Paper to be presented at the DRUID 2011

on

INNOVATION, STRATEGY, and STRUCTURE -
Organizations, Institutions, Systems and Regions
at
Copenhagen Business School, Denmark, June 15-17, 2011

science-based firms: Their effect on innovation in the acquired firm and the local sc

Marcela Miozzo
University of Manchester
Manchester Business School
marcela.miozzo@mbs.ac.uk

Lori DiVito
The University of Manchester
Manchester Business School
lori'divito@gmail.com

Panos Desyllas
The University of Manchester
Manchester Business School
panos.desyllas@mbs.ac.uk

Abstract

This paper asks what happens to the technological resources and assets of host country science-based firms when they are acquired by foreign firms.

Jelcodes:L00,-

Cross-border acquisitions of science-based firms: Their effect on innovation in the acquired firm and the local science and technology system[1]

Marcela Miozzo, Lori DiVito and Panos Desyllas
Manchester Business School
The University of Manchester
Booth Street West
Manchester M15 6PB, UK
marcela.miozzo@mbs.ac.uk
lori.divito@gmail.com
panos.desyllas@mbs.ac.uk

June 10 2011
Draft – please do not quote without permission

Abstract
This paper asks what happens to the technological resources and assets of host country science-based firms when they are acquired by foreign firms. Drawing on a multiple case study research design and interviews with UK biopharmaceutical firms and on patent data, the paper derives different patterns of knowledge base combinations through acquisition that have different outcomes in terms of innovation. These patterns are based on combinations of two factors: the complementarity or similarity of the technology and the complementarity or similarity of the discovery and development capabilities of the target and acquiring firm. These combinations have clear differential outcomes in terms of investment in the acquired firm's technology and important effects for the local science and technology system.

1. Introduction

Mergers and acquisitions are acknowledged in both the literature of corporate control and of innovation as one of the main means for firms to create and add value by gaining access to new knowledge and capabilities or by a synergy of complementary productive resources (Blonigen and Taylor, 2000; Hagedoorn 2002; Inkpen et al. 2000; Sleuwaegen and Valentini, 2006; Uhlenbruck et al. 2006). The rapid growth in technological knowledge, in the sources of production of that knowledge, and the increasing need to integrate multiple technologies from different sources presents a challenge to even the largest corporations (Granstrand and Sjolander 1990), making the sourcing of technology assets externally as well as their integration with internally developed assets increasingly important.

Nevertheless, there is consensus among numerous studies that acquisitions result in at best a neutral effect on the invention and innovation outputs of the combined firm (Prabhu et al., 2005; Hitt et al., 1991; Ornaghi, 2009). In particular, several scholars have suggested and found evidence that even the most carefully thought-out acquisition deals often suffer from an ailing post-acquisition innovation performance of the acquired business units (Graebner, 2004; Kapoor and Lim, 2007; Calderini et al., 2003). This has been attributed to obstacles to knowledge transfer across organisational boundaries, disruptions in the innovation activity of the target firm, a high turnover of the target's key scientists, reduction in the incentives and productivity of the remaining scientists

[1] The authors are grateful for financial support from the Institute for Small Business and Entrepreneurship and Economic and Social Research Council Research and Knowledge Exchange Fund (RAKE2009-003) and the Economic and Social Research Council (RES-189-25-0227).

and dissimilarities in organisational routines and knowledge bases between the acquiring and acquired firms (Kapoor and Lim, 2007; Ernst and Vitt, 2000; Ranft and Lord, 2002).

Despite the rather discouraging findings about the acquisition effect on invention and innovation outputs, we have witnessed yet another merger wave in the 1990s, featuring cross-border mergers and acquisitions and involving numerous high-technology and science-based firms. The increase in cross-border mergers and acquisitions has raised concern for host country policymakers. There is a fear that the innovative activity of the target firms could be reduced and shifted away, depriving the host economy of strategic technologies and technological spillovers (Bertrand, 2009; UNCTAD, 2005). Indeed, it has been argued that multinationals tend to concentrate their more strategic activities such as R&D at home due to their embeddedness in their national systems of innovation and need for internal cohesion (Blanc and Sierra, 1999; Patel and Pavitt, 1997; Zanfei, 2000). This raises the question of whether host countries lose valuable economic benefits and science resources to foreign firms in technology-related mergers and acquisitions.

On the other hand, there is also evidence of increased internationalisation of R&D by multinationals. The importance of R&D of foreign affiliates has grown in most host economies since the 1990s. There is evidence of a shift in the role of R&D abroad from just supporting local production units and adapting products or processes to make them suitable and competitive in a foreign market to investment where firms improve existing assets or acquire new technological assets through foreign-located R&D (Dunning, 1994; Kuemmerle, 1999; Pearce, 1999). The assumption is that the foreign location provides access to complementary location-specific advantages derived from the presence and activities of other firms, suppliers or centres of excellence in research, offering the potential for science-based developments (Cantwell, 1995; Ietto-Gillies, 2001).

This paper asks what happens to the technological resources and assets of host country science-based firms when they are acquired by foreign firms. Motivated by this question, we investigate empirically under what conditions these technological assets are reduced and relocated abroad or are enhanced by further investment into the target's technology assets. The empirical analysis is based on an in-depth case study of six acquisitions of UK biopharmaceutical firms acquired between 2006 and 2010 and on the patent data of the target and buyer in each case to assess the knowledge relatedness between the acquiring and target firms. Adopting a detailed first-hand observation approach seems appropriate given the relative lack of theoretical and empirical attention to the relation between mergers and acquisitions on investment in the acquired firm's technology in science-based industries. In this way we can study not only to what extent mergers and acquisitions have an impact on investment in the acquired firm's technology but also how, by analysing the reorganisation of the R&D processes following an acquisition.

The contribution of this paper is three-fold. First, we advance the discussion at a conceptual level by arguing that multiple combinations of firms' technology and discovery and development capabilities have different effects on the innovation performance of the acquired firm. For this purpose, we build on previous literature that has explored the effects of the relatedness of the knowledge bases of acquiring and target firms on innovation in technology-related mergers and acquisitions (Seth, 1990; Cassiman et al., 2005; Bertrand, 2009; Cloodt et al., 2006; Makri et al., 2010).

A second contribution is to extend the realm of inquiry to science-based firms. Previous literature has explored the relation between mergers and acquisitions and innovation for medium- and high-tech firms. Science-based firms, mainly in the life sciences, are firms that both participate in the creation and advancement of science and attempt to capture financial returns from this participation (Pisano, 2006). In contrast to firms in other sectors (even high-tech ones), their assets are largely

composed of R&D projects and they face market forces but in many cases do not obtain earnings. They face markets without a rich revenue stream and dominant market position, with prolonged periods of risky investment in research. Their R&D projects involve the simultaneous and iterative integration of activities rooted in diverse scientific and technological domains along an emergent technology trajectory.

Finally, the paper contributes to the extant literature methodologically, by drawing on a combination of both interview and patent data involving the acquiring and acquired firms. Previous studies have assessed firms' location in the knowledge space, including knowledge relatedness, solely on the basis of patents (see, for example, Makri et al. 2010). However, we argue here that given our focus on biotechnology firms, we need to assess knowledge relatedness on the basis of careful analysis for each case of interview and patent data. There are questions as to the extent to which patent data alone can reflect accurately biotechnology firms' knowledge bases and requires instead careful case-by-case examination of the knowledge relatedness between target and acquiring firms.

2. Mergers and acquisitions, technological relatedness and innovation

The literature on internationalisation of the firm shows that in order to exploit effectively but also to consolidate an existing capability, it is necessary to extend the firm's capabilities into related fields of production and technology, and across a variety of geographical sites through investment or mergers and acquisitions (Cantwell and Piscitello, 2000). In that context, opportunities for organisational learning increase in technology-related acquisitions when the firm is exposed to new and different ideas based on differences in technological capabilities between the acquiring and target firm. This paper builds on recent contributions integrating insights from the corporate control and innovation studies literature that explores the influence of a set of factors on a firm's innovative performance after mergers and acquisitions.

Both the strategic and technology management literature have focused on the impact of mergers and acquisitions on innovation. It is argued that mergers and acquisitions can enable scale and scope economies in R&D (Cassiman et al., 2005); they can help firms to enter new technology and markets complementing internal R&D resources; they can facilitate reorganisation of their R&D efforts among different research centres; they can facilitate greater internal finance for R&D projects (Hall, 2002); and they can increase the buyer and target firms' absorptive capacity resulting in greater innovation output (Ahuja and Katila, 2001; Desyllas and Hughes, 2010). On the other hand, it is also argued that mergers and acquisitions can lead to reduction in research due to reduced competition (Kamien and Schwartz, 1982); they can lead to the re-organisation of business units, disrupting R&D departments or forcing the exit of scientists (Ernest and Vitt, 2000); and they can cause managers to postpone decisions regarding long-term investment such as R&D, and a change in emphasis from strategic to financial controls, hindering investments in R&D (Hitt et al.,1991, 1996).

