Research Networks of Pharmaceutical Firms: Geographical Patterns of Research Collaboration within and between Firms[1]

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Abstract
Industry's scientific output in terms of research articles are one of industry's collaborative quantifiable research outcomes. Large-scale systemic measurements of worldwide trends and sectoral patterns can be disclosed from scientific and technical articles that are (co)authored by industrial researchers and published in the peer-reviewed international scientific journals. Co-authored research papers are assumed to signal research cooperation and associated knowledge flows and exchanges.

We focus our attention on the large science-based Pharmaceuticals multinational enterprises (MNEs) that are active in many countries and produce many research articles - either with partners both within the MNE and/or with external partners within the private sector. The study is based on research articles jointly written by corporate researchers and published in peer-reviewed scientific and technical journals during 1996-2001.

The network analyses of co-publication linkages indicate structural differences between types of Pharmaceuticals MNEs and geographical regions. A general typology is developed of MNEs in terms of their patterns of research cooperation linkages. Separate aggregate analyses are conducted for exemplars of each type broken down by the geographical region in which the partnering companies are located. Some patterns indicate a centralized research cooperation profile; others reflect geographical dispersion of research partners – both within and outside the MNE.

Introduction

According to many commentators and analysts, three interrelated structural factors now seem to be driving industry's attraction to external knowledge bases, and related partnering strategies, aimed at supporting their long-term R&D activities.

First, the changing business strategies and competitive pressures are claimed to have reduced their investments of long-term "basic" research (e.g. Coombs and Georghiou, 2002). Many large firms have downsized or closed down research labs. Corporate in-house research alone is no longer able to create enough economic value to warrant large expenditures and uncertain outcomes. In order to reap economies of scale and scope beyond the reach of a single technology-driven firm, many large and medium-sized firms now engage in collaborative and cooperative inter-organizational arrangements such as joint research ventures, or have increasingly turned to outsourcing.

Secondly, the process of internationalisation within scientific research and science-based R&D in which cutting-edge basic science has become an expensive and complex affair often involves interaction between many partners and scientific disciplines. Due to improved modes of communication, and the need to supplement local or regional knowledge by participating in cross-border cooperative arrangements, firms seek out the most advanced knowledge and world-class researchers available to gain a lead position. Multinational enterprises (MNEs) are leading the way in their search for applicable knowledge and first-rate research partners through their global networks of R&D labs.

Thirdly, in order to develop and exploit existing repositories of information, to create new knowledge, or to transfer existing forms of knowledge, research performers within an MNE often engage in close and informal interaction to access those implicit parts of codified knowledge. For this reason, local and national research networks, or related institutional settings such as joint research centers, are now considered a key element in advanced R&D infrastructures. These partnerships and networks promote and shape knowledge transfer and exchange processes in which codified

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information and tacit knowledge "spill over" to (end) users. They are heavily influenced by proximity and by social and cultural factors (e.g. Pavitt, 1998), and constitute an important factor in the geographical constraints on technological innovation (e.g. Jaffe, 1989).

Most empirical analyses of the research cooperation and knowledge flows within an MNE's corporate research base, and with partners and academic science, involve case studies dealing with a single firm or a science-based R&D-intensive sector. Unfortunately for analysts or policy makers, the lack of comprehensive factual data hampers systemic comparisons across countries and industrial sectors. One of the few ways out of this dilemma is the use of data derived from scientific and technical articles that are authored by industrial researchers and published in the peer-reviewed international scientific and technical journals. These articles constitute an intermediate product of knowledge creation processes and enable large-scale quantitative estimates of basic research activity. Moreover, the affiliate addresses of the author(s) listed on these research articles enable comparative analyses by company and their countries of location (e.g Godin, 1996), as well providing a source of factual information on collaboration patterns and related knowledge-spillovers (Tijssen and Van Wijk, 1999).

This progress paper provides the first set of comparative measurements of geographical patterns of collaboration and knowledge flows within industry's most R&D-intensive sector and also one of the most science-based ones: the pharmaceuticals sector.

Our basic assumption is that these big companies will publish and co-publish, albeit for a variety of reasons (e.g. Tijssen, 2004), in sufficient quantities to provide us statistically robust aggregate-level information on characteristics of their activities and outputs in basic research.

Our hypothesis is that depending on the geographic situation of the company's headquarters, and the organizational structure of its R&D activities, it will follow different "internationalization" strategies, which means to do research (and co-publish) with other companies, or other branches of the same MNE, that belong to a different region. So we will be able to classify the firms according to their strategies and organizational structure: basically, into MNEs with an international projection related to their R&D spreading strategy, and those with a local projection.

