Path-dependency and coherence in international networks of technological innovation: An analysis at the country and industry level

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Abstract

Much of the research on internationalisation is based on assumptions that date from Vernon's product cycle. However, the extent of applicability of these traditional assumptions for the recent period has been questioned by Cantwell and Kosmopoulou (2002) through the use of patenting data for the worlds' largest firms, organised by nationality of ownership and by primary industry. It is argued that today the internationalisation of innovative activity varies across countries and industries according to the degree of technological competitiveness of different national groups within each industry (leading groups are more internationalised, but also more diversified in their foreign research strategies), and according to the significance for innovation of localised inter-firm interdependencies in the home country (tightly coupled local innovation systems may constrain internationalisation). In this paper first, we focus on three main groups of industries to explore these contentions in greater depth and extend the broader theoretical framework constructed for national groups of industries in general, and second we explore the role of inter-industry networks of corporate technological development at a national level.

Corporate technological diversification at home or abroad through internationalisation can be seen as two complementary corporate strategies that have to balance the increasing necessity to tap into new technological areas while retaining knowledge links with other actors in the home base. At home strong industries tend to diversify and to connect in their home country with the primary technologies of other major national industries, often at the expense of a strong focus upon their own primary technologies. For some countries (like Japan) the amalgamation of technological competences at a national level has a particularly strong influence upon the diversification of research activity. Abroad, the international diversification of corporate technology has recently tended to develop not any longer just in order to support the servicing of international markets but also to tap into new sources of technological competence, which may include mutually beneficial technology spillovers between the subsidiary and a host industry or industries. For some industries the nature of production and for some countries historical contingencies make this necessity to maintain close inter-industry links essential. Historical path dependency is also an important factor in an industry's technological structure as inter-industry technology linkages run mainly from the oldest established and/or stronger industry as a source to the one that has more recently been established or has a lower competitive advantage as a recipient. Moreover, the relative local innovative efforts of foreign-owned firms from the same industry developing their primary technologies in the leading centres are always lower than the equivalent value for the domestic comparative advantage of indigenous firms.

While it is widely accepted that the sythesis of a firm's capabilities is more than the sum of the constituent parts, in much of the current literature there is an implicit assumption that scale within an industry matters more than the scope of inter-company networks of technological capabilities. However, national systems of innovation imply interrelated country-specific technological profiles. Our results show that successful national cases rely upon consistent inter-industry networks of technological innovation often with an historical path dependency. Such networks are successful in combining technological competencies gained from one industry to benefit other industries. The policy implications of these findings would be in placing emphasis first, on the development of networks to co-develop competencies/capabilities and to facilitate the passing of technological capabilities gained in one industry to the benefit of other industries and second, to encourage the development of general purpose kinds of technologies.

1. Introduction

Firms and large multinationals in particular need a large number of technologies to support the production of their usually extensive product diversification (Granstrand, Patel and Pavitt, 1997). This phenomenon is enhanced by recent developments in communication, the fall of economic and other boundaries and the development of ever more technologically complex products. Although most research has been focused on firms' primary technological field (eg. chemical technologies for chemical firms) an extended portfolio of corporate technological competencies is necessary to enable firms to compete successfully. While different industries need an amalgamation of different technologies to support their activities there are a number of technologies of a very 'pervasive nature' for many sectors of the economy. These technologies that abide by with the characteristics explored in the work of Breshahan and Trajtenberg (1995), are termed general purpose technologies (GPTs) and it is their composition and evolution that defines technological paradigms and signals their transition from one to another[1].

Different considerations may be relevant when international specialisation is concerned. Firms may pursue different strategies in their research abroad, through a division of labour with their technological efforts at home. There is a literature that explains the internationalisation of corporate technology on the basis of the explanatory framework Vernon's product cycle. In this context first, small countries internationalise more than larger countries; second, firms in less research intensive industries internationalise proportionally more than firms in high research intensive industries and third, technologies developed abroad should be technologies primarily supporting the adaptation of products for local markets, rather than developing new competences for the international corporate group as a whole (to enhance the subsidiaries' productivity). However, there seems to be only limited empirical support for such a framework of internationalisation from the patenting activity of firms during the years 1969-95.
Firms diversify internationally their corporate technology not any more just in order to support their servicing of international markets but also to tap into new sources of technological competence, which may include mutually beneficial technology spillovers between the subsidiary and a host industry or industries (ie. which may facilitate local spillovers of an inter-industry kind).

It is common practice for academics to measure the strength of an innovative economy with aggregate figures of R&D or scores of patents and thus in many ongoing analyses there is an inherent implicit assumption that scale is the only important factor when the innovative capacity of country is examined. This undue emphasis on the scale of corporate technology figures disregards the role of innovation as part of a network of technological capabilities developed by firms, and national industrial groups.
It is widely accepted that the sum of a firm's capabilities is more than the aggregate of the constituent parts, and the concept of economies of scope in corporate technology is employed at the micro, firm level analysis to explain the insurgence and success of large diversified firms. It is suggested that one important reason for firms' diversification, both at home and abroad, is in order to take advantage of economies of scope. In this process the patenting data show that during the period 1969-95 some national groups of firms are

more successful than others in successfully combining their limited innovative resources into coherent networks of technological innovation. Such excellence in the construction of coordinated networks of corporate technologies could have a major impact in national economies and potentially provide an explanation for the differential growth among national economies and the failings of national economies to achieve continuous successful growth.

Moreover, even once successful, coherent networks of innovation may eventually become less functional (or altogether obsolete) and can impede national growth. In particular, countries with once successful national systems of innovation can, if policy makers are not alert, be trapped into previously prevailing paradigms and fail to recognize evolution.

2. Data and Methodology

In this paper the data used are patents granted in the US to the world's largest firms during the period 1969-95. US patents are an established indirect measure of innovation, closer to production -than other indirect measures- and consistent historically. The study focuses on the patenting activity of the three most important -technologically- groups of firms from a selection of European countries (Germany, the UK, France, Netherlands, Switzerland, Sweden), the US and Japan.

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.

Much of the research on internationalisation is based on assumptions that date to Vernon's product cycle and have been disputed in length in earlier work (Cantwell, 1995; Cantwell and Kosmopoulou, 2002). It has been argued that rather than the research intensity it is the nature of the technology and the relative comparative strengths of each national group of firms within an industry that has a greater impact on the degree of internationalisation of innovative efforts. In this paper we develop this thesis further focusing more on three main groups of industries and their technological diversification. However, the data used here are only in part comparable with the data presented in Cantwell and Kosmopoulou (2002) for a number of reasons concerning the arrangement and use of the data as explained below.

First, the analysis of this paper is concerned with corporate technological diversification and internationalisation within a specific industry of output while the previous work referred to the technological diversification of firms from all industries organised by national group. The existence of intra-industry technological diversification plays a small but sometimes significant part in the analysis of the data organised by technological activity where all technological activity of all firms -from all industries- is included since it challenges the assumption that most of the technological activity originates from the primary industry (i.e. the bulk of chemical patents come from chemical industry). However, this assumption is not necessarily true even though it may be true that a high share of patenting by chemical firms is in chemical technology. In other words, in the example given above with the chemical industry and the primary chemical technologies, the aggregate number of patents in chemical technologies performed in a country from non-chemical firms may exceed the number of chemical patents from that country's chemical industry[2].

Second, in this study firms are organised in a different way than previously. In Tables 3, 4 and 5 firms belong to a narrowly selected combination of industries closely related historically in their technological activity. The significance of this grouping is in the shift in the technological composition of the historically produced patents in one direction or another. In Table 3, for instance, firms in the chemical and pharmaceutical industries have the bulk of their patenting activity in chemical technologies. However, in recent years there has been a large increase in the development of pharmaceutical technologies in both industries; in the pharmaceutical industry in particular in the primary pharmaceutical technologies[3]. Nevertheless, this change is recent and not likely to be evident in data that covers firms in both chemical and pharmaceutical industries over the extended period of 1969-95.

In the same context, the extended time period, and the grouping of technologies used in the present analysis is designed to underline the long run positioning of an industry in terms of the bulk of its innovative activity wherever this lays, irrespective of how the composition of technological efforts may be changing at the frontier. Recent work however shows both the increased importance of technological interrelatedness in modern industries and the changing structure of industries' technological profiles[4].

Third, the present work refers to RTA figures depicting patterns of technological specialisation within industries across countries and not absolute share values (ie. it controls for the fact that all parts of eg. the chemical industry have high shares of chemical patenting) which may account for some divergence in the results from those of some other studies (this difference in explored in other earlier work on the technological structure of industries over time).

3. Figures 1 and 2: Development of an analytical framework

In this context, we begin from but then explore how to go beyond two background propositions on the determinants of the internationalisation of corporate technological activity which can be found in the literature (see in particular Patel and Pavitt, 2000). 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). Until around 1980 international direct investments tended to be market-seeking or natural resource-seeking, and not technological asset-seeking. So historically when the internationalisation of technology followed the internationalisation of production, which in turn was motivated by a search for markets or resources, the share of 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, in which a higher proportion of research is directed towards the development of entirely new products and processes rather than simpler adaptation.

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. 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 resourc" (Lee, 1998, pp. 47-48) that induces national industrial groups to remain local in their innovative es and "has a cumulative and continuous property with a time dimension 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[5].

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 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).

4. Description of Tables

Table 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 gives instead the profile of national competencies in a variety of technological fields. In this table we can observe the relative technological advantage of national groups of firms from all industries -at home and abroad- including those not in the three broad industrial groups (in Tables 3, 4, 5) but linked to these tables through the technological sectors.

In general, firms, 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 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 is due to the British motor vehicle component firms whose expertise lies in engines in general.

In Tables 3, 4 and 5 we examine (i) the extent, and the selection of technologies (primary and other) that national groups of firms develop, (ii) their spatial distribution between the home and host country, and (iii) the type (and degree) of technological innovative activity host countries attract in the industry in question.

Table 3: Chemical and pharmaceutical industry: German and Swiss domestically-owned chemical and pharmaceutical industrial firms are focused at home in their primary technological activities; German-owned firms in chemical technologies (1.22) and Swiss-owned firms in both chemical (1.34) and pharmaceutical technologies (1.16). However, UK-owned firms apart from their efforts in (primary) pharmaceutical (1.56) and petrochemical technologies (1.72), also develop mechanical engineering technologies (1.16), an important general purpose technology for the support of production activity (Pavitt et. al., 1989). On the other hand, they develop extensively non-core technologies, in fact even more than primary ones. Dutch-owned firms innovate in chemical (1.11), mechanical (1.45) and petrochemical (1.44) technologies, French-owned firms in pharmaceutical (1.11), metal (1.51) and mechanical engineering (1.55) technologies, and Swedish firms innovate considerably in pharmaceutical technologies[6] (1.81), but even more in a variety of other technologies such as instruments (2.56), metals (1.82), electrical equipment (1.54), and mechanical engineering (1.41). Furthermore, the US-owned firms do only average innovative research in the primary technologies (an RTA just below unity for both chemical and pharmaceutical technologies) while at the same time keeping a distributed research agenda in most of the non-core technologies for the industry.

National groups of firms maintain in their foreign-located research a similar pattern to that pursued domestically although the research interest is clearly shifted in the development of pharmaceutical technologies. German and Swiss-owned firms are as focused abroad as they are in their domestic research, while all other national groups maintain the same diffused innovative portfolio. However, both the US and German-owned firms are now very active in pharmaceutical technologies (1.59 and 1.32 in Table 3.2) as opposed to the modest innovative performance in their home country (0.96 and 0.89 in Table 3.1).

In the UK for foreign-owned firms the balance is strongly in favour of research in pharmaceuticals (2.08), while in Germany foreign-owned chemical and pharmaceutical firms place their innovating activities neither especially in Chemicals (0.97 in Table 3.3) nor Pharmaceuticals (0.88), but in Mechanical Engineering (1.95). This is consistent with the country's leading position in the world Chemical and Pharmaceutical industries, and the strong development by German indigenous firms of their core technological base in Chemicals at home (Table 3.1) makes it more costly for weaker firms from abroad to participate in the local development of the equivalent fields. In Switzerland, metals, mechanical engineering as well as instruments are among the most successfully researched technological areas of foreign-owned chemical and pharmaceutical firms. Mechanical engineering is for chemical and pharmaceutical companies a technological area of great importance. The relatively high competitiveness of France for Pharmaceuticals (1.98) may be, to some extent, inflated by regulatory requirements rather than actually reflecting the local comparative advantage. In the Netherlands and Sweden, the foreign-owned research in Chemical and Pharmaceutical industry reflects the comparative advantages of individual countries and concentrates in the countries' major fields of technological development. So in the Netherlands, foreign innovation is mainly in the area of food (4.47), Coal and Petroleum (3.39), Office Equipment (2.60) and Mechanical Engineering (1.35), [and Instruments (1.17). While in Sweden, there is strong emphasis on Metals (2.84), Professional and Scientific Instruments (2.66), and Mechanical Engineering (1.50)

Table 4: Electrical Equipment and Electronics industry

Firms tend to have as between their primary technological fields a higher relative technological advantage in the electrical equipment rather than the ICT technologies and in among non-primary technologies instruments is the preferred choice of most national groups, in both their domestic and foreign-located activities. Further, the focus of technological activity generally coincides with whatever are the most prominent national industries. This applies in the case of Motor Vehicles in Sweden, Metals and Mechanical Engineering in both Sweden and Switzerland, and Chemicals in the US, and gives a hint of the direction of corporate diversification of the national groups of industries in question.

Domestically-owned firms in all European countries, apart from Switzerland, show a high degree of innovation in electrical equipment technologies. The RTA of both Switzerland and the US is about one (RTA=0.97, for both countries) and all national groups, apart from the UK and Swedish, innovate more abroad in their primary field of research than in their home country.

The US, and on the other side of the Atlantic France, display the highest degree of penetration from foreign-owned research in both electrical equipment and office equipment. In the UK and Switzerland the interest of foreign research is limited to electrical equipment. On the other hand, Germany and the Netherlands in electrical equipment are much less affected by foreign-owned research, while Sweden is not at all. The US innovates both at home and abroad, in non-core technological areas, while it attracts foreign innovation in some core ones and motor vehicle technologies. France seems to draw relatively more from research situated abroad in both electrical equipment, and especially office equipment technologies, while the Dutch concentration of research at home in electrical equipment is not successfully challenged by foreign-owned firms. Foreign firms however, are quite prevalent in the Motor Vehicle and Chemical technologies in the Netherlands.

Table 5: Metal and Mechanicals industry

Both, the RTA figures (in Tables 5.1, 5.2, and 5.3), as well as the absolute numbers, show a higher research activity in the Mechanical Engineering technologies in comparison to Metal technologies.

Domestically owned firms, apart from the Dutch-owned firms (in Metal technologies) and the Japanese owned firms (in Mechanical Engineering technologies) all have a higher patenting activity at home in primary than in non-primary activities. However, especially conspicuous among the non-primary fields are the cases of French, German and Swiss-owned firms in chemical technologies (3.22, 1.68, and 1.39), and Swedish and French in electrical equipment technologies (1.65 and 1.37 respectively).

Foreign-located patenting activity is less diversified and more focused in the primary technologies. Exceptions to this are French owned firms (in chemicals RTA is 2.35), and

German owned firms (in motor vehicle and chemical technologies with RTA values are 1.47 and 1.30 respectively). The Dutch and Swedish firms in Mechanical Engineering technologies and Swiss in both primary technologies are more dynamic in their foreign situated research, where their RTA figures for these technologies are significantly higher, in comparison to their domestic situated research in the same technological fields. They are also less diversified in their research abroad although Sweden, with a strong research base at home in Electrical Equipment technologies (RTA is 1.65) maintains an average RTA figure (1.02) abroad.

In Europe, national groups in the metal and mechanical industry tend to situate their foreign research either in chemical technologies or electrical equipment technologies. This division is very distinct and strong. The industry’s technological interest in Chemicals is prevalent for French or German firms, in foreign -as well as in domestically-situated research. Swiss and Dutch owned firms on the other hand diversify considerably in Chemicals but only in their domestic research activities. UK, German, Swedish, and US firms on the other hand, diversify into electrical equipment. Swedish and UK firms have a competitive advantage in electrical equipment development both at home as well as abroad, while German and US companies only do so in their foreign-located research. However, US domestically owned firms, and foreign-located German firms, diversify also in Motor Vehicle related technologies.

Foreign-owned firms do not seem to have any problem in getting into direct competition in the industry’s core research activities, in the great majority of cases in mechanical engineering. However, foreign research activities are expanded in instruments (France and Switzerland), electrical equipment (in the US), and motor vehicles (in the UK).

4. Discussion

Corporate technological diversification at home or abroad through internationalisation can be seen as two complementary corporate strategies that have to balance the increasing necessity to tap into new technological areas while retaining the knowledge links with the home base. According to the model (Cantwell and Kosmopoulou, 2002) as illustrated in Figs 1 & 2 we identified the leaders in a selection of industries as the countries leading an industry and the industry's primary technology (Tables 1 and 2). Then under the assumption that the primary technology of an industry is also the industry's most important technology we examined the international diversification strategies of national groups of firms away from this primary technological area and towards other non-primary technological areas. The balance in Fig. 1 is in favour of internationalisation of corporate technology as a diversification strategy by leading groups of firms, while in Fig. 2 strong user-producer interaction puts a powerful constraint on the internationalisation of firms. On the other hand both Figs. 1 and 2 show compelling pressure of leading national industries not to 'allow' direct invasion of their technological 'space' from other leading national industries that are direct competitors in the same product area, while other industries, not directly competitive with the firms of the leading centre in output markets demonstrate a strong interest in spillovers from the leaders' area of comparative technological advantage.

In this part of the paper we examine how far this model fits the empirical evidence presented here and we explain the reason for some apparent inconsistencies in relation both to the data as discussed above in the data and methodology section, and more importantly to the nature of technologies, and national industries. The appropriateness of the model is to be tested in two separate cases: first, whether the leading national industries in their outbound investment in development abroad conform with Fig. 1 or 2 and second, in terms of the composition of foreign-owned innovation conducted by the firms of a given industry in each location, whether the 'deterrence-attraction' relation between industries of different leading status is present.

First, in Fig. 1 it is maintained that firms tend to utilise their international networks of technological development mostly to promote their own comparative technological diversification (Cantwell and Piscitello, 2000) keeping their primary technologies at home and tapping into foreign centres of excellence for their innovative potential in related technologies or in general purpose technologies. In accordance with this are the German-owned firms as leaders in the chemical industry and US-owned firms leaders in the ICT industry. German-owned firms, the leaders in the chemical industry and technological area when considered among the chemical and pharmaceutical groups of firms perform better in their domestic relative to their foreign-located research in the primary technology of chemicals, while they do more research abroad in the pharmaceutical technological area (see Tables 3.1 and 3.2). US-owned firms, leaders in ICT industry and technological area (Tables 1 and 2) perform about the same at home or abroad in ICT technologies, while the relative comparative advantage in electrical equipment technologies in domestic research is higher than the equivalent in foreign locations.

However, not all the empirical evidence on the leading groups in Tables 3, 4 and 5 complies with Fig. 1 of our model. The leading national industries that do not are the Swiss-owned pharmaceutical group, the Dutch-owned electrical group, and the Swedish mechanical firms, all however originating from small countries. There seem to be significant constraints due to the size of the country, which can be brought into account here to explain this inconsistency. First, the small size of the country confines not only the size of the market but also the supply of available resources, especially of high quality skilled labour and second, the small size is often a sign that only a very few firms and sometimes only a single firm is present in the sample albeit with a very strong presence, for example Philips in the Netherlands. These two considerations might be of relevance to the Dutch-owned case in which firms have (the leading firm has!) a higher relative technological advantage in that industry's primary technology, electrical equipment, in foreign-located research than in home-based research (see Tables 4.1 and 4.2) while in ICT technologies domestic research is relatively stronger than is the foreign-located. The home country technology base may simply be too small when a leading world company originates from a small country.

Another factor that plays an important role is the nature of the technology, and in particular whether fields constitute general purpose technologies (GPTs), that is, technological areas relevant to most industries and characteristic of a technological paradigm. Broad electrical technologies (electrical communication and computing technologies) for instance, during the period 1969-95 account for 28% of the overall

patenting activity and had significant growth during this period (from 25% in the period 1969-72 to 36% in the period 1991-95'. However, the broad mechanical technological field (mechanical, metal and instrument technologies) is still the most important GPT accounting for 35% of the total patenting, although its role has steadily declined (from 38% during the period 1969-72 to 31% during the period 1991-95, and this decrease would be even larger if instrument technologies were not included). Swedish-owned firms, leaders in the industry and technological area of mechanical engineering have a higher relative competitive advantage in foreign-located research in this field than they do in the home country, given that the primary field in which they specialise is that of a GPT that may be best developed in some all-round foreign centres of excellence, which pool together the potentially interactive efforts of firms of different industries.
Lastly, Swiss-owned firms are leaders in the pharmaceutical industry and technological area and have a higher comparative advantage in foreign located research than in their home country (see Tables 3.1 and 3.2). Although the size of the country has already been mentioned as being one of the reasons for this apparent departure from the expectations of Fig. 1, in this case there are a number of additional reasons that may explain the higher RTA value in foreign located research in comparison to the domestic one. According to recent research the most advanced research areas in pharmaceuticals rely increasingly on ICT. Surprisingly enough however Switzerland has neither a substantial IT industry nor technology (Tables 1 and 2) or any significant indication of gaining any local IT spillovers, although the presence of ABB might suggest otherwise, for an internationally leading industry which would tend to require favourable local interaction with other industries in its home base (Table 3 and Table 4). This void might have been one of the reasons why Swiss compatibility with the newly emergent paradigm was falling along with its position in chemicals and pharmaceuticals and led the industry into a merger wave (the creation of Novartis in 1996). Furthermore, following the same line of thought the lack of expertise in an essential technological area and the pressure of expiring patents might have led to an increased internationalisation in research in the later stages of development for example though new investments in the US, where the presence of strong pharmaceutical capabilities in ICT technologies and their successful interlinkage has helped to create the very recent emergence of a strong technological advantage in the area of pharmaceuticals and in particular in biotechnology (Nightingale, 2000).

The motivation to tap into new technological areas abroad can be contrasted with the need to maintain strong links with other parts of the technological base at home. For some industries the nature of production and for some countries historical contingencies make this necessity to maintain close supplier-buyer links essential. In Fig. 2 of Cantwell and Kosmopoulou (2002), the nature of the industry and its technological structure -at a particular time- are identified as important determinants for the nature and direction of international activity. In our previous work the metal industry and Japan have been identified as examples that best illustrate the argument, but it is obvious that the dividing line is very fine in a number of other cases. In the two examples discussed in our earlier work, both Japanese-owned firms and Swedish-owned firms as leaders in the electrical and metal industries comply with the model as described in Fig. 2.

When examining the degree of foreign penetration from other industries in a leading host country then the results are very clearly supportive of the position proposed by the model. In no case has a leading industry received a higher penetration in the respective primary technology than occurs in the same technology in other countries in the same industry and in almost all cases (except mechanical engineering in Sweden and ICT in the US) the relative comparative advantage of foreign-owned firms from within the same industry in a leading centre's primary area of technological development is lower than unity. In addition, the relative technological advantage of foreign-owned firms investing locally in the primary technological areas is in all leading national groups lower than the equivalent value for the domestic comparative advantage of indigenous firms.

While until this point the focus of attention has been on the location of development efforts for the primary technologies of firms and the objectives of this locational choice, the second part of this paper is concerned with what we can learn from the location of research efforts in the non-primary technologies. The generally quantified analysis of corporate patenting in which the patents of a firm are allocated in their entirety to the primary industry of firm, or in which patents are assigned to the primary industry of use based on a patent class-SIC concordance, largely fails to understand the importance of corporate technological diversification from the perspective of the firm or the industry, while it ignores a valuable indicator for the interactive nature of the growth of firms, industries and countries[7].
On the other hand, the location of efforts in developing those non-primary technologies in which industries invest are not randomly distributed, but often closely linked in the case of domestic research with other strong national industries and abroad to other local industries in which the host economy may be a leading country or have been important in the some time in the past. In addition, in many cases the technological profiles of industries are consistent with investment in what are the primary technologies of other industries that are locally strong in that host country, and hence suggestive of inter-industry technology linkages in many of the cases that we can examine with the present data the potential link runs mainly from the oldest established and/or stronger industry as a source to the one that has more recently been established or has a lower competitive advantage as a recipient (Table 1).

By improving our understanding of the relationship between industries and technologies, and their evolution over time, we may come closer to explaining the underlying sources of firms' competence and national growth. Most importantly by linking the micro-level (firm and industry level) and macro-level (national level) of analysis we may be able to develop indicators for the use of policy makers and managers about the direction of industries and economies alike.
In general, the domestic activity of firms is focused on at least some non-primary sectors in all three tables (3, 4 and 5). In all cases except for German and Swiss-owned firms in chemicals and pharmaceuticals, and Dutch-owned firms in the metal and mechanical industrial groups, the specialisation in the primary technology has a lower RTA than do efforts in some other non-primary technologies developed by each national group[8]. Domestic activity seems to be very skillful in 'connecting' industries and in fusing

together technologies. This is hardly surprising in the light of the recent development in technological paradigms, with the growing emphasis on constructing combined packages of innovative effort that bring together the most -potentially- interrelated technologies.

The discussion below takes a closer look at national technological profiles and in particular at the ability of national groups to take advantage of economies of scope in technological innovation. The discussion of Tables 3, 4 and 5 is focused only on some groups of firms due to data restrictions[9] and takes into account the structure and evolution of technological profiles of industries.

Firms from smaller countries tend to have high RTA figures in only a handful of industries and technological fields (Table 1 and 2). It is interesting to note that UK-owned firms have a singularly large number of both industries and technologies with high RTA values (above unity) and although most national groups have a high relative comparative advantage in more technological sectors than industries (Germany and Switzerland excepted), Japan has even more.

Links with national leaders and/or long established industries play an important role in the distribution of the development of non-primary technologies by US-owned firms. US-owned firms connect with food, motor vehicle, coal and petroleum and aircraft and aerospace technologies more in the home country (and sometimes abroad) more than most other national groups of firm do.

This is particularly obvious in the historically strong food industry (and which remains a strong industry and -more so- technological sector, 1.16 and 1.33 in Tables 1 and 2 respectively). Food technologies absorb a large amount of research sited in the US in all three main industrial groups' domestic activity (the RTA is 1.60, 1.50 and 1.13, in Tables 3.1, 4.1 and 5.1 respectively and attracts strong inward research from the broad metal and mechanical group of firms, with an RTA of 1.85 in Table 5.3.

The strong historical ties of US-owned firms in other industries with those of the motor vehicle industry, rather than its present day strength, and its technological links (mostly though with metal and mechanical technologies but not chemical and pharmaceutical) seem to also play an important role. There is relatively more technological activity directed towards motor vehicles than in developing primary technologies in both the chemical and pharmaceuticals and metal and mechanical groups (see Tables 1, 2, 3.1 and 5.1).

Although German-owned chemical and pharmaceutical firms are very focused in their domestic research agenda both the other broad groups invest in non-primary technologies such as petrochemicals (both in Tables 4 and 5), aircraft, metals and chemicals (the electrical and ICT group, Table 4) relatively more than in their primary fields of activity. These technological links may be associated with the historical strength of German industry in organic chemistry, which has hence connected with so many other lines of complementary research; and the presence of the Lufthansa airline (although there is not a significant independent presence in either Tables 1 or 2), and the leading position in the metal industry (Tables 1 and 2).

Dutch-owned firms dedicate more of their domestic research to the development of mechanical, petrochemical and motor vehicle technologies in the chemical and pharmaceutical group in which the country does not have any apparent strength -in either industry or technology-and so has a greater tendency to diversify away from the primary technologies of the group. In the electrical and ICT group as well relatively more research is done in pharmaceuticals than in the strong primary electrical field (few national firms research in this technology and small numbers may be a problem here).
Moreover, internationally Dutch firms from the chemical and pharmaceutical group of firms have a high RTA in aircraft, and a significant interest in food technologies among the metal and mechanical group of firms. Although it is not clear the strength of these industries in the neighbouring UK and investment by foreign-owned car and component part companies (see also Table 4 in which Dutch-owned firms are the only national group with high inward investment in the field, RTA=4.24) may have a role to play in these odd deviations from the norm. Especially so since the figures of a small country as the Netherlands may be highly influenced by a few multinationals (eg. Shell and Uniliver).

The Swiss corporate technology profile resembles in many respects that of Germany. Both countries have a strong presence in chemicals and pharmaceuticals and are very concentrated in their domestic, as well as their foreign specialisation in the primary technologies in this group, in which both are leaders. Moreover, Swiss-owned firms have a stronger technological advantage in the metal, mechanical and motor vehicle fields than in the primary electrical and ICT technologies (in Table 4) and more pharmaceutical and chemical technologies in Table 5 than metal and mechanical technologies. These non-primary technologies correspond to the advantages of leading Swiss and German industries, another indication again of the strong connection of Swiss industries to those of the neighbouring Germany.

The UK seems to have one foot in Europe and the other in the US. The UK has a close connection with both continents, having long historical interaction with both the US and continental Europe[10]. The wide range of industries and technologies in which UK-owned firms have a strong relative comparative advantage compares only to that of the US (6 industries and 8 technological fields in comparison to the 7 US industries and an equal number of technological fields with RTA above unity, in Tables 1 and 2). However, the UK lacks the size the US has and this wide range of technological capabilities may well have been one of the reasons UK firms require such an internationalised effort and why the UK as a country has become a fertile ground for foreign multinationals.
UK-owned firms also diversify mostly at home but also in foreign locations in technologies of other nationally strong industries. Both the electrical and ICT, and metal and mechanical groups of firms diversify in their domestic research into aircraft technologies to a relatively greater extent than in their primary fields (4.23 and 1.60 respectively) and abroad in the same technological fields on the part of the UK-owned chemical and pharmaceutical and metal and mechanical groups (2.15 and 1.52 in Tables 3.2 and 5.2 respectively). In addition, the chemical and pharmaceutical group in the home country has a high RTA in motor vehicles and petrochemical technologies (3.70 and 1.72 in Table 3.1) The UK coal and petroleum industry is by far the strongest, as it is also in petrochemical technologies (Tables 1 and 2). However, the UK motor vehicle industry

(RTA =1.24) is far less competitive in comparison to the leaders in the industry and its strength lies in component parts firms. Lastly, the UK that has the strongest food, drink and tobacco industry[11] and both chemical and pharmaceutical, and metal and mechanical groups of firms tap into the resources of foreign locations in these fields (in Table 3.2 and 5.2).

The French chemical and pharmaceutical group of firms invests domestically in metals in which France is strong but not the leader (as well as in the mechanical field) and the electrical and ICT group develops aircraft technologies (in which industry France is the leader). Furthermore, the mechanical group of firms has a high RTA abroad in petrochemical technologies (possibly to support activities related to mining and extraction in foreign locations) as the coal and petroleum industry is the most competitive in France during the period 1969-95 (although far behind the UK national industrial group but ahead of the US).

Diversified technological activity closely related with the industries of domestic strength is also apparent among Swedish-owned firms. All groups have high comparative advantage in metal and mechanical technologies at home as well as in foreign locations (although less so the metal and mechanical group itself). Swedish-owned electrical and electronic firms devote effort to developing motor vehicle technologies as also do -quite intensively- the foreign located chemical and pharmaceutical firms. Sweden also has a lot of research in instrument technologies from the chemical and pharmaceutical group of firms both at home and abroad (as well as a lot of inward investment, see Tables 3.1, 3.2 and 3.3). Finally, the development of food technologies interests equally all domestically-owned firms, as well as the metal and mechanical companies abroad, although Sweden is not strong in the food industry or technological field.

The corporate technological diversification of Japanese-owned firms seems to be in close relation with the technologically stronger industries of the country, and the complementary technologies most needed by each industry. Japan seems to have the most coherent network of technologies among all the countries in the sample. Interestingly, although Japan is often rightly described as being little internationalised, some of the technologies developed by Japanese-owned firms in the particular industries examined here are quite highly internationalised. In particular, all three industrial groups have a strong diversification in ICT technologies both at home and abroad, while the electrical and ICT group also has at home and abroad a lot of research in motor vehicle technologies, as does the metal and mechanical group abroad.

A preliminary assessment:

Strong industries tend to diversify and to connect in their home country with the primary technologies of other major national industries, often at the expense of a strong focus upon their primary technologies. It seems that the amalgamation of technological competences at a national level has for some countries (like Japan) had a particularly strong influence upon the diversification of research activity. Historical path dependency is also an important factor in an industry's technological structure. In other words, the connecting factor among industries within a country is often not the relatedness of the technology to the core fields of the investing industry, but rather the past and present strength of an other supporting industry's primary technology.

Another interesting finding is that the industry that tends to create the most to links with technologies primary to other industries, in both the home and host country, is the longer established and stronger industry. In some countries such as the US this tendency seems to have been more historically bounded than for example in Japan. However, it is not clear if this is caused by institutional inertia being more prevalent in the case of the US and the greater flexibility of adjustment in Japan, or if instead it has to do with factors related to the timing of the successful industrial paradigm in each country (the US developed successfully industries during the mechanical technological paradigm in the last decades of the 19th century, while Japanese success came later and is more connected with the electronic and information paradigm/industries).

The data are better suited to explain the pattern of internationalisation of development in highly industrialised countries with significant activity by multinational firms, and to the extent that these large multinationals determine a significant part of a countries' economic activity. However, since only the very largest firms are included the results are bound to ignore significant technological ties that are the outcome of smaller scale activities. Hence, the overall significance of the results depends on the degree to which multinational technological activity is representative of the overall technological activity in each country. More research should thus be conducted to determine the nature and importance of technological activity performed by small and medium sized firms, especially in their innovative interaction with the development efforts of larger companies.

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[1] "We shall argue that each "technological paradigm" defines its own concept of "progress" based on its specific technological and economic trade-offs."…"Why did certain technological development emerge instead of others?"…"Are there regularities in the process of generation of new technologies and in technical progress thereafter?" (Dosi p.148)

[2] In all of the three cases of the leading national industries with higher RTA in the primary technology in their foreign located activity in comparison to the domestic value (tables 7,8,9) there is indication of intense domestic activity in the primary technology from other industries. This is true in the cases of the Swiss pharmaceutical technologies (have an RTA in table 2.2 of 3.59 while the RTA in table 7.1 is 1.16), the Dutch electrical equipment technologies (an RTA of 2.23 in table 2.2 and 1.19 in table 8.1), and the Swedish mechanical technologies (have an RTA of 2.22 in table 2.2 and 1.03). The data are not directly comparable since table 2.2 includes both domestic and foreign located activity and in tables 7,8,9 two industries are involved in each case and it is not possible to distinguish what is done by each industry and to each industry's primary technology.

[3] The data on the evolution of the technological structure of pharmaceutical industry measured with the share of technological activity show the very important increase of the primary pharmaceutical technologies that become the most important technology of the industry, a position that until recently was held by chemical technologies).

[4] For example, in the case of electrical equipment industry and broad electrical sector the growing relevance of 'computing' technologies has replaced -according to the RTA count- the previously most important field of 'communication' technologies or -according the share count- the 'other electricals' technological field.

[5] 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*, 1996).

[6] This is evident also by the number of firms in the dynamic area of biotechnology, Economist 1999

[7] "…nearly all the innovations in any one industry –not just electricity - had a significant impact on many other industries." Chandler in Scale and Scope (p. 63) and to the same end he also quotes Nathan Rosenberg's work 'Technological Interdependence in the American Economy' in Technology and Culture 20: 28 (September 1979) "The growth in productivity of industrial economies is the complex outcome of large number of interlocking, mutually reinforcing technologies, the individual components of which are of a very limited economic consequence by themselves"
An example of this point is: "In the refining of sugar and vegetable oil, where the process of production was similar to that of petroleum (in fact, several of the innovations in petroleum refining were borrowed from the sugar industry), modern production methods were adopted by a number of enterprises almost simultaneously." (Chandler in Scale and Scope, p. 149)

[8] This does not mean however, that the share of non-primary technologies -which is not examined here- is necessarily higher than that of the primary technologies.

[9] For example small numbers in the food industry

[10] The chemical industry took its lights by German professors introduced by Albert, Victoria's husband; long rivalry between Germany and England in shipping and mechanical engineering) and on the other hand a close proximity to the US that shares the same language and to great extend values and ways of thinking through the immigrant population that show themselves in the strong economic links from a very early stage. Courtalds is good example of the relation of UK with both EU and US: capitalizing in the scientific knowledge of continental Europe and the British ingenuity the largest portion of sales before the WWII was coming from the US benefiting from the US large market and technical/entrepreneurial skills (quote owner), and then the firms most important assets were passed to the US as part of a political more than economic arrangement connected with the war debts.

[11] The food industry is involved with the sale of branded packaged products that can reap economies of scale in production, marketing and distribution rather than delicatessen products aimed at the upper end of the market.

Figure 1: The effect of leading locally-owned national groups on the degree and structure of internationalisation of innovation

Home/ Host Country Perspective

Level of Analysis		Outward	Inward
	Industry	High Degree of Internationalisation (H)	Local Deterrence in the Primary Industry (L)
	Technology	Exploitation for Diversification (M)	Local Attraction for Diversification (M)

Where:

	H	High internationalisation of technological activity in the industry or technological field in question
	M	Medium-intensity internationalisation of technological activity in the industry or technological field in question
	L	Low internationalisation of technological activity in the industry or technological field in question

Figure 2: The effect of tight localised coupling of capable downstream user (or upstream supplier) firms as the source of innovation on the degree of internationalisation of technological activity

		Home/ Host Country Perspective	
		Outward	Inward
Level of Analysis	Industry	Dependence On Local Users or Suppliers (L)	Deterrence due to Established Local Inter-Firms Linkages (L)
	Technology	Exploitation of User or Supplier Capabilities (M)	Local Attraction for Diversification (M)

Where:

M — Medium-intensity internationalisation of technological activity in the industry or technological field in question

L — Low internationalisation of technological activity in the industry or technological field in question

Table 2: The revealed technological advantage (RTA) of selected nationally-owned groups of firms, across fields of technological activity, during the period 1969-1995.

Technological Sector	United Stated	Germany	United Kingdom	France	Netherlands	Switzerland	Sweeden	Japan
Food, Drink, and Tobacco	1,33	0,36	2,41	0,27	0,23	1,11	0,79	0,29
Chemicals	1,00	1,58	1,18	0,99	0,52	2,23	0,33	0,65
Pharmaceuticals	0,93	1,80	1,56	1,22	0,40	3,59	0,86	0,45
Metals	1,11	0,67	1,11	1,05	0,67	0,64	1,80	0,83
Mechanical Engineering	1,08	0,89	1,36	0,97	0,59	0,66	2,22	0,72
Electrical Equipment	0,99	0,61	0,59	1,13	2,23	0,27	0,91	1,26
Office Equipment	0,87	0,42	0,26	0,83	1,50	0,07	0,27	1,89
Motor Vehicles	0,51	1,72	0,65	0,78	0,12	0,11	0,82	2,24
Aircraft and Aerospace	1,32	0,75	2,03	3,07	0,26	0,12	1,00	0,06
Coal and Petroleum Products	1,48	0,33	1,56	1,00	0,10	0,08	0,06	0,20
Instruments	0,90	0,83	0,67	0,74	1,16	0,46	0,86	1,52
Other Manufacturing	1,04	0,94	1,19	1,14	0,59	0,55	1,28	0,93
STDEV(of Sample)	0,25	0,52	0,62	0,67	0,64	1,06	0,61	0,68
CV(=sd/mean)	0,24	0,57	0,51	0,61	0,91	1,29	0,66	0,74

Table 1: The revealed technological advantage (RTA)of selected nationally-owned groups of firms, across industries, during the period 1969-1995.

Industry	United States	Germany	United Kingdom	France	Netherlands	Switzerland	Sweden	Japan
Food, Drink, and Tobacco	1,16	0,00	4,74	0,48	0,19	1,18	0,03	0,41
Chemicals	0,75	2,58	1,10	0,96	0,89	2,78	0,31	0,76
Pharmaceuticals	1,24	1,05	0,87	0,94	0,00	3,98	0,84	0,22
Metals	0,69	2,19	1,03	1,34	0,45	0,94	2,37	1,00
Mechanical Engineering	1,19	1,01	1,01	0,24	0,00	1,69	6,74	0,32
Electrical Equipment	0,84	0,67	0,51	1,12	3,29	0,36	0,87	1,54
Office Equipment	1,46	0,02	0,11	0,49	0,00	0,00	0,00	0,80
Motor Vehicles	0,64	1,58	1,24	1,07	0,00	0,00	0,87	1,82
Aircraft and Aerospace	1,65	0,22	0,84	1,35	0,00	0,00	0,00	0,00
Coal and Petroleum Products	1,43	0,02	2,79	1,64	0,00	0,00	0,00	0,08
Professional and Scientific Instruments	0,82	0,28	0,02	0,00	0,00	0,00	0,62	2,46
Other Manufacturing	1,13	0,16	0,94	1,31	0,00	0,46	1,58	1,01
STDEV(of Sample)	0,33	0,89	1,29	0,50	0,95	1,29	1,89	0,75
CV(=sd/mean)	0,31	1,09	1,02	0,55	2,37	1,36	1,60	0,87

Table 2: The revealed technological advantage (RTA) of selected nationally-owned groups of firms, across fields of technological activity, during the period 1969-1995.

Technological Sector	United Stated	Germany	United Kingdom	France	Netherlands	Switzerland	Sweeden	Japan
Food, Drink, and Tobacco	1,33	0,36	2,41	0,27	0,23	1,11	0,79	0,29
Chemicals	1,00	1,58	1,18	0,99	0,52	2,23	0,33	0,65
Pharmaceuticals	0,93	1,80	1,56	1,22	0,40	3,59	0,86	0,45
Metals	1,11	0,67	1,11	1,05	0,67	0,64	1,80	0,83
Mechanical Engineering	1,08	0,89	1,36	0,97	0,59	0,66	2,22	0,72
Electrical Equipment	0,99	0,61	0,59	1,13	2,23	0,27	0,91	1,26
Office Equipment	0,87	0,42	0,26	0,83	1,50	0,07	0,27	1,89
Motor Vehicles	0,51	1,72	0,65	0,78	0,12	0,11	0,82	2,24
Aircraft and Aerospace	1,32	0,75	2,03	3,07	0,26	0,12	1,00	0,06
Coal and Petroleum Products	1,48	0,33	1,56	1,00	0,10	0,08	0,06	0,20
Instruments	0,90	0,83	0,67	0,74	1,16	0,46	0,86	1,52
Other Manufacturing	1,04	0,94	1,19	1,14	0,59	0,55	1,28	0,93
STDEV(of Sample)	0,25	0,52	0,62	0,67	0,64	1,06	0,61	0,68
CV(=sd/mean)	0,24	0,57	0,51	0,61	0,91	1,29	0,66	0,74

Table 3: Chemicals and Pharmaceuticals*

Technological Sectors	United States	Germany	United Kingdom	France	Netherlands	Switzerland	Sweden	Japan
Food, Drink and Tobacco	1,60	0,36	0,61	0,52	0,61	0,29	1,37	0,58
Chemicals	0,92	1,22	0,89	0,99	1,11	1,34	0,53	0,98
Pharmaceuticals	0,96	0,89	1,56	1,11	0,68	1,16	1,81	0,62
Metals	1,40	0,52	0,64	1,51	0,40	0,08	1,82	0,61
Mechanical Engineering	1,13	0,73	1,16	1,55	1,45	0,26	1,41	0,91
Electrical Equipment	1,17	0,38	0,79	0,92	0,20	0,12	1,54	1,75
Office Equipment	0,87	0,47	0,19	0,09	*0,00*	0,21	0,61	3,21
Motor Vehicles	*1,20*	*0,41*	*3,70*	*0,84*	*10,70*	*0,00*	*0,00*	*0,45*
Aircraft and Aerospace	*1,90*	*0,56*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
Coal and Petroleum	1,21	0,95	1,72	0,61	1,44	0,09	0,00	1,22
Instruments	1,08	0,66	0,40	0,41	0,37	0,45	2,56	1,71
Other Manufacturing	1,23	0,66	1,19	0,74	1,40	0,15	0,85	1,19
Standard deviation of sample	0,29	0,26	0,98	0,49	2,94	0,44	0,84	0,84
CV(=sd/mean)	0,24	0,40	0,91	0,63	1,92	1,28	0,81	0,76

Table 3.1: The revealed technological advantage (RTA) from domestically-owned activity in selected host countries, across fields of technological activity and during the period 1969-1995.

Technological Sectors	United States	Germany	United Kingdom	France	Netherlands	Switzerland	Sweden	Japan
Food, Drink and Tobacco	0,70	0,76	1,23	2,09	0,38	0,32	0,56	0,51
Chemicals	0,85	1,04	0,79	0,73	0,69	1,16	0,53	0,86
Pharmaceuticals	1,59	1,32	1,17	1,36	0,50	1,47	2,00	0,50
Metals	1,16	0,96	1,51	2,99	0,74	0,25	1,34	1,63
Mechanical Engineering	1,12	0,76	1,60	1,06	3,86	0,42	1,42	1,39
Electrical Equipment	1,24	0,55	1,54	1,11	1,82	0,10	1,08	2,64
Office Equipment	0,27	0,81	0,24	2,21	0,00	0,30	0,81	16,19
Motor Vehicles	*1,42*	*0,46*	*1,34*	*0,00*	*0,00*	*0,00*	*11,15*	*0,00*
Aircraft and Aerospace	*0,00*	*0,00*	*2,15*	*0,00*	*4,93*	*0,00*	*0,00*	*0,00*
Coal and Petroleum	0,48	0,36	0,72	0,48	0,87	0,26	0,00	1,92
Instruments	0,84	0,81	0,86	1,89	0,47	0,98	2,32	0,62
Other	0,85	0,74	1,37	0,60	1,54	0,26	0,96	0,62
Standard deviation of sample	0,47	0,34	0,50	0,93	1,55	0,48	3,01	4,46
CV(=sd/mean)	0,53	0,48	0,41	0,77	1,18	1,04	1,63	1,99

Table 3.2: The revealed technological advantage (RTA) from foreign-located activity by firms of selected home countries, across fields of technological activity and during the period 1969-1995.

Technological Sectors	United States	Germany	United Kingdom	France	Netherlands	Switzerland	Sweden	Japan
Food, Drink and Tobacco	0,84	0,42	0,44	0,44	4,47	1,17	0,00	0,85
Chemicals	0,98	0,97	0,93	0,80	0,90	0,98	0,79	1,00
Pharmaceuticals	1,35	0,88	2,08	1,98	0,61	0,62	0,95	1,18
Metals	1,05	0,78	0,82	0,66	0,36	1,41	2,84	0,77
Mechanical Engineering	0,85	1,95	0,57	1,82	1,35	1,70	1,50	0,42
Electrical Equipment	0,83	0,98	0,40	0,38	0,58	0,85	0,00	1,96
Office Equipment	1,26	0,20	0,07	0,14	2,60	1,27	0,00	0,46
Motor Vehicles	*0,29*	*0,70*	*0,49*	*5,93*	*0,00*	*0,00*	*0,00*	*0,00*
Aircraft and Aerospace	*0,00*	*2,26*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*3,41*
Coal and Petroleum	0,53	0,40	0,18	0,19	3,39	0,74	0,00	0,47
Instruments	1,01	0,74	0,65	0,53	1,17	1,17	2,66	0,55
Other Manufacturing	0,64	0,91	0,47	0,38	1,61	0,97	1,01	1,44
Standard deviation of sample	0,39	0,60	0,54	1,64	1,40	0,52	1,05	0,91
CV(=sd/mean)	0,49	0,65	0,92	1,49	0,98	0,57	1,29	0,87

Table 3.3: The revealed technological advantage (RTA) from foreign-owned activity in selected host countries, across fields of technological activity and during the period 1969-1995.

* The sectors represented in italics have less than 1,200 patents

Table 4: Electrical and Office Equipment*

Technological Sectors	United States	Germany	United Kingdom	France	Netherlands	Switzerland	Sweden	Japan
Food, Drink and Tobacco	*1,50*	*0,71*	*0,00*	*0,00*	*0,00*	*0,00*	*3,03*	*0,54*
Chemicals	1,25	0,75	0,41	0,50	0,92	0,64	0,29	0,78
Pharmaceuticals	*0,88*	*0,51*	*1,29*	*0,23*	*4,13*	*0,48*	*0,00*	*1,04*
Metals	1,21	0,99	0,86	0,78	1,10	2,28	1,81	0,65
Mechanical Engineering	1,12	0,88	0,85	0,57	0,66	1,83	1,98	0,85
Electrical Equipment	0,97	1,07	1,11	1,23	1,19	0,97	1,06	0,97
Office Equipment	0,89	0,48	0,59	0,74	0,83	0,16	0,45	1,38
Motor Vehicles	0,40	0,78	0,44	0,34	0,07	1,56	3,98	2,30
Aircraft and Aerospace	*1,57*	*0,14*	*4,23*	*4,23*	*0,63*	*0,00*	*0,00*	*0,13*
Coal and Petroleum	*1,09*	*2,76*	*1,09*	*0,77*	*0,62*	*0,00*	*0,00*	*0,73*
Instruments	0,92	1,49	1,59	1,27	0,88	0,93	0,59	1,01
Other Manufacturing	1,09	1,42	1,04	0,90	0,81	2,06	1,45	0,83
Standard deviation of sample	0,31	0,67	1,07	1,09	1,05	0,84	1,29	0,53
CV(=sd/mean)	0,29	0,67	0,95	1,14	1,07	0,92	1,05	0,56

Table 4.1: The revealed technological advantage (RTA) from domestically-owned activity in selected host countries, across fields of technological activity and during the period 1969-1995.

Technological Sectors	United States	Germany	United Kingdom	France	Netherlands	Switzerland	Sweden	Japan
Food, Drink and Tobacco	*0,00*	*0,00*	*0,00*	*0,00*	*0,59*	*0,00*	*0,00*	*0,00*
Chemicals	1,19	0,36	0,88	0,23	0,70	0,68	0,30	0,51
Pharmaceuticals	*1,42*	*1,56*	*0,40*	*0,00*	*1,62*	*0,00*	*0,77*	*0,00*
Metals	1,09	0,56	0,80	0,32	0,78	1,50	2,24	0,63
Mechanical Engineering	1,33	0,35	1,16	0,30	0,58	0,94	3,05	0,54
Electrical Equipment	0,93	1,12	0,98	1,40	1,23	1,03	0,87	0,94
Office Equipment	0,89	1,28	0,44	1,54	0,63	0,09	0,13	1,97
Motor Vehicles	0,60	0,42	0,53	0,09	0,80	1,75	1,45	0,99
Aircraft and Aerospace	*0,07*	*0,00*	*0,00*	*0,47*	*0,94*	*0,00*	*0,00*	*0,00*
Coal and Petroleum	*1,37*	*0,00*	*0,00*	*0,00*	*1,15*	*0,00*	*0,00*	*0,00*
Instruments	1,03	1,49	1,72	0,48	1,30	0,71	0,58	0,95
Other Manufacturing	0,92	0,38	1,18	0,24	0,77	4,84	1,96	0,68
Standard deviation of sample	0,47	0,58	0,54	0,52	0,33	1,37	1,02	0,58
CV(=sd/mean)	0,52	0,93	0,81	1,22	0,35	1,42	1,07	0,97

Table 4.2: The revealed technological advantage (RTA) from foreign-located activity by firms of selected home countries, across fields of technological activity and during the period 1969-1995.

Technological Sectors	United States	Germany	United Kingdom	France	Netherlands	Switzerland	Sweden	Japan
Food, Drink and Tobacco	*0,00*	*0,73*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
Chemicals	0,67	0,58	0,62	0,46	2,10	0,48	0,21	1,94
Pharmaceuticals	*0,64*	*0,42*	*4,45*	*1,43*	*0,00*	*0,54*	*3,83*	*0,22*
Metals	0,78	1,27	1,24	0,56	0,93	0,64	1,11	0,53
Mechanical Engineering	0,67	1,52	1,05	0,54	1,82	1,17	1,06	0,74
Electrical Equipment	1,18	0,94	1,08	1,21	0,90	1,17	0,50	0,86
Office Equipment	1,06	0,69	0,75	1,14	0,35	0,54	0,52	0,88
Motor Vehicles	1,14	0,39	0,14	0,45	4,24	0,15	0,69	1,13
Aircraft and Aerospace	*0,00*	*0,14*	*0,24*	*0,99*	*0,00*	*0,00*	*8,80*	*0,00*
Coal and Petroleum	*0,00*	*1,41*	*4,64*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
Instruments	0,96	1,20	1,20	1,03	0,75	1,27	3,64	1,59
Other Manufacturing	0,65	1,52	0,79	0,69	1,08	1,04	0,92	0,61
Standard deviation of sample	0,43	0,48	1,55	0,46	1,24	0,49	2,56	0,62
CV(=sd/mean)	0,67	0,53	1,15	0,65	1,22	0,83	1,44	0,88

Table 4.3: The revealed technological advantage (RTA) from foreign-owned activity in selected host countries, across fields of technological activity and during the period 1969-1995.

* The sectors represented in italics have less than 1,200 patents.

Table 5: Metals and Mechanical Engineering*

Technological Sectors	United States	Germany	United Kingdom	France	Netherlands	Switzerland	Sweden	Japan
Food, Drink and Tobacco	*1,13*	*0,92*	*0,16*	*0,38*	*0,00*	*0,34*	*2,74*	*0,38*
Chemicals	0,84	1,68	0,91	3,22	1,14	1,39	0,44	0,95
Pharmaceuticals	*0,90*	*1,35*	*1,12*	*2,78*	*0,00*	*2,63*	*1,58*	*0,51*
Metals	0,97	0,57	1,27	1,06	0,77	1,00	0,94	1,42
Mechanical Engineering	1,06	0,95	0,90	0,42	1,51	1,14	1,03	0,68
Electrical Equipment	0,99	0,64	1,28	1,37	0,19	0,56	1,65	1,31
Office Equipment	*0,99*	*1,21*	*0,61*	*0,62*	*0,58*	*0,17*	*0,51*	*1,72*
Motor Vehicles	1,20	0,83	0,17	0,04	0,27	0,66	0,24	1,16
Aircraft and Aerospace	*0,89*	*1,96*	*1,60*	*0,38*	*0,00*	*0,00*	*4,04*	*0,21*
Coal and Petroleum	*1,11*	*1,37*	*0,29*	*0,92*	*0,00*	*0,41*	*0,47*	*1,06*
Instruments	1,06	0,83	1,31	0,44	0,85	0,49	0,96	1,27
Other Manufacturing	0,93	1,23	0,97	0,50	0,41	0,83	1,19	1,26
Standard deviation of sample	0,11	0,42	0,48	1,00	0,50	0,70	1,10	0,46
CV(=sd/mean)	0,11	0,37	0,54	0,99	1,06	0,87	0,84	0,46

Table 5.1: The revealed technological advantage (RTA) from domestically-owned activity in selected host countries, across fields of technological activity and during the period 1969-1995.

Technological Sectors	United States	Germany	United Kingdom	France	Netherlands	Switzerland	Sweden	Japan
Food, Drink and Tobacco	*0,42*	*0,32*	*1,70*	*0,00*	*1,34*	*2,36*	*3,63*	*0,00*
Chemicals	0,48	1,30	0,83	2,35	0,27	0,70	0,36	0,78
Pharmaceuticals	*0,39*	*0,39*	*0,94*	*1,86*	*1,08*	*1,91*	*1,27*	*7,06*
Metals	1,12	0,72	0,81	0,97	0,77	1,45	0,74	0,85
Mechanical Engineering	1,23	0,91	1,28	0,49	1,60	1,33	1,54	0,65
Electrical Equipment	1,03	1,11	1,02	0,62	0,54	0,45	1,02	0,85
Office Equipment	*0,74*	*0,96*	*0,69*	*0,00*	*0,00*	*0,08*	*0,18*	*3,47*
Motor Vehicles	0,90	1,47	0,51	0,00	0,16	0,08	0,43	2,46
Aircraft and Aerospace	*0,00*	*1,90*	*1,52*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
Coal and Petroleum	*0,57*	*0,00*	*0,84*	*1,39*	*0,00*	*0,20*	*0,15*	*2,10*
Instruments	1,19	0,71	0,47	0,09	0,27	0,32	0,78	2,42
Other Manufacturing	0,64	1,36	0,81	2,43	1,14	0,83	0,42	1,05
Standard deviation of sample	0,38	0,54	0,38	0,94	0,57	0,78	0,99	1,97
CV(=sd/mean)	0,52	0,58	0,40	1,11	0,96	0,97	1,13	1,09

Table 5.2: The revealed technological advantage (RTA) from foreign-located activity by firms of selected home countries, across fields of technological activity and during the period 1969-1995.

Technological Sectors	United States	Germany	United Kingdom	France	Netherlands	Switzerland	Sweden	Japan
Food, Drink and Tobacco	*1,85*	*0,99*	*0,52*	*0,67*	*1,04*	*2,95*	*0,00*	*0,00*
Chemicals	0,75	0,49	0,72	0,53	0,55	0,82	0,75	1,22
Pharmaceuticals	*1,34*	*0,17*	*0,73*	*0,00*	*0,00*	*2,77*	*0,00*	*1,25*
Metals	1,06	1,03	1,18	0,70	1,94	0,74	0,81	0,94
Mechanical Engineering	1,05	1,42	1,29	1,40	1,14	1,38	1,34	1,00
Electrical Equipment	1,26	0,69	0,66	0,80	0,20	0,50	0,33	1,56
Office Equipment	*0,77*	*0,42*	*0,51*	*0,17*	*0,00*	*1,22*	*0,00*	*0,58*
Motor Vehicles	0,82	0,71	1,03	0,16	0,12	0,12	0,00	1,00
Aircraft and Aerospace	*0,57*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*	*0,00*
Coal and Petroleum	*0,18*	*0,59*	*0,00*	*0,81*	*0,62*	*0,00*	*0,00*	*1,39*
Instruments	0,61	0,90	0,64	1,61	0,76	1,24	0,50	0,57
Other Manufacturing	1,11	0,58	0,75	0,62	1,25	0,52	1,68	0,58
Standard deviation of sample	0,43	0,39	0,40	0,51	0,62	0,98	0,58	0,51
CV(=sd/mean)	0,46	0,58	0,59	0,82	0,97	0,96	1,30	0,60

Table 5.3: The revealed technological advantage (RTA) from foreign-owned activity in selected host countries, across fields of technological activity and during the period 1969-1995.

* The sectors represented in italics have less than 1,200 patents