In particular, we focus on contributions about the role of knowledge relatedness between acquiring and target firms as an important determinant of acquisition outcomes. The reasoning behind studies on knowledge relatedness is that an acquisition can expand a firm's knowledge base and innovation output by providing economies of scale and scope in research, shorter innovation lead times and the possibility to engage in larger combined projects (Hagedoorn and Duysters, 2003); but integration of a new knowledge base can also disrupt established routines (Haspelagh and Jemison, 1991). This reasoning is justified on the basis of the concept of absorptive capacity, which suggests that the ability to use new information and to learn is enhanced when the new knowledge is related to what is already known, that is, when there are common skills, shared languages and similar cognitive structures (Cohen and Levinthal, 1990; Makadok, 2001). This can enable smooth absorption of the

related knowledge and inventive recombination (Henderson and Cockburn, 1996) and enhance the capacity to recognise the value of new information and absorb and exploit it commercially. If the innovation routines of the firms are very different, then the integration of knowledge will be disruptive to the routines of the firm and demand great efforts of adaptation and integration and radical changes in the way of organising research. Similarly, if the knowledge base of the target is too similar to that of the acquiring firm, then it will contribute little to further innovation performance, involving cost of transfer without knowledge enrichment (Ghoshal, 1987; Hitt et. al, 1996). To summarise, the argument is that mergers and acquisitions improve innovation performance when the technological knowledge of the acquiring and target firms is similar enough to facilitate learning but different enough to provide opportunities to enrich the acquiring firm's knowledge base.

Indeed, Ahuja and Katila (2001), tracing the acquisitions and patenting activities of a sample of 72 leading firms in the medium-technology chemical industry between 1980 and 1991, found that relatedness of acquired and acquiring knowledge bases (as measured by overlap of cited patents) in technology-related acquisitions has a curvilinear impact on the acquiring firm's innovation output (patent counts). Cloodt et al. (2006), who extend Ahuja and Katila's analysis to four major high-tech sectors using a sample of 347 international firms between 1989 and 1995, found evidence confirming the curvilinear relationship between relatedness and innovation output for technology-related acquisitions. Also, Cassiman et al. (2005), drawing on 31 case studies of horizontal mergers and acquisitions deals, explored the effect not only of technological relatedness but also of market relatedness (building on Piscitello, 2004). They used a EU data set collected by interviewing key personnel of medium- and high- tech firms involved in mergers and acquisitions. They found that mergers and acquisitions involving firms with complementary technologies result in more active R&D performers after the acquisition. In contrast, when acquired and target firms are technologically substitutes, they decrease their R&D level after acquisition. R&D efficiency increases more when the firms are technologically complementary than when they are substitutive. This supports the argument of scope economies effects of mergers and acquisitions, but rejects that of economies of scale effects. If firms have similar technology, the reduction in R&D is more prominent, while R&D efficiency gain is smaller if acquiring and target firms were rivals than if they were non-rivals in the product market.

Makri et al. (2010) built on these insights and examined not only the effect of the relatedness of the technological knowledge but also of the science base for a sample of high-technology mergers and acquisitions in the drug, chemical and electronics industry. They elaborated further on the concept of 'relatedness'. They argued that 'relatedness' across product and market domains does not necessarily imply relatedness in knowledge domain and vice versa. Their argument is that for high-tech firms, it is important to examine relatedness in terms of the firms' knowledge domain. Also, they argue that relatedness has been used in broad terms, using similarity and complementarity interchangeably. They differentiate between similarity and complementarity in both science (scientific disciplines and research communities) and technology (patents). They argue that "When two firms similar in both science and technology domains merge and combine their knowledge bases, they are commonly 'dancing to the same music, using similar steps' because they are familiar with the types of technological problems likely to surface and rely on similar sets of scientific theories to understand and resolve them' (Makri et al. 2010, p. 606). By looking at the similarity or complementarity of both technology and science and the effects on invention quantity, quality and novelty, they show that firms acquiring other firms with complementary science and technology knowledge can produce higher quality and more novel invention. In contrast, when a firm acquires a target with similar technologies (and based in similar areas of science), integration is easy but results in low invention performance. When mergers and acquisitions involve similarity in technology and complementarity in science, they lead to more novel inventions only.

Our paper builds on these contributions and extends the study to science-based firms. In contrast to high-tech firms which use scientific knowledge to create innovative products (e.g. semiconductors, electronics), science-based businesses actively participate in the process of advancing and creating science. These firms confront specific challenges, including an unusually high risk profile and longer term horizons compared to medium- and high-tech sectors. We focus here in the biotechnology segment of the pharmaceutical industry. Every R&D project in science-based firms is an experiment, and the vast majority of R&D projects fail. R&D is about successively reducing uncertainty through the acquisition of information (selecting and screening), a process highly iterative and inductive, unlike other high-tech industries where products evolve through design-test iterations (Pisano, 2006). As argued by Pisano (2006, p. 151): "Biotechnology is quite different from semiconductors and software. The pieces of the drug discovery puzzle are often not modular at all but constitute a set of interdependent problems. Subtle interactions between a target, a molecule's structure and its physical properties, dosage form, the manufacturing process, the dose, and the patient population can profoundly influence the performance of a drug." Indeed, to perform well, science-based firms require appropriate mechanisms to integrate cross-disciplinary skills and capabilities to identify targets, develop molecules, develop formulations, design clinical trials, choose the target population and select the manufacturing process. Each technological/scientific choice has implications on other choices. This makes integration across firm boundaries very difficult.

Because of the particular nature of science-based firms, it is reasonable to follow Makri et al.'s (2010) argument regarding the unsuitability of examining market relatedness between acquiring and target firm. We propose that for science based firms, it may be suitable to examine not only technology relatedness but also the relatedness of the acquiring and target firms' discovery and development capabilities, which in the case of science-based firms reflects their knowledge base. In science-based firms, firms are continuously integrating a variety of activities rooted in many technology and scientific domains along an emergent technological trajectory (Dosi, 1982). Each project is unique and demands an iterative process of integration of activities for drug invention, pre-clinical and clinical trials, regulatory approval and the final market launch, all of which are highly interdependent. Also, despite the growing use of bioinformatics and computer-aided discovery, this process still has a strong tacit dimension (Pisano, 2006). Therefore, unlike many high-tech sectors such as software or electronics, shared experience is very important. Proximity (both to universities and industry clusters) matters to access these kinds of scientific tacit knowledge embedded in individuals (Balconi et al., 2007). This suggests that the similarity and complementarity of the technologies and discovery and development capabilities of the merging firms can play an important role in decisions about the future of the acquired firm's R&D projects.

Most of the studies evaluating the impact of mergers and acquisitions on invention/innovation do not distinguish explicitly between domestic and cross-border mergers and acquisitions. Nevertheless, it is easy to see that both the positive and negative effects of mergers and acquisitions on invention and innovation can be enhanced with foreign mergers and acquisitions. Cross-border mergers and acquisitions can enable access to a wider set of resources residing in different country boundaries (Inkpen et al., 2000). However, there is the danger that acquiring firms may centralise R&D in the home country, to enable economies of scale in research and avoid the costs of coordinating dispersed R&D centres (Kumar, 2001). As a result, the innovative activity of the target firm could be reduced or shifted away, thereby reducing the potential of R&D as a source of innovation and economic growth.

The contribution by Bertrand (2009) addresses this issue. Based on accounting data on French innovative manufacturing firms, this author found that acquisitions of French firms by foreign firms

boost both external and in-house R&D expenditure of acquired French firms. There is more contracting out to local research suppliers, such as local public laboratories and universities. The growth of the R&D budget is not only financed by internal resources but also by the acquiring firm. These results call into question the idea that foreign acquisitions hinder innovation in the target firm and are detrimental to the national production and innovation system of the host country.

Our study builds on this to explore what happens with the technological resources of science-based firms when they are acquired by foreign firms. We focus here on a set of resources, the R&D projects of the acquired firms and ask whether the development of them is continued in the host country. In other words, we ask whether and under what conditions foreign acquirers offer long term funding and complementary technology assets and discovery and development capabilities to develop the distinctive technologies of the acquired firms. Given the important role of tacit knowledge in science-based firms, this is likely to depend on and affect the strength of the regional and national science and technology capabilities.

3. Methodology

The research objective was to learn about what happens with the technological resources of host country science-based firms when they are acquired by foreign firms. We designed an exploratory study building on a multiple case study approach that allows the researchers to compare findings across cases and build inductively on extant theory. As technological knowledge transfer is expected to be highly tacit and interactive, the case study approach was preferred because it enabled the researchers to understand in greater depth the underlying mechanisms, barriers and processes used in transferring technological knowledge across firm and country boundaries. Given the relatively early stage of research, we did not select cases based on a full, logically complete typology. It is not so much a matter of whether the selected cases are representative of the larger population but more whether the selected cases illuminate particular relationships and constructs of the question being investigated (Eisenhardt and Graebner, 2007). Our aim is to build gradually a typology and work towards a typological theory through empirical analysis of cases within a given theoretical framework. In contrast to a general explanatory theory, these can explain the pathways through which some configurations (or 'types') can relate to specific outcomes, offering a rich and differentiated depiction of a phenomenon and can generate discriminating and contingent explanations and policy recommendations (George and Bennet, 2005).

The case studies include the acquisitions of six biotechnology firms in the Cambridge, Oxford and Manchester areas in the UK between 2006 and 2010. We focus purely on the biopharmaceutical industry because of the extensive amount of funding that these firms need for developing new products, the difficulty these firms experience in securing funding for later stage development, and the high levels of scientific and technological knowledge. Also due to the high level of internationalisation in the industry, the number of foreign acquisitions is high and we were able to find a number of cases that met our selection criteria.

The biotechnology firms included in our sample were identified by scanning the trade press from 2006 onwards for instances of foreign acquisitions of British biotechnology firms. The acquirers in the first five cases are large and small firms from a range of countries, including Australia, Belgium, Germany and USA. The sixth case involves a domestic acquisition, added to our sample to compare and contrast the findings with respect to those of the cross-border acquisition cases. Table 1 provides an overview of the target and buyer case study firms. Our aim was to include a variety of firms that followed different models of drug development, diagnostics and service provision.

Insert Table 1

Qualitative information about the deals was gathered by conducting in-depth interviews with the founders and/or scientists on the premises of the target and acquirer firms. Interviews with senior management of both the target and the buyer were carried out, providing dyad relationships in the sample. Table 2 lists the interviews held with target firms and buyer firms. The interviews lasted approximately two hours and covered two main themes: i) the nature of the technology and capabilities of the target and buyer firms prior to acquisition; ii) the changes that occurred in the technology and business after the acquisition including the extent to which the combined entity continued to invest further in the target's R&D projects. All interviews were digitally recorded and transcribed. The use of a detailed interview schedule aided the creation of codes; each transcript was coded and the coded data was compared to identify patterns among the data. We focus in this paper on uncovering knowledge transfer practices as a result of the acquisitions and the development of the technology following acquisition. We complemented the deal analysis with information on various economic characteristics of the sample acquirer and target firms using Datastream and Fame databases.

Insert Table 2

We develop two types of independent variables: i) complementarity and similarity of technology and ii) complementarity or similarity of the discovery and development capabilities of the buyer and the target firms. By technology we mean the therapeutic areas in which the firms are involved. We judge the complementarity or similarity between target and acquired firms from the interview data. The technology complementarity and similarity between the acquiring and acquired firms is also proxied using information from patent applications by the target and acquirer firms. Data on patented inventions, technology classes and categories, assignee names and inventor identity were collected from Thomson's Delphion database. Because our sample of acquirers originates from different counties, we consider patent applications to the World Intellectual Property Office (WIPO) as a proxy for the technological knowledge of both the acquiring and acquired firms. Using patent applications to the WIPO also makes sense because the biopharmaceutical industry is a global industry. The focus on WIPO patent applications imposes a quality filtering on the patented inventions, given the evidence that applicants tend to file for international patent protection for the relatively more "important" inventions (OECD, 2004). To avoid a possible time bias arising from the fact that applicants have up to 12 months from first filing their patent application (usually in their own country) in which to make further applications in other countries for the same invention, we consider WIPO patent applications by the original priority date.[2]

Following Makri et al. (2010), we construct objective measures of technology similarity and complementarity. Technology similarity between firms is the degree to which their technological problem-solving focuses on the same narrowly defined areas of knowledge. It is calculated as the number of patents applied for by the target (T) and the acquirer (A) that are in the same patent class, multiplied by the total number of patents the acquirer has in all classes divided by total acquirer patents. Hence, technology similarity is given by:

$$\frac{\text{Overlap all patent classes}}{\text{Total patents A \& T}} x \frac{\text{Total acquirer patents in common classes}}{\text{Total acquirer patents}}$$

Technology complementarity between firms is the degree to which their technological problem solving focuses on different narrowly defined areas of knowledge within a broadly defined area of

[2] The priority date is the first date of filing of a patent application, anywhere in the world, to protect an invention. The priority date is used to determine the novelty of the invention, which implies that it is an important concept in patent procedures (OECD, 2006).

knowledge that they share. It is calculated using the number of patents in the same category but in different patent classes. Hence, technology complementarity is given by:

$$\frac{\text{Overlap all patent categories}}{\text{Total patents A \& T}} - \frac{\text{Overlap all patent categories}}{\text{Total patents A \& T}} x \frac{\text{Total acquirer patents in common categories}}{\text{Total acquirer patents}}$$

The measures of technology similarity and complementarity are weighted by the importance of each patent class for the acquirer in order to account for the fact that large firms tend to patent in various patent classes. Patent categories and classes are defined using the hierarchical structure of the International Patent Classification (IPC) system. For example, a broad patent category of inventions related to "Heterocyclic compounds", which is coded as C07D according to IPC's hierarchical structure, consists of several more detailed classes, such as "Heterocyclic compounds containing hydrogenated pyridine rings" which is coded as C07D 211. Similar to previous work (e.g. Ahuja and Katila, 2001; Cloodt et al., 2006), we assess the similarity and complementarity in the technology of the acquiring and acquired firms over the five-year period leading to the deal date.

However, the well-documented general and biotechnology-specific weaknesses in the use of patents as proxies for technological knowledge lead us to question the extent to which patent data alone can reflect accurately biotechnology firms' knowledge bases.[3] We thus complement the patent analysis by adopting careful case-by-case examination of the similarity and complementarity in the knowledge bases (therapeutic areas) of the acquiring and acquired firms by drawing on information from the in-depth interviews.

The complementarity and similarity of the discovery and development capabilities (hereafter referred to as capabilities) between the target and acquirer firms are also assessed by using information from the in-depth interviews. We define capabilities as the knowledge that a firm possesses to enable it to perform its activities (Dosi et al. 2000). Within an organisation, capabilities are aimed at 'solving' problems such as the purposeful activity of search for new drugs. In science-based environments, the capabilities of a firm depend heavily on their R&D resources; however, coordination between R&D and other functions, and often with suppliers or partners, is needed to identify and link technological options and market opportunities. In our case, we focus on the activities of the firms in conducting drug discovery and development, including their ability to provide services to clients, links to customers, to do clinical trials, capacity for safety and efficacy testing, ability to deal with regulatory authorities and capacity for manufacturing.

Similar to the operationalisation approach for our independent variables, we assess our dependent variable, the impact of acquisition on investment in target technology assets, using information

[3] There can be several sources of weaknesses of patent-based metrics. First, the problems of using only patents as indicators of technological activity are well known: a patent is one form of protection of innovation (and much of a firm's technical knowledge may remain unpatentable); it can be seen as an intermediate output resulting from inputs of resources into R&D; and there are differences in patents between countries and sectors in the importance of patents and variation in the technological and economic value embodied in individual patent (Basberg, 1987; Griliches, 1990; Pavitt, 1985; Piscitello, 2004). Second, it has been shown that there is substantial bias and imprecision from patent-based relatedness measures when applied outside the most frequently patenting firms (Benner and Waldfogel, 2008). Third, there are two particular considerations that apply to patents in the biotechnology sector. One is that in this sector, the trend is towards considering as patentable research discoveries for which "usefulness" can only be defined with respect to their value in performing further research (rather than its potential practical application) (Mazzoleni and Nelson 1998). The other is that despite the fact that biotechnology is subjected to extreme uncertainty, biotechnology patent scope are granted by applying patent doctrines developed for other medium- or high-tech sectors (Ko, 1992).

from interviews and patent records. We focus on whether there was further research and/or development investment in the acquired technology in the host country after acquisition and on three aspects of this investment: preservation of the target business unit; retention or redundancy of scientists and other technical staff; and investment in development of acquired drug programmes or in facilities or capital equipment of the target firm. Combining information from open ended questions and closed questions on the extent to which the target firms' patent assignees (whose names have been identified from patent data) have been retained post-acquisition and on the percentage of the R&D budget of the combined entity invested in the target's projects allowed us to triangulate findings.

4. Findings

In the analysis of the case findings, we concentrate on three main constructs: technology similarity or complementarity; capabilities similarity or complementarity; and investment in and deployment of the acquired technological assets post-acquisition. Table 3 summarises the patent analysis.

Insert Table 3

4.1. Technology similarity or complementarity

Technological similarity or complementarity is defined by how similar or complementary the therapeutic areas of the target and acquirer are (see Table 4). Case 1, 2, 5 and 6 show evidence of technological similarity between target and acquirer. In case 1, the target firm expanded from platform services to drug product discovery and development and ADME (absorption, distribution, metabolism and excretion) testing of molecules. Following funding difficulties, the target firm rationalised its focus to services only and was thereafter acquired by the buyer, a larger international biopharmaceutical firm offering a comprehensive suite of discovery products and services. We concentrate here on the target firm's ADME services which were similar to the buyer's technological knowledge but filled a gap in the services offered by the buyer, which had a full service subsidiary based in the UK (the other part of the target was rationalised and divested). This classification is supported by patent analysis, which shows a technological similarity index of 0.73, much higher than the complementarity index of 0.13 (see Table 3).

Insert Table 4

The target firm in case 2 was not acquired as an entire firm, but rather its technological assets were sold to several firms. At its founding in 1999, the target licensed technology (compounds) from UK universities and spent 10 years developing drug programmes in skin repair and regeneration, including wound care and hair regeneration, their lead programme completing Phase III clinical trials. After disappointing results from Phase III clinical trials of their lead programme, the board of directors decided to sell the firm. However, the target was unsuccessful in selling the firm as a whole and has sold the different technological assets to various biotechnology and large pharmaceutical firms for a fraction of their value. Three of the lead programmes were sold to two separate biotechnology firms. A subsidiary business of the target focused on stem cell research was sold to a large pharmaceutical firm and the last drug development programme in early stage has been taken over by the target's founder. We focus on the acquisition of the two lead drug programmes in wound care sold to a biotechnology firm. It is clear from the interview data that there is a high level of technological similarity between the acquirer and the target firm. The chief scientific officer and founder of the target firm explained that the acquirer was "already experienced in cellular therapies and there aren't many companies in the world that are in cellular therapies of wound care so they were one of maybe four or five companies that could have possibly purchased this and pursued it." Patent data shows no similarity or complementarity in this case. This finding is reflecting not only the very few patents of the buyer, but also the concentration of the two firms

in different technology classes – at least in relation to the knowledge that was included in patent application records.

In case 5, the target firm developed a diagnostic kit product by collaborating with a large pharmaceutical firm. The diagnostic product was used to determine the effectiveness of drug therapies for cancer and the target firm had first mover advantage because its product became a regulated diagnostic. The target firm, however, could not expand rapidly enough to keep up with the demand for their product and entered into a distribution and marketing collaboration with another large pharmaceutical firm. It was at this time that the target firm was approached and acquired by another medium-sized diagnostic firm producing molecular biology tools, with a diagnostic division (excelling at HPV testing) with similar methods for doing molecular biology. It had a product that competed in the same market as the target firm but it was considered to be harder to use and less sensitive than the target firm's product. In this instance, the patent indices of similarity and complementarity are rather close to each other and do not square well with the interview evidence. When asked about this discrepancy, the buyer argued that, although the two target patents were potentially valuable, they referred to the target's technology platform and not the diagnostic product, which was not patented. Furthermore the patents had not been researched further and were a somewhat poor representation of the overall knowledge base of the target firm. The technology object of our analysis is hard to patent but also hard to copy.[4] In the words of the UK chief scientific officer, the technology implies "experience running through processes, being familiar with the technology, having the expertise of how to document, perform the work, put everything down so that the [US Food and Drug Administration (FDA)] can be happy with how everything has been documented".

In case 6, at the time of the acquisition, the target firm was developing three vaccines, one for use in melanoma, one for hepatitis B and one for HIV. The first two programmes, in melanoma and hepatitis B, had passed through Phase I and Phase II clinical trials but there was limited interest in these potential drug products from large pharmaceutical firms and, faced with increasing development costs, the target firm decided to enter a trade sale. The acquiring firm was developing a cancer vaccine based on a protein called 5T4, expressed in the small pox virus, and found primarily on cancer cells, all except melanoma. By acquiring the target's cancer vaccine, the acquirer was essentially increasing the coverage of their cancer vaccine to a wider variety of cancerous tumours. Representatives of both the target and the acquirer explained that the products were based on very similar underlying technology. The target firm explained that the viral vector in both technologies underlying the products was MVA and that "[the technology] was not exactly the same thing but it is the same material. They knew how to make MVA." A further indication of the technological similarity of target and buyer was that prior to the acquisition there was a patent dispute regarding the target's platform technology. When the target filed for the patent, the acquirer, along with five other firms, opposed the patent and thought it was invalid due to prior art. The patent was upheld but these five firms appealed and between the opposition hearing and the appeal, the acquiring firm acquired the target. The acquiring firm was able to maintain the patent claims. This classification is supported by patent analysis, which shows a technological similarity index of 0.74, much higher than the complementarity index of 0.13.

Case 3 and 4 are cases of technological complementarity. In case 3, at the time of the acquisition, the target firm had three clinical development programmes in the central nervous system field and focused on sedatives, e.g. post-operative pain and chronic pain. The acquiring firm had a lead

[4] Put differently, it follows from the interview and patent analyses that the technology similarity between the two firms can be attributed to non patent-protected technological knowledge.

programme on stroke that had just failed Phase III clinical trials, and as a public company, attracted some bad press and reduced the firm's market value. The acquirer was, therefore, interested in acquiring drug programmes that had some therapeutic fit, "for example in central nervous system or thromboses" and that could be further developed without a lot of risk. The complementarity in the technological field is acknowledged by both the target and acquirer firms. The former chief scientific officer of the target firm from case 3 explained the complementarity in these terms: "There is some similarity, they are hospital products, intravenous and acute … [and] they were central nervous system. Stroke [therapeutic area of the acquirer] and pain and sedation [therapeutic areas of the target] are quite different areas." This statement shows that the knowledge base of each firm is specialized in different but complementary therapeutic fields. The knowledge base differs but the way the eventual drug products would be marketed and administered (through hospitals and intravenously) is similar. This leads us to conclude that although there may be similarities downstream in the marketing and production of the drug, there is a high level of complementarity in the technological knowledge of the target and acquirer firms. This classification is supported by patent analysis, that shows a technological complementarity index of 0.90, much higher than the zero similarity index.

In case 4, at the time of the acquisition, the target firm had two early stage drug programmes in anti-bacterials. The acquiring firm is specialized in anti-virals. As in case 3, where the common factor was the central nervous system, the common factor in case 4 is anti-infective drugs. And again as in case 3, the specific therapeutic focus within the common field is quite different. The target firm characterized the complementarity as: "We haven't really explored too much about their anti-viral discovery in the same way that most of our virologists haven't had much experience in anti-bacterials". By acquiring the target firm, the acquirer broadened their pipeline in anti-infective drugs. However, the patent analysis does not correspond with the evidence from the interview data. The patent analysis shows a higher index of technology similarity compared with the complementarity index. When asked about the discrepancy with the patent analysis, the chief scientific officer of the target firm in case 4 justified the technological complementarity, "the compounds that are patented may be the same but they are put together differently for different uses".

4.2. Capabilities similarity or complementarity

To determine the similarity or complementarity in discovery and development capabilities, we have used the evidence from the interview data (see Table 4). As discussed in section three, discovery and development capabilities are represented in the knowledge that the firm has to perform its activities, to match technological and market opportunities, including its activities related to carrying out clinical trials, regulatory approval and safety and efficacy testing. To determine the similarity or complementarity in capabilities, we examine the activities of the target and acquirer firms prior to the acquisition. Similarity in discovery and development capabilities implies a certain level of redundancy for efficiency purposes or even competition reduction. Conversely, complementarity in these activities implies that the firms benefitted from combining them, for instance gaining economies of scope, cross-fertilization of solutions or access to complementary skills.

Cases 2, 3 and 6 show evidence of similarity of capabilities between target and acquirer. In case 2, both firms were developing drug products and were specialized in the therapeutic field of regenerative medicine in wound care. Having the knowledge and expertise in the therapeutic area, the acquirer performs similar production activities. Evidence from the interview data shows that the acquiring firm was able to transfer primarily the documentation related to the technological assets.

In case 3, the target and acquirer firms were developing drugs in the central nervous system area. Both firms prior to the acquisition were carrying out activities related to producing drug products, namely the management of preclinical and clinical trials, safety and efficacy testing, quality control; however the acquirer was perhaps operating on a larger scale than the target, "what they had is something similar to what we had here but we ran in an extremely light fashion, an under-resourced fashion". Furthermore, the target firm explained the similarity of their production activities: "The [acquirer's] clinical development expertise is very good … but it is not bad here. There isn't any particular thing that they do that we couldn't get somewhere else or that we didn't do beforehand. There is a lot of commonality in the type of work we do." Additional evidence of the similarity in capabilities is that post acquisition the target and acquirer firms integrated these activities across country borders. According to the acquirer firm, the decisions of who was responsible for which activities were based on the "background and experience level of people". This resulted in some staff redundancies but the majority of these redundancies occurred in the acquirer's location. The cross-country, cross-location reporting structure indicates that the knowledge and expertise of drug development production activities were present in both locations and had a high level of similarity.

Also, in case 6, the acquirer and the target firms were both developing drug products in a similar therapeutic field, cancer vaccines. Both firms were also carrying out similar production activities in the drug development value chain, e.g. safety and efficacy testing and clinical trials. The founder of the target firm explained that, "how it works is in the public domain. We can make the stuff … anyone can do that" but he further explained that owning the intellectual property and being able to defend it was the 'real value'. The acquiring firm substantiates this claim by saying they had all the in-house expertise and skills because they were developing a very similar product and that they "already knew what to do with it". The overlap in the knowledge and expertise of the staff of the two firms in case 2 is high and the similarity in the capabilities between the two firms allowed the acquirer to absorb and integrate the acquired technological assets easily into its own R&D organization.

In contrast, cases 1, 4 and 5 show evidence of complementarity of the capabilities of the target and acquirer. In case 1, the target firm offered services based on two different technologies, one based on proprietary technology (computer-based drug discovery) and one based on generic technology to determine proper dosing (safety and efficacy testing). The acquiring firm acquired both technologies but was primarily interested in the safety and efficacy testing as it, has since, divested the computer-based drug discovery service. The acquirer firm was interested in the target firm's safety and efficacy testing service in order to extend its service offering to its customers. The acquisition extended the scope of their services. First, the service that was acquired requires specialist knowledge that the acquirer did not have. The target firm described their safety and efficacy testing service as having "specialists in knowing when something is going to get into the bloodstream and then when it's in the bloodstream how quickly it's removed." This type of testing is generally required for FDA approval of drugs and the acquirer was 'relatively weak' in this service area. Secondly, although the customers of this safety and efficacy testing service tend to be regional (80% of the target's customers), the acquirer has successfully gained new service sales from its existing customer base that have begun to use the safety and efficacy testing service.

In case 4, both firms were developing drug products (one in anti-virals and the other in anti-bacterials) and both firms had been carrying out activities related to drug development. However, the target firm had less experience with larger scale clinical trials as its products were still in the preclinical development stage. The acquirer had drug products in Phase II clinical trials and had a much larger organization with in-house chemists. The target firm described the firms as having

"quite a high degree of common language and processes"; he explained further that that this was "partially due to a fairly large proportion of their scientists coming from the UK and having a shared approach". The two firms made an effort to integrate their businesses without disturbing their activities "They [the acquirer] are quite different in the therapeutic areas in processes and assays...making sure that we use similar platforms for ourselves so for instance, if we have the same assay, we should call it the same name". The acquirer contributed with project management systems and there was an important effort to harmonise assays and other processes including occupational health and safety systems. With the acquisition, the target acquired access to internal toxicology, chemistry, biology, clinical and business development. The target contributed with both technology and market knowledge in developing products in a new therapeutic area with significant funding from the Wellcome Trust:"I think there is an added value to having people focused on the area, like I've been doing in this area for about 15 years and so you have to understand the market, you've seen results, you've seen people make mistakes so you don't need to make them again in this area. It is that kind of developed experience I think that is harder to put down."

Lastly, in case 5, the target and acquirer firms produce diagnostic products and the acquirer bought the target firm in order to expand into a new market of companion diagnostics (diagnostic products used in conjunction with prescribing new drugs). From the acquisition the target gained access to complementary assets to scale up production; the combined entity gained economies of scope. The acquirer contributed with more standardised processes related to harmonisation of product development, regulatory approval and quality control and more supporting functions such as marketing and sales and general human resource management. The increasing market demand for the target's diagnostic product required rapid expansion to meet US FDA requirements that was very difficult for the target firm to manage prior to the acquisition. The target firm acknowledged that there were gaps: "nobody grows at that rate without leaving some holes". The expertise and knowledge from the acquirer firm in regards to first the European regulation and later the FDA processes was crucial to scale up the target's manufacturing operations. The acquirer realised that the target had been more successful than them in this market and it intends to keep the target's local facility as a 'centre of excellence'. The acquirer also realised that a large portion of the value of the acquired technological assets lies in the relationships that the target's top management has with large pharmaceutical firms and their ability to enter funded R&D collaborations with these firms. The acquirer acknowledged this by stating that they were very good at relationships at the lower level in a customer's organization, the bench or scientist level, but did not have staff with large pharmaceutical experience to build relationships at the higher levels, the vice president level. The top management from the target firm had large pharmaceutical experience and therefore knowledge and expertise related to acquiring and building large pharmaceutical R&D partnerships.

4.3. Investment post-acquisition

We now present evidence from the cases regarding the extent of the acquirer's investment in and deployment of the target technology assets post-acquisition. Table 5 summarises the outcomes for the different cases.

Insert Table 5

In cases 3 and 4, there was an expansion of R&D in the UK. In case 3, we have evidence of retention of the full technical and scientific staff of the target and substantial investment in the development of the acquired drug programmes. The quotation below from the acquirer firm substantiates our view on their investment:

> "We decided right from the start that we would focus our investment on one asset, which was at that stage a preclinical asset … since then we have been able to move it forward very rapidly. We have done three clinical trials, the fourth clinical trial is on the verge of being launched. Due to our overall financial situation, we were not able to invest major into [other programmes], there were three more assets … [for]

> one we did some regulatory, very broad reanalysis and want to partner this. [Another] had nearly completed an ongoing Phase II trial but as we got feedback from big pharma that this would probably not be very partnerable without us taking very high development risks, we decided to stop [investing] this year. There was a very early programme which was in its research phase which we stopped right from the start because running one programme is requiring all the focus of the team.
>
> Investment in development of drug programmes: from the start was clear that one of the acquired programmes was the best candidate to invest in; did some other testing/trials in the other programmes but stopped investing in them …"

Initially, the acquirer firm invested in all of the acquired assets in order to determine which programme would provide the best return on investment. In the end, the investment has been primarily in one drug programme, which they have taken, post-acquisition, from preclinical to Phase II. This level of product development requires substantial investment. The combined entity invests 50% of its R&D budget in the target's projects. Most of the target's staff was retained post-acquisition, although there were some redundancies in the acquirer's firm. The retention of patent-assignees was 100%. The target location became a UK subsidiary for the acquiring firm.

In case 4, the acquirer has maintained and further invested in the programmes and associated capabilities of the target firm, which were highly valued by the acquirer as shown in the quote:

> "The [specialized] function is exclusively performed in the UK, adopted without change. It is fit for purpose and it is world class"

In this case, there has been further research and development of the two target firm's drug programmes (both still at pre-clinical stages). Since acquisition, the combined entity invested 30% of its R&D budget in the target's projects in the target's research programmes. All staff was retained, including 100% of the patent-assignees, and the target firm's location has become a subsidiary for the acquirer firm.

In cases 5 and 1, there was continuation of development operations, but no further investment in research in the UK. Indeed, in case 5, which is the case that involves the diagnostic product firms, all staff was retained; however the acquirer lost 80% (or 4 out of 5) of the patent assignees in the acquisition process. There was substantial investment from the acquirer firm, primarily in staff and facilities (about 3% of the R&D budget of the combined entity) for product development and not in the further research. The target firm relocated to new facilities in the UK forming a new UK subsidiary. There has also been an investment in staff, increasing the headcount at the UK location considerably from approximately 70 staff at the time of acquisition to 140 (the amount of staff doing product development has risen from 20 to 53, which was necessary to meet FDA requirements).

In case 1, which involves the acquisition of a service business, the acquirer firm has also invested primarily in staff and facilities. All of the staff related to performing the activities for the service were retained, about 15 persons in total, and were moved to the acquirer firm's subsidiary in the UK. However the target firm informed us that 5 of these retained staff had left and spun out a new business. No further investment had been made in developing the acquired technology. The investments made were mainly to continue and expand their services through facilities, staff recruitment and equipment maintenance but not to carry out further research. The combined entity retained 26% of the target's patent assignees.

Finally, in case 2 and 6, R&D in the UK was interrupted or shifted away. In case 2, in which two drug programmes were acquired, there is evidence of investment in product development but in the acquirer's home country. There was a high level of staff redundancy (the target firm originally had grown to 70 employees but had already contracted to approximately 25 by the time of acquisition).

The acquirer firm did not retain any scientists from the target firm, except a key scientist who was hired temporarily to act as a consultant. Although there was no retention of staff or patent assignees from the target firm, nor investment in facilities or equipment, the acquirer indicated that they were currently investing approximately 20% of their R&D resources in early pre-clinical development for one of the drug programmes. For the other drug programme, that was in late stage development and had completed Phase III but with negative results, the acquirer was re-evaluating the programme and was uncertain if there would be further development.

In case 6, we see that there is no further investment in technological development, staff or facilities of the target post-acquisition. The target's staff was made redundant, retaining none of the patent-assignees, although a key scientist and IP manager was retained for a year to transfer the documentation. In this case, the acquirer experienced some financial difficulty following disappointing results in Phase III studies of their main cancer vaccine, which occurred shortly after the acquisition of the target firm. Facing financial constraints, the acquirer was not in a position to invest in the further development of the technology. From the interview data, we ascertained at the time of the interview that the acquirer was not using the acquired technology; however the acquirer was looking for licensing partners in order to outlicense the use of the technology.

5. Discussion

As previously stated, this paper seeks to understand what happens to the technological resources and assets of science-based firms when they are acquired by foreign firms. The main contribution of this paper is to advance the discussion at a conceptual level by showing that multiple combinations of firms' technology and discovery and development capabilities have different effects on the post-acquisition investment in the acquired firm's technological assets. We investigate this issue drawing on evidence from six case studies of UK biopharmaceutical firms. Depending on the similarity or complementarity of the technology and discovery and development capabilities in each pair of acquiring and acquired firms, we derive four types of knowledge base combinations: i) *technology-enhancing*, ii) *capabilities-enhancing*, iii) *technology- and capability- enhancing*, and iv) *non-technology- and non-capabilities-enhancing* (Table 6). We are interested in the implications of these different combinations on the further investment, continuation or suppression of the target's R&D projects. Our findings suggest that there are differential outcomes depending on the complementarity or similarity of the combined technology and capabilities regarding further investment or shift of the target's R&D.

Insert Table 6

We first discuss the two polar types. In what we call *technology- enhancing* combinations, involving complementary technology but similar discovery and development capabilities, acquisitions tend to reflect a strategic intent to explore new technological knowledge domains. This can be explained by the organisational learning literature, which explores the competition in firms for resources between exploration and exploitation (March, 1991). *Technology- enhancing* combinations create a potential for R&D 'exploration' through experimentation with new alternatives (Vermeulen and Barkema, 2001) and for inventions emerging from the integration and redeployment of the components from the amalgamated knowledge base (Fleming and Sorenson, 2004). These combinations require the buyers to invest further in the R&D projects of the target in order to build their capacity to absorb the tacit, complex and embedded nature of the complementary technology being acquired (Cohen and Levinthal, 1990; Makadok, 2001; Zahra and George, 2002). As for the discovery and development capabilities between the acquiring and acquired firms, similarity enables the firms to integrate and harness tacit knowledge relatively more easily. Thus, capability similarity may facilitate the integration of processes, methods and systems related to clinical development, and hence justify a further expansion of R&D projects of the target

firm. Overall, our case evidence suggests that, in such combinations, target firms benefited from accessing additional skills and financial resources for clinical development, whereas buyer firms primarily diversified their product pipelines by developing in different therapeutic areas, overall increasing the variation, search and experimentation for the combined entity (also see Schweizer, 2005).

The finding of the increased investment in the target technology assets has important resonance in the literature. While prior literature has often shown that R&D-intensive biotechnology firms developing drug products access downstream capabilities through alliances and other forms of collaborative arrangements (Arora and Gambardella, 1990; Pisano, 1991), our findings illustrate the effects of accessing these capabilities through acquisitions. Also, the finding that R&D on the target firm's technology is continued and enhanced in these combinations is consistent with the contributions that argue that complementarity of science and technology lead to high quality and quantity of innovative output (Makri et al., 2010).

In the type that we call *capabilities-enhancing* knowledge base combinations, involving similar technology but complementary discovery and development capabilities, acquisitions tend to reflect a strategic intent to explore new product market domains (Bower, 2001). In an organisational learning context, these combinations can be explained as an acquisition strategy aimed at further 'exploitation' of the extant knowledge bases through the adoption of complementary discovery and development capabilities (March, 1991) and the cross-fertilization of solutions. In these cases, we see the continuation of development operations but not further investment in basic research in the target's R&D projects after acquisition. The focus of these acquisitions was primarily on scope economies and efficiency improvements through scaling up operations and acquiring complementary manufacturing or service capabilities. In these combinations, the target firm's development activities were continued but there was little inventive output. The motivation to maintain the target firms' operations primarily stemmed from the embedded tacit knowledge of the employees in the acquired firms, such as the valuable collaborative relationships with large pharmaceutical firms that constituted a large part of the acquired value of the target firm.

Furthermore, in the type that we call *technology- and capabilities-enhancing* combinations, involving complementary technology and complementary discovery and development capabilities, the acquisition may reflect a strategic intent to explore new technological knowledge and product market domains simultaneously. Acquirers active in such types of acquisitions emphasized both 'exploration' and 'exploitation'. There was exploration through experimentation with new alternatives and for inventions emerging from the integration and redeployment of the components from the amalgamated knowledge base. But these combinations also enabled further 'exploitation' of the combined knowledge base through scope economies and the utilization of complementary discovery and development capabilities. The case evidence suggests that the buyers increased investment in the R&D projects of the target. This was required in order to build the acquirer's capacity to absorb the tacit, complex and embedded nature of the complementary technology and capabilities that were acquired (Cohen and Levinthal, 1990; Makadok, 2001; Zahra and George, 2002). As we argued in section 2, drug discovery and development involves a highly iterative and interactive process, requiring much tacit knowledge (Pisano, 2006). In the context of the acquisition literature, such acquisitions may be seen as part of a platform or buy-and-build strategy, where an initial acquisition provides the acquirer a foothold to a new domain and the option to build on that platform with a series of follow-on acquisitions (Haspeslagh and Jemison, 1991; Smit, 2001).

Finally, in what we call the *non-technology- and non-capabilities-enhancing* type, the potential for exploitation or exploration may be more limited. Here, given the similarity in both technology and discovery and development capabilities, effort was done to 'transfer' or 'translate' the intellectual

property documentation to the buyer but the retention of technical and scientific staff was not seen as necessary to continue the exploitation of these capabilities. These acquisitions are likely to represent attempts to deal with the escalating drug development costs and risks (e.g. DiMasi et al., 2003) or to increase market power and reduce the degree of competitive rivalry in the increasingly globalised drugs market. In these cases, we see the interruption or even shifting away of R&D of the target firm to the home country of the acquirer. The closure of the target's facilities and job losses are inevitable in acquisitions that involve the combination of highly similar knowledge bases and capabilities. This resonates with studies that show that the level of relatedness in knowledge bases between targets and buyers has a curvilinear relation with innovation output (Ahuja and Katila, 2001; Cloodt et al., 2006). Knowledge bases that are similar contribute little to the innovation output post-acquisition and the opportunities for recombination of assets/resources are limited (Desyllas and Hughes, 2010). Indeed, our findings show that although similar knowledge bases (both in terms of technology and discovery and development capabilities) are easily integrated and require minimal resources to do so, the increase in innovative output to targets, buyers and, as we will see below, the larger innovation system is also minimal.

Our conceptual categories allow us to distinguish between the different outcomes in terms of implications for the local science and technology system. We show here how the different types of knowledge based combinations through acquisitions have different effects on the extension, retention or exit of R&D of the host country (see Table 6). The *technology- and capabilities-enhancing* and *technology-enhancing* knowledge base combinations are expected to have positive effects on the local science and technology system as buyers are keen to access the assets and knowledge embedded in the host regional/national innovation system and further investment is directed towards R&D of the acquired firms' technology in the host country. The tacit nature of knowledge in science-based firms requires buyers to retain this knowledge that is embedded and location-bound in scientists and their personal relationships and constrains buyers from shifting R&D activities away from the host country of the target firm or centralising it in the buyer's home country (Carayannopoulos and Auster, 2010; Kogut and Zander, 1992; Pisano, 1991). Proximity to qualified universities or other research organisations that deliver this kind of tacit knowledge of a cognitive type and to clusters of firms operating in the same or complementary sectors is crucial to accessing this knowledge (Balconi et al. 2007). It is therefore likely that for acquisitions involving access to complementary technology (much of which will be tacit), this knowledge will be embedded in ties to the regional and national innovation systems, and that the combined entity will have the imperative to remain and continue R&D activities in the UK.

The picture is different for *capabilities-enhancing* knowledge base combinations. In this case, buyers acquire targets with complementary discovery and development capabilities. Here the focus is on 'exploiting' these complementary capabilities, which also have a degree of tacitness and are embedded in regional/national innovation system. Again, in these acquisitions, the technological knowledge base of the target is kept intact and local operations tend to be continued by forming a subsidiary in the UK, mirroring many of the developments discussed in the *technology-enhancing* combination. However, in contrast to the *technology-enhancing* combination, buyer firms acquiring targets with complementary capabilities and similar technology invest very little in further research regarding the acquired technology. The target firm's ties to the innovation system and the client base provide a strong rationale to maintain operations in the host country of the target firm. But, in these cases, the combined entity 'exploits' the complementary capabilities and knowledge to generate scale and scope economies. The embedded tacit knowledge in the host economy/region is used to continue the specialist scientific operations and local ties and collaborative relationships of the target hold potential for valuable contract research projects and would be difficult to recreate or transfer. But in this case, the combined entity does not seek to explore, create and absorb new

knowledge from new projects of the target firm or allocate new resources to these research activities.

For the final, *non-technology- and non-capabilities-enhancing* type, the case evidence suggests that this type of combination between buyer and target firms will have negative effects on the local science and technology system. In these cases, R&D activities of the targets will be eliminated or shifted away from the host country, thus avoiding redundancies and duplications in the combined entity, resulting in the loss of skilled employment and the suppression of the target's technological assets (unless target assets are readily re-deployable for alternative uses).

As argued above, our contribution involves the development of the above conceptual categories and their implications in terms of the local science and technology system. Our findings highlight the importance of developing national/regional capabilities. Some regions have developed regional innovative capabilities embedded in virtual laboratories in the form of broad and deep networks of operational, technological and scientific researchers which cut across firms and universities (Almeida and Kogut, 1999; Audretsch and Feldman, 1996; Best 2001; Saxenian, 1994). In these regions, there are important industry-university partnering models, decentralisation of research and development, encouraging technological diversity and new firm creation. The development of these capabilities is especially necessary in countries which invest heavily in sustaining a strong and healthy science base, but face challenges in the ability to commercialise and benefit from the economic impact of science and innovation. Regions that invest in policies that support and develop tacit, cognitive and interpretative knowledge strengthen the ability to appropriate value in these acquisitions. This involves not only proximity to universities, guaranteeing access to scientists, but a number of other features of a regional system of innovation and production. Indeed, as argued by a representative of the target firm in case 4: "There are tangible benefits in being [in the UK location]. There is a network, advisors and consultants that you tap into, particularly if you are a small organization, you get access to these things cost effectively. This includes intellectual property, human resources and regulatory, we can find people and also in terms of good skilled and experienced staff. There is a good critical mass and there is turnover so often there are people available. We don't have to recruit from a long way away."

These conceptual categories were developed from an examination of cross-border acquisition cases. A question is the extent to which this framework may be applicable to all acquisitions, including domestic ones. The inclusion of case 6 for control purposes shows that the impact of domestic acquisitions can also be explored using this framework. It may be the case, however, that by designing the study for cross-border acquisitions, the likelihood of finding cases with complementary technology and discovery and development capabilities was increased because of regional/national technological specialisation and path dependencies. It is possible that if the study was extended to more domestic acquisitions, there would be more instances of non-technology- and non-capabilities- enhancing types of knowledge base combinations.

Another question is the extent to which this framework may be applicable to other industries, especially other science-based sectors such as nanotechnology and energy technologies. Firms in these sectors also have very complex and heterogeneous scientific knowledge bases requiring integration across disciplines and functional areas of expertise. Perhaps the framework holds more strongly in the biopharmaceutical sector, however, where there are problems of asymmetric information, specialised assets, lack of modularity, fragmentation of technology domains (with multiple technologies leading to similar product/service solutions) and uncertainty in the scope and efficacy of patents. If in other sectors the market for know-how can work more efficiently, then it can be expected that some of the variables considered here, such as the complementarity/similarity of the discovery and development capabilities, may play a less important role.

An additional contribution is our study's design, which relies on case studies and is complemented by patent data, which advances and refines existing studies (Ahuja and Katila, 2001; Cloodt et al., 2006; Makri et al. 2010). While previous studies have relied solely on patent information to analyse the effect of technology relatedness on post-acquisition innovation outcomes, we have combined case study evidence and patent data. Interestingly, the innovation-related proxies based on patent records and case study evidence did not always lead to identical findings.

To an extent, these discrepancies can be attributed to the general criticism of the reliability of patent data as a measure of economic value and regarding their result in practical applications. In particular, the evidence shows that smaller firms - as is the case for most of the target firms in our sample deals - have a lower probability to apply for at least one patent, perhaps reflecting the costs of the patenting process and the availability of internal relevant legal capacity (Kleinknecht et al., 2002). Evidence also suggest that firms often find "secrecy" or "keeping qualified people in the firm" as being relatively more effective means of appropriation of innovation benefits. Furthermore, patent-based indicators can be obscured by strategic behaviour; that is firms may seek patent protection to prevent a competitor from using a particular technology. The reliability of patent data as a proxy for knowledge can be more severely questioned for the case of biotechnology. Unlike the nature of technological and production knowledge in other high tech sectors, such as software and semiconductors (codified technology, modular designs and standard platforms), the technology in biopharmaceuticals is not modular and not well codified, with drug discovery steps consisting of many interdependent problems (Pisano, 2006). Also, unlike the strong intellectual protection afforded by patents in software and semiconductors, intellectual protection boundaries for biotechnology drug development are not clearly specified – it is often difficult to establish what is patentable, which leads to secrecy and restrictions in the sharing of vital information in licensing deals and partnerships and much contractual litigation (Pisano, 2006). Biopharmaceutical firms rely on extensive and detailed documentation and 'standard operating procedures' related to each step of the drug discovery and development. In the cases studied, much knowledge integration and transfer occurred through an interpretation of the documentation trail of clinical testing between the buyer and target firms. This is well illustrated in our study as even in acquisitions involving similarity in both technology and capabilities, the transfer of patents is not enough to ensure the exclusive use of the technology, and we witness an important effort to 'transfer' or 'translate' the intellectual property through the retention of a scientist or intellectual property specialist. In these cases, these key scientists are retained temporarily for this despite the fact that all other staff are made redundant. Therefore, our findings suggest that patent-based proxies for technological knowledge capture only a small part of an organization's knowledge base (and sometimes a part that is not the core technology of the firm).

6. Conclusion

This paper examined what happens to technological assets and capabilities of science-based target firms after a cross-border acquisition takes place. A study of cases of acquisitions of six biopharmaceutical firms in the UK provided insights to derive four ideal types of knowledge base combinations of cross-border acquisitions and the effects of these on the further investment or suppression of the target's technological assets and the local science and technology system.

Our results suggest four possible outcomes. First, the *technology-enhancing* as well as *technology- and capabilities-enhancing* combinations refer to acquisitions that are driven by the potential for further exploration, opening up possibilities for recombination and variation in search in drug development programmes. They are characterised by the acquisition of technology platforms that can potentially generate products in a complementary therapeutic area, and result in the expansion of research in the target firm's technology and the retention of the staff of the target firm and of the knowledge and capabilities in the host country. Second, the *capabilities-enhancing* type of

combinations where firms integrate vertically and horizontally are driven by the potential for exploitation, making it possible to benefit from economies of scale and scope in the production of services or products to existing or new customers. This compels the buyer to retain the knowledge and continue development in the UK but results in little further investment in continued research of the acquired technology. Finally, the *non technology- and non-capabilities-enhancing* type is characterised by the acquisition of similar technology and capabilities, facilitating post-acquisition integration and ensuring the exclusive exploitation of the capabilities, but resulting in the shifting away of the knowledge and technological assets from the UK or the suppression of the technology to eliminate duplication of R&D and also remove from the market a potential competitor.

This study thus contributes both to conceptual discussions of technology-related acquisitions and has important policy implications. We argue that multiple combinations of firms' technology and discovery and development capabilities have different effects on the innovation performance of the acquired firm. The relation between the complementarity and similarity of the technology and the discovery and development capabilities of the target and buyer firms and the buyers' ability to absorb the knowledge and capabilities play an important role in the further development of the acquired firm's technological assets and capabilities in the host country after acquisition. The cognitive, tacit knowledge embedded in scientists and specialists in universities, firms and laboratories provides the innovation system with unique competitive advantages and draws investment from both foreign and domestic firms. Regions that invest in policies that support and develop tacit, cognitive and interpretative knowledge would strengthen the ability to appropriate value from science-based firms' technological assets through increased employment and investment, even if they are acquired by foreign firms.

References

Ahuja, G. and Katila, R. 2001. Technological acquisitions and the innovation performance of acquiring firms: a longitudinal study. ***Strategic Management Journal***, 22(3): 197-220.

Almeida, P. and Kogut, B. 1999. Localisation of knowledge and mobility of engineers in regional networks. ***Management Science***, 45(7): 905-917.

Arora, A. and Gambardella, A. 1990. Complementary and external linkages: the strategies of the large firms in biotechnology. ***The Journal of Industrial Economics***, 4: 361-379.

Audretsch, D. B. and Feldman, M. P. 1996. R&D spillovers and the geography of innovation and production. ***The American Economic Review***, 86(3): 630-640.

Balconi, M., Pozzali, A. and Viale, R. 2007. The "codification debate" revisited: a conceptual framework to analyse the role of tacit knowledge in economics. ***Industrial and Corporate Change***, 16 (5): 823-849.

Basberg, B. L. 1987. Patents and the measurement of technological change: a survey of the literature. ***Research Policy***, 16, 131-141.

Bertrand, O. 2009. Effects of foreign acquisitions on R&D activity: Evidence from firm-level data for France. ***Research Policy***, 38: 1021-1031.

Benner, M. and Waldfogel, J. (2008) Close to you? Bias and precision in patent-based measures of technological proximity. ***Research Policy***, 37, 1556-1567.

Best, M. 2001. ***The New Competitive Advantage: The Renewal of American Industry***. Oxford: Oxford University Press.

Blanc, H. and Sierra, C., 1999. The internationalization of R&D by multinationals: A trade-off between external and internal proximity. ***Cambridge Journal of Economics***, 23: 187-206.

Blonigen, B. A. and Taylor, C. T. 2000. R&D intensity and acquisitions in high technology industries: evidence from the US electronic and electrical equipment industries. ***Journal of Industrial Economics***, 98 (1): 47-70.

Bower, J. L. 2001. Not all M&As are alike - and that matters. ***Harvard Business Review***: 93-101.

Bresman, H., Birkinshaw, J., and Nobel, R. 1999. Knowledge transfer in international acquisitions. ***Journal of International Business Studies,*** 30(3): 439-462.

Calderini, M., Garrone, P. and Scellato, G. 2003. The effects of M&As on the innovation performance of acquired companies. in Calderini, M., Garrone, P. and Sobrero, M. (2003) ***Market Structure, Corporate Governance and Innovation***. Edward Elgar, Cheltenham.

Carayannopoulos, S. and Auster, E. 2010. External knowledge sourcing in biotechnology through acquisition versus alliance: a KBV approach. ***Research Policy***, 39: 254-267.

Cassiman, B., Colombo, M. G., Garrone, P. and Veugelers, R. 2005. The impact of M&A on the R&D process: An empirical analysis of the role of technological- and market-relatedness. ***Research Policy***, 34(2): 195-220.

Cantwell, J. A. 1995. The globalisation of technology: what remains of the product cycle model, ***Cambridge Journal of Economics***, 19: 155-174.

Cantwell, J. A. and Piscitello, L. 2000. Accumulating technological competence: its changing impact upon corporate diversification and internationalisation. ***Industrial and Corporate Change***, 9 (1): 21-51.

Cloodt, M., Hagedoorn, J. and van Kranenburg, H. 2006. Mergers and acquisitions: Their effect on the innovative performance of companies in high-tech industries. ***Research Policy***, 35: 642-654.

Coff, R. 2003. Bidding wars over R&D-intensive firms: knowledge, opportunism, and the market for corporate control. ***Academy of Management Journal***, 46(1): 74-85.

Cohen, W.M., and Levinthal, D.A. 1990. Absorptive capacity: A new perspective on learning and innovation. ***Administrative Science Quarterly***, 35(1): 128-152.

Day, G. S., and Schoemaker, P. J. H. 2006. Peripheral Vision: Detecting the Weak Signals that Will Make or Break your Company. Boston, Mass: Harvard Business School Press.

Desyllas, P., and Hughes, A. 2010 Do high technology acquirers become more innovative. ***Research Policy***, 39(8): 1105-1121.

DiMasi, J. A., Hansen, R. W., and Grabowski, H. G. 2003. The price of innovation: New estimates of drug development costs. ***Journal of Health Economics***, 22(2): 151.

Dosi, G. 1982. Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change. ***Research Policy***, 11 (3): 147-162.

Dosi, G., Nelson, R. And Winter, S. 2000. ***The Nature and Dynamics of Organisational Capabilities***. Oxford University Press: Oxford.

Dunning, J.H. 1994. Multinational enterprises and the globalisation of innovatory capacity. ***Research Policy***, 23: 67-88.

Eisenhardt, K. and M. Graebner, M. E. 2007. Theory building from cases: opportunities and challenges. ***Academy of Management Journal***, 50 (1): 25-32.

Ernst, H. and Vitt, J., 2000. The influence of corporate acquisitions on the behaviour of key inventors. ***R&D Management***, 30, 105-119.

Fleming, L. and Sorenson, O. 2004. Science as a map in technological search. ***Strategic Management Journal,*** 25(8/9): 909-928.

George, A. and Bennett, A. 2005. ***Case Studies and Theory Developments in the Social Sciences***. Boston: MIT Press.

Ghoshal, S. 1987. Global strategy: an organising framework. ***Strategic Management Journal,*** 8 (5): 425-440.

Graebner, M.E. 2004. Momentum and serendipity: how acquired leaders create value in the integration of technology firms. ***Strategic Management Journal***, 25: 751-777.

Graebner, M. E., and Eisenhardt, K. M. 2004. The seller's side of the story: acquisition as courtship and governance as syndicate in entrepreneurial firms. ***Administrative Science Quarterly***, 49(3): 366-403.

Graebner, M. E., Eisenhardt, K. M., and Roundy, P. T. 2010. Success and Failure in Technology Acquisitions: Lessons for Buyers and Sellers. ***Academy of Management Perspectives***, 24(3): 73-92.

Granstrand, O. and Sjolander, S. 1990. The acquisition of technology and small firms by large firms. ***Journal of Economic Behaviour and Organisation***, 13 (3): 367-386.

Griliches, Z. 1990 Patent statistics as economic indicators: a survey, ***Journal of Economic Literature***, 27, 1661-1707.
Hagedoorn, J. 2002. Inter-firm R&D partnerships: an overview of major trends and patterns since 1960. ***Research Policy***, 31: 477-492.
Hagedoorn, J. and Duysers, G. 2002. The effects of mergers and acquisitions on the technological performamce of companies in a high-tech environment. ***Technology Analysis and Strategic Management***, 14, 68-85.
Hall, B.H. 2002. The financing of research and development. ***Oxford Review of Economic Policy***, 18, 35-51.
Haspelagh, P.C. and Jemison, D. B. 1991. ***Managing Acquisitions: Creating Value through Corporate Renewal***. The Free Press: New York.
Henderson, R. and Cockburn, I. 1996. Scale, scope and spillovers: the determinants of research productivity in drug discovery. ***RAND Journal of Economics***, 27 (1): 32-59.
Hitt, M.A., Hoskisson, R. E., Ireland, R.D. and Harrison, J. S. 1991. Effects of acquisitions on R&D inputs and outputs. ***Academy of Management Journal,*** 34 (3), 693-706.
Hitt, M.A., Hoskisson, R.E., Johnson, R.A., Moesel, D.D.1996. The market for corporate control and firm innovation. ***Academy of Management Journal,*** 39 (5), 1084-1119.
Ietto-Gillies, G. 2001. ***Transnational Corporations: Fragmentation amidst Integration***. London, Routledge.
Inkpen, A., Sundaram, A. K. and Rockwood, K. 2000. Cross-border acquisitions of US technology assets, ***California Management Review***, 42 (3), 50-67.
Kamien, M. and Schwartz, N. 1982. ***Market Structure and Innovation.*** Cambridge, MA, Cambridge University Press.
Kapoor, R. and Lim, K. 2007. The impact of acquisitions on the productivity of inventors at semiconductor firms: a synthesis of knowledge-based perspectives, ***Academy of Management Journal***, 50 (5), 1133-1155.
Kleinknecht, A., Van Montfort, K., & Brouwer, E. 2002. The non-trivial choice between innovation indicators. ***Economics of Innovation & New Technology***, 11(2): 109-121.
Ko, Y. 1992. An economic analysis of biotechnology patents, ***Yale Law Journal***, 102, 777-804.
Kogut, B., and Zander, U. 1992. Knowledge of the firm, combinative capabilities and the replication of technology. ***Organization Science***, 3(3): 383-397.
Kuemmerle, W. 1999. Foreign direct investment in industrial research in the pharmaceutical and electronic industries: results from a survey of multinational firms. ***Research Policy***, 28: 179-93.
Kumar, N. 2001. Determinants of location of overseas R&D activity of multinational enterprises: the case of US and Japanese corporations. ***Research Policy***, 30: 159-174.
Makadok, R. 2001. Toward a synthesis of the resource-based and dynamic-capability views of rent creation. ***Strategic Management Journal***, 22(5): 387-401.
Makri, M., Hitt, M. A., and Lane, P. J. 2010. Complementary technologies, knowledge relatedness, and invention outcomes in high technology mergers and acquisitions. ***Strategic Management Journal***, 31(6): 602-628.
Mazzoleni, R. and Nelson, R. R. 1998. The benefits and costs of strong patent protection: a contribution to the current debate. ***Research Policy***, 27, 273-284.
March, 1991.Exploration and explotation in organisational learning. ***Organization Science***, 2 (1): 71-87.
Morosini, P., Shane, S. and Singh, H. 1998. National cultural distance and cross-border acquisition performance. ***Journal of International Business Studies***, 29(1): 137-158.
OECD 2004. Patents and Innovation: Trends and Policy Challenges. OECD: Paris.
OECD 2006. Glossary of Patent Terminology. OECD: Paris.
Ornaghi, C. 2009. Mergers and innovation in big pharma. ***International Journal of Industrial Organisation***, 27 (1), 70-79.

Patel, P. And Pavitt, K. 1997. The technological competencies of the world's largest firms: complex and path-dependent, but not much variety. ***Research Policy***, 26 (2), 141-156.
Pavitt, K. 1985. Patent statistics as indicators of innovative activities: possibilities and problems, ***Scientometrics***, 7, 77-99.
Pearce, R. 1999. Decentralised R&D and strategic competitiveness: globalised approaches to generation and use of technology in multinational enterprises (MNEs). ***Research Policy***, 28 (2-3): 157-78.
Pisano, G. 1991. The governance of innovation: vertical integration and collaborative arrangements in the biotechnology industry. ***Research Policy***, 20: 237-249.
Pisano, G. 2006. Science Business: The Promise, the Reality and the Future of Biotech. Harvard Business Press: Boston, MA.
Piscitello, L. 2004. Corporate diversification, coherence and economic performance. ***Industrial and Corporate Change***, 13(5), 757-787.
Prabhu, J.C., Chandy, R.K. and Ellis, M. 2005. The impact of acquisitions on innovation: poison pill, placebo, or tonic? ***Journal of Marketing***, 69 (1): 114–130.
Ranft, A. L. and Lord, M.D. 2002. Acquiring new technologies and capabilities: a grounded model of acquisition implementation. ***Organization Science***, 13 (4), 420-441.
Sabatier, V., Mangematin, V. and Rouselle, T. 2009. *From business model to business model portfolio in the European biopharmaceutical industry.* Working paper.
Saxenian, A. 1994. ***Regional Advantage: Culture and Competition in Silicon Valley and Route 128***. Cambridge: Harvard University Press.
Seth, A. 1990. Sources of value creation in acquisitions: an empirical investigation. ***Strategic Management Journal***, 11 (6): 431-446.
Schweizer, L. 2005. Organizational integration of acquired biotechnology companies into pharmaceutical companies: The need for a hybrid approach. ***Academy of Management Journal***, 48(6): 1051-1074.
Sleuwaegen, L. and Valenti, G. 2006. Trends in Mergers and Acquisitions. Northampton, MA: Edward Elgar.
Smit, H. 2001. Acquisition strategies as option games. ***Journal of Applied Corporate Finance***, 14(2): 79-89.
Uhlenbruck, K., Hitt, M.A. and Semadeni, M. 2006. Market value effects of acquisitions involving Internet firms: a resource-based analysis. ***Strategic Management Journal*** 27 (10): 899-913.
UNCTAD, 2005. ***Transnational corporations and the Internationalisation of R&D.*** New York/Geneva: United Nations.
Vermeulen, F., and Barkema, H. 2001. Learning through acquisitions. ***Academy of Management Journal***, 44(3): 457-476.
Zahra, S. A. and George, G. 2002. Absorptive capacity: A review, reconceptualization, and extension. ***Academy of Management Review*** 27(2): 185-203.
Zanfei, A., 2000. Transnational firms and the changing organisation of innovative activities, ***Cambridge Journal of Economics***, 24(5): 515-542.
Zollo, M. and Singh, H. 2004. Deliberