be employed in order to assess the different technological strengths and the different degrees of internationalisation of each sub-group of firms. Of course, in the most recent years very little locally-owned vehicle assembly activity remains in the UK.

The leading national groups in aircraft and aerospace, the US-owned firms (1.65 and 1.32 in Tables 2.1 and 2.2), and the French-owned firms (1.35 and 3.07 in Tables 2.1 and 2.2) operate in an industry with a relatively low propensity to patent. However, despite the difficulties of small numbers, and taking into consideration the special situation of this industry, both the US and French cases conform to the theoretical framework of Figure 1. US-owned firms have high - with respect to the industry - outward internationalisation (2.34% in Table 2.2) while the US has low inward investment in the technology (0.86% in Table 6, but 0.00% in the industry in Table 5). Comparing the aircraft industry with the national average, France as well has much lower inward investment (2.85% and 4.76% in Tables 6 & 7) than the extent to which its firms engage in outward development abroad (3.83% and 0.90% in Tables 4 & 5**)**. Furthermore, inward research activity by foreign-owned firms in both countries is much higher in the primary technological field than it is in the industry as a whole (see Tables 5 & 6).

UK-owned firms in coal and petroleum products (oil) lead the industry and technological field (2.79 and 1.56 in Tables 2.1 & 2.2) and have a long-standing international tradition (83.90% in Table 3 and 68.74% in Table 4). In comparison, in line with the contentions of Figure 1, foreign-owned innovation in the UK remains at exceedingly low levels in both industry and technological field (19.43% and 18.32% in Tables 5 & 6).

However, the reverse trend is observed in the metals industry, in which localised user-producer interaction with the firms of other industries is often of great importance in innovation. As illustrated in Figure 2, we expect to observe considerably lower internationalisation in this case than the strength of the relevant national groups might otherwise indicate, accompanied by a consistently higher internationalisation of the primary technology with respect to the industry. Likewise, foreign penetration of the industry in a centre with strong indigenous firms is as expected at a lower level still, while the relatively higher level of foreign-owned innovation in the technological field - compared to the industry - is also in line with the framework suggested in Figure 1.

Swedish-owned companies are the technological leaders in the metal industry and the metals technological field (RTA is 2.37 and 1.80 in Tables 2.1 and 2.2). The Swedish-owned industry's internationalisation is relatively low (18.89% in Table 3) while the internationalisation of the technological field is moderate (25.83% in Table 4). The RTA figures in Table 9.1 in the case of Swedish-owned mechanical engineering firms (see also discussion above), suggest that the cause may be the close connection with other firms situated in Sweden. Foreign-owned innovation, although at a low degree, is higher in the technological field than in the industry, indicating again that local capabilities are tapped into indirectly more by non-metal industry firms (1.81% and 7.89% in Tables 5 and 6). This is in line with the Tables 7.3 and 8.3, which show that metal technologies are noticeably accessed locally by foreign-owned firms in the chemical and pharmaceutical (2.84), and electrical equipment and computing (1.11) industries respectively.

Besides the Swedish-owned, German-owned and French-owned firms are leaders in the metals industry too (2.19 and 1.34 in Table 2.1 respectively). Both national groups and their home economies follow patterns that are consistent with Figure 2. They have a moderate level of internationalisation that is more prevalent with respect to the primary technological field (12.73% and 10.29% in Table 3) than in the metals industry (7.79% and 8.83% in Table 4). Moreover, inward investment in the industry is lower than is the level of outward internationalisation with respect to the relevant national averages, and more to the point, the industry is significantly less affected by foreign penetration (9.87% and 11.20% in Table 5) than the field of the primary technology (28.78% and 20.37% in Table 6). Furthermore, foreign-owned specialisation in metal technologies in Germany in the industry (1.03 in Table 9.3) and the higher RTA figure for foreign-owned local specialisation in metals in the electrical and computing industry (1.27 in Table 8.3) is an additional indication of the difficulty foreign-owned direct competitors may face in their effort to tap into innovation in the primary metal technologies, and suggests that local German technological resources are more easily accessed indirectly by firms that are not competitors in output markets. The same is true, although to a lesser extent, for France, in which foreign-owned metal and machinery firms prefer to develop locally the non-primary instruments (1.61 in Table 9.3) and the less strong mechanical engineering technologies (1.40 in Table 9.3) rather than those of metals (0.70 in Table 9.3).

Although the theme of Figure 2 is most obvious in the case of metals, the same internationalisation-suppressing effect is relevant to other national industrial groups for which a strong indigenous advantage is inward-looking. The higher the degree to which innovation depends upon localised inter-industry linkages within or between companies, the less will be the imperative and the capacity to internationalise, not because of the inability to compete in markets on a global scale, but instead because the main driving forces behind innovation lie in the form of location-specific relationships with other local industries.

Even if this is true, to some extent, for a number of national industrial groups, it is in Japan that this framework has greatest relevance, due to the particular form of historically developed business organisation as in the keiretsu structure (hub and spike). Japanese-owned firms have a leading position in motor vehicles (1.82 and 2.24 in Tables 2.1 and 2.2), instruments (2.46 and 1.52 in Tables 2.1 and 2.2), and electrical equipment (1.54 and 1.29 in Tables 2.1 and 2.2). Yet the internationalisation of innovation in these industries is moderate in terms of both industry and even country levels, and in all three cases internationalisation is higher in the local resources from the development of primary technologies than in the corresponding industries (in motor vehicles 0.81% and 0.84%; in instruments 0.77% and 0.95%; in electrical equipment 0.92% and 1.17% in Tables 3 & 4 respectively); Further, inward penetration from foreign-owned firms, apart from in motor vehicles, is very low in Japan, and local resources from the development of primary technologies are more notably accessed by the technology sourcing strategies of foreign-owned companies in other industries (motor vehicles 0.81% and 0.84%; instruments 0.77% and 0.95%; electrical equipment 0.92% and 0.95% in Tables 5 & 6 respectively).