Data collection and methodology

The publication data for this study are extracted from a CRP (Corporate Research Papers) database. This database comprises bibliographic information on research papers published in international scientific and technical journals covered by the Institute for Scientific Information (ISI) in which at least one of the affiliate addresses of the authors refers to a private sector organization; it includes some 250,000 research papers published in 1996- 2001 and (partially) assigned to the private sector. The coverage extends across all countries and fields of science and some 40,000 different main organizations are covered. The data were consolidated in mid-2002. Foreign branches and foreign subsidiaries of multinational companies are labelled with the consolidated name of the parent company. Companies that were added to the parent company through mergers and acquisitions in the years 1996-2002 were renamed to the current (ultimate) parent company to ensure backwards and forwards compatibility in trend analyses.

The name companies were selected based on two conditions: that the company (at least one business unit belonging to a (parent) company) was assigned to the Drugs Standard Industrial Code (SIC), code number 2834 following the Dunn & Bradstreet's "Who owns Whom" database; and that have published at least five research articles in 1996-2001 as covered by the CRP database.

Each name (variation) of a firm was linked to the country of location as listed in the author affiliate address information in the research article. We have unique name/country pairs to identify companies in our database (e.g. "Bayer AG/Germany" and "Bayer Corp/USA"), which can then thus be analyzed and interpreted in terms of national affiliates of the same multinational company. In fact, the unit of analysis will be this combination between country name and country of location.

The last step to get the final core set of publications was to extract from the CRP database all the research papers that list at least two addresses referring to two selected company/country units.

Co-authoring scientific publications is one of the clearest links to informal networking that can be made. These joint research papers reflect successful scientific co-operation and are likely to signify related knowledge flows and R&D networking activity between companies. Nevertheless, bibliometric

statistics and indicators should be handled with due care as a reliable source of conclusive empirical evidence on actual scientific cooperation (Katz and Martin, 1997).

A network analysis was applied to represent relations between companies based on their co-authorship and to identify patterns of co-publication activity. Each of the graphs will represent the relations between the headquarters and the subsidiaries located in different countries; and between each of them and the rest of the companies from the dataset grouped by region of location.

Main Results

Distribution of co-publication partnerships by regions

The companies that took part in this set of publications were mostly (very) large pharmaceutical firms, especially MNEs. In total, there were 378 companies/locations of which 37% were located in EU15 countries; 42% were North American-based companies (US and Canada); 18% in the Pacific Asia region (mainly Japan and Taiwan, and excluding Australia); 2% were based in 'Other European countries', principally in Switzerland, Norway, and Israel; and only 1% were assigned to 'other countries' containing companies located in Australia.

Figure 1 displays the co-authorship links between the various companies grouped by the five regions of location. The co-publication linkages include both the headquarters of the companies as well as their foreign affiliations. The size of the lines reflects the strength of the link between two regions. The size of the nodes shows the co-publication activity between the companies inside the regions. Between North America and the EU15 the links are strongest. The Pacific Asia region has strong connections with both EU15 and North America. It is remarkable for other European countries that their stronger link is with the North American region.

Only 35 companies (accounting for 149 company-country combinations) are in fact MNEs with co-publication links between their various affiliations (i.e. company headquarters and subsidiaries/branches in different countries). The remainder comprises multinational enterprises with only one research facility or R&D laboratory that is producing research papers, and national enterprises with no foreign affiliations.

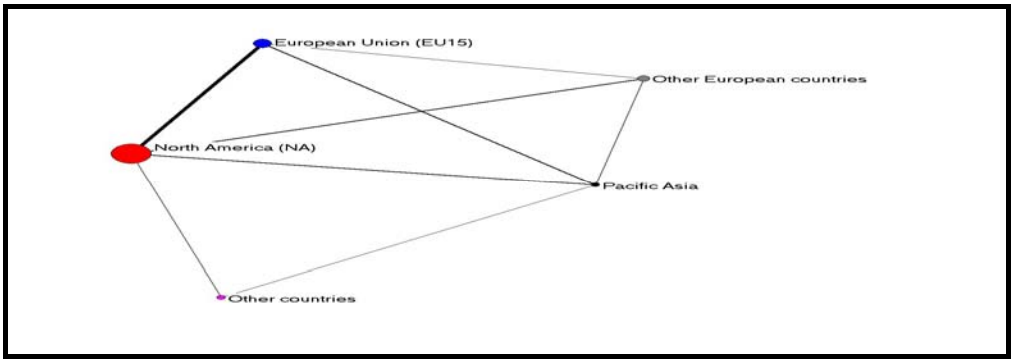

Figure 1: Research co-publication links between pharmaceuticals companies by region

Types of MNE research networks

Starting from the arrays of co-authorship frequencies by region of location described above, we extracted, one at a time, the MNEs that appear on the data set located in different countries. The result will be 35 graphs, one for each of the MNEs considered. Each graph will represent two types of nodes: the company name with the different locations (headquarters and subsidiaries) and the regions where their other companies are located. The links between the nodes will represent the co-authorship activity.

We have identified three general types of co-publishing networks between headquarters and subsidiaries of the same pharmaceuticals company:

1. Centralized research network

The company headquarters (i.e. central R&D laboratory) and the subsidiaries (national research facilities) co-publish, as well as publishing with other companies.[2] This set includes 19 MNEs. Figure 2 displays an illustrative example of this type: Bayer. All Bayer subsidiaries co-published with the headquarters in Germany and with Bayer labs in the USA. The headquarters, USA and Great Britain all have research collaborations with other firms based in the EU15, in other European countries and in North America. Bayer/Japan extends this network with additional collaborations with companies in its own region.

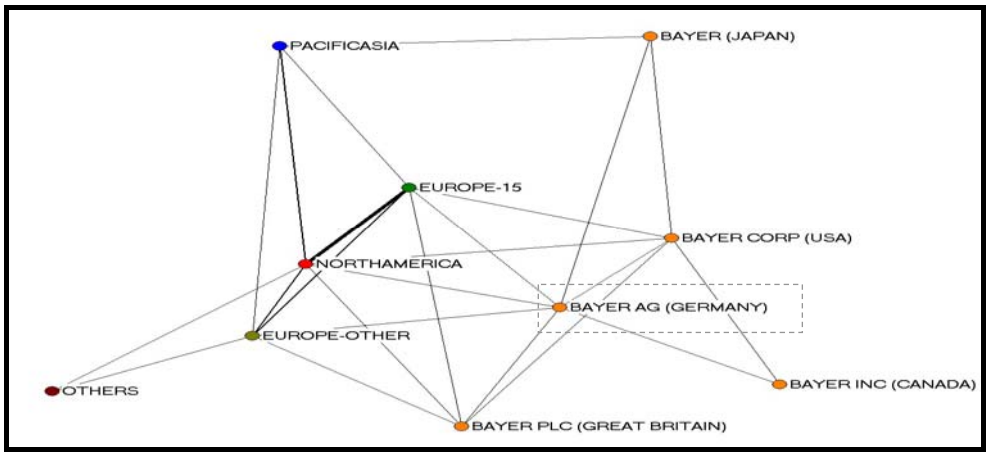

Figure 2:Example of a centralized network: Bayer
The headquarters is highlighted by a rectangle.

2. Decentralized research networks

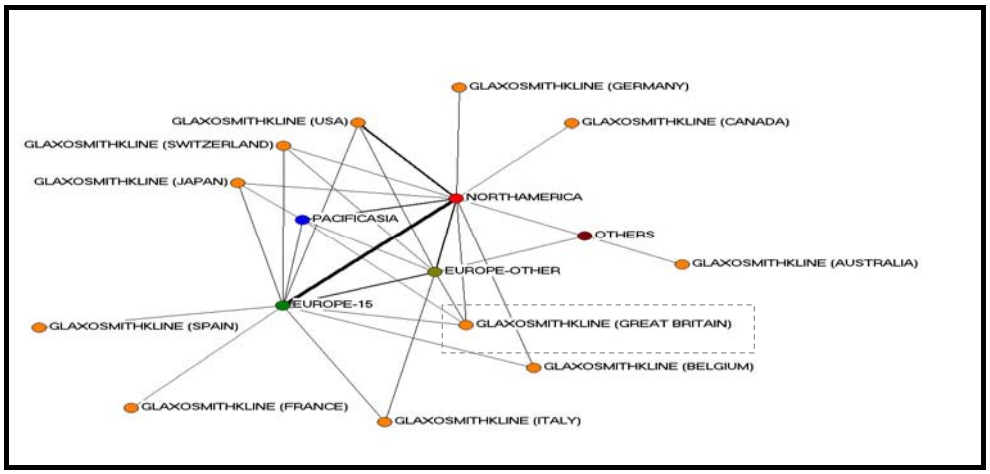

Figure 3: Example of a decentralized network: GlaxoSmithKline
The headquarters is highlighted by a rectangle.

This set of MNEs includes 13 companies. The type of network is characterized by the lack of (strong) links between the company headquarters (i.e. central research laboratory) and subsidiaries that do not co-publish. Rather, each research laboratory co-publishes with other companies located in the different regions of the globe. The pattern reflects a corporate R&D strategy with geographically dispersed and (semi) autonomous research laboratories. Figure 3 shows an example of this kind of network. GlaxoSmithKline's headquarters are located in the United Kingdom with several subsidiaries scattered

[2] The information on the Bayer web pages confirms that branches or subsidiaries are located in all countries listed in Figure 2.

across the globe.[3] GlaxoSmithKline UK is connected with all regions, with an especially strong link to GlaxoSmithKline's operations in the USA and the North America region. We can see how each of the subsidiaries have their own pattern of collaboration, sometimes focused on their own region, as the case of GlaxoSimithKline's research in Spain and GlaxoSmithKline in France, while others focus more than one region, like in the case of GlaxoSmithKline's research activities in Switzerland.

3. Gateway network

This is small set that totals only 3 MNEs. The researchers based at the company's subsidiaries co-publish exclusively with their colleagues based at headquarters/central R&D facility. The researchers at headquarters co-publish with external partners within the corporate research network. Figure 4 displays an example of this type of 'gateway' network for Baxter Healthcare, a US company with two subsidiaries that run research facilities – Baxter Germany and Baxter Belgium. Each subsidiary co-publishes with their headquarters, which in turn co-publishes also with other companies located elsewhere, [4] North America and EU-15.

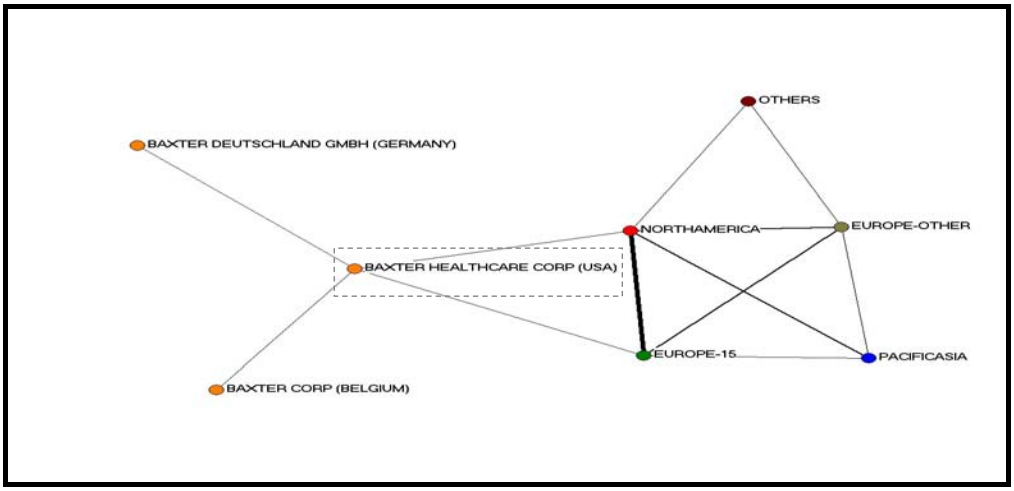

Figure 4: Example of a gateway network: Baxter
The headquarters is highlighted by a rectangle.

Concluding remarks and follow-up research

The first results of this exploratory empirical investigation into the organizational and geographical characteristics of intra-MNE research networks has revealed interesting information with respect to the geographical dispersion of corporate research partnerships. The central position of North America in the global research network is remarkable but not entirely surprising in view of the US dominance in the pharmaceuticals sector. The interpretation of this finding is more complex given the mix of intra-firm and extra-firm research linkages. We observe a particularly strong link between North American pharmaceutical companies and those based in the European Union, which would seem to be the main location of research partners – either their own affiliations or external companies.

Our first investigation into the black box of intra-MNE research networking reveals three main types of networks in terms of geographical distributions: centralized, decentralized and gateway networks. The first two are the most common types.

Follow-up research is planned to further unravel these corporate research networks, to explain the main characteristics of this network typology, and extend our analysis into the framework of industrial economics. Specific questions that need to be addressed relate to both the company-specific

[3] Checks of the company websites indicated that this company has branches and/or subsidiaries in all countries listed in Figure 3.

[4] We have checked the Baxter web pages and found the company has a subsidiary with research facilities in these two countries.

determinants of networking, as well as geographical and economic factors at play, that collectively shape and drive the R&D activities of MNEs in the pharmaceuticals sector.

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