6. Summary and conclusions

Our results support the conclusions that first, there is no single, uniform pattern of internationalisation of the corporate research and development in an industry which holds across different national groups of firms with different degrees of technological strength in the industry in question; and second, penetration in locations of domestic technological excellence tends to be low in most host countries. Hence, while Patel and Pavitt (1988) have emphasised that the internationalisation of corporate technological activity is on average greatest in low research-intensive industries such as food products (to adapt to local consumer needs and demand-side conditions) or resource-based industries such as oil (to facilitate extraction processes), this appears to be only a rather partial story, and a potentially misleading one since it is derived only from an analysis of global industry averages, without taking into account substantial cross-country variations in the industrial distribution of foreign-located research. From positions of technological strength, firms in science-based industries such as chemicals, pharmaceuticals or computing can often become highly internationalised and develop cross-border networks of diversified and locationally specialised innovation; while if technologically weak, firms in industries such as oil and food tend to have little research abroad. What is more, technologically leading firms in low research-intensive industries such as food may utilise their international networks to tap into complementary science-based excellence abroad in fields such as biotechnology (rather than simply to adapt their products to the needs of local markets). Conversely, science-based companies may access mainly engineering skills in foreign locations, and develop machinery and instruments outside their home base.

Tables 3 and 4 show how individual national groups expand their research activities in a varied manner that has little to do with the average position of the relevant industry and technology. First, only a few national groups are responsible for the foreign-located research activity of the most internationalised industries. Among the most internationalised industries, food is internationalised mostly due to the leading UK-owned and Swiss-owned firms, as well as to French-owned companies, foreign activity in pharmaceuticals is largely attributable to the leading US, Swiss, and German firms, development abroad in chemicals is due mainly to German-owned companies which are the technological leaders in that industry, and foreign research in petrochemicals is almost exclusively due to the leading British-owned firms abroad.

On the other side, in instruments which is one of the least internationalised industries (in the global average position), there is internationalisation which is due to Swedish firms, in an area in which they seem to be less constrained by domestically integrated structures than in other industries. In the most internationalised sectors of food, pharmaceuticals, chemicals and oil the main contributors are the national groups that are technological leaders in the relevant industries. Second, the greatest internationalisation occurs in technological areas that do not always coincide with the core fields of the most internationalised industries, especially when individual national groups are considered separately. Significantly above average in its degree of internationalisation is the pharmaceutical technological field, which is due again largely to German and US firms, and to a lesser extent due to Swiss companies, but the internationalisation of food technologies is in good measure due to the diversification abroad of German firms from other industries. Likewise, unlike the indigenous companies of the comparatively weak computing industry in Germany, German firms in other industries show great interest in developing computing technologies abroad. Further, unlike the high internationalisation of research in the coal and petroleum product industry, research in petrochemical technologies is below average in its degree of internationalisation. Moreover, foreign-located activity is lowest not only in aircraft but also in the motor vehicles industry and technological area (see the totals in Tables 3 and 4) in contrast to what might be expected if the siting of research abroad were simply to facilitate adaptation to foreign markets. Internationalisation in the motor vehicle industry, like in the Japanese national system of innovation as a whole and to a lesser extent in the Swedish system, seems to be constrained by the importance of localised vertically integrated linkages for generating and transmitting innovation.

Tables 5 and 6 show, from the host country's perspective, in which industries and technologies the world's largest firms tap into local host country research expertise, and the degree of accessibility they enjoy. Countries such as the US, the UK and Germany, while they play host to local technological development in a wide variety of industries and technologies, do not tend to experience penetration in their domestic research to the same extent in those activities in which their indigenous firms are strongest. Foreign ownership of research facilities is of little significance in the US in computing, for instance, in the UK in food (in both the relevant industry and technological field), in both countries in petrochemicals (at least in the technological field), and in Germany in chemicals and pharmaceuticals (in both the industry and technological area). These are all signs of the deterrence of technological leadership. However, from a weaker position France is to almost the same extent open to foreign-owned research as its indigenous firms are themselves internationalised in food and computing, but to a much lesser degree in mechanical engineering technologies (in comparison with the machinery industry). Lastly, from a position in which local strength comes mainly from the firms of other related industries, although the Swedish instrument industry is open to foreign-owned firms, penetration in instrument technologies is minimal.

To conclude, while we must be careful in our cross-country cross-industry analysis that in looking at the trees we do not lose sight of the forest, we have seen that restricting ourselves to a panoramic or 'average' view may be misleading if it skates over the complexity that is associated with substantial variations in the quality and type of the timber. Our picture is altogether richer when we compare the experiences of different national groups with varying strengths in the degree of their internationalisation of corporate technology at an industry level and at the level of technological fields instead of just examining the totals that represent global average values.

What is especially notable from our findings is the restatement they provide of the significance of technological ownership advantages as a condition for internationalisation (Cantwell, 1989; Dunning, 1995). Some commentators have attempted to present the latest phase of asset-seeking investments of MNCs abroad which promotes their corporate technological diversification - a facet that we have also emphasised ourselves, both here and elsewhere (Dunning and Wymbs, 1999; Cantwell and Piscitello, 2000) - as somehow in conflict with the notion that MNCs require some initial ownership advantages. Instead, we observe that the augmenting and strengthening of ownership advantages through internationally dispersed innovation is complementary to the initial advantages of firms developed in their home base. It is the technological leaders of each industry with the strongest inherited ownership advantages that are best able to develop an international network of innovation (Cantwell, 1995) and so extend their advantage.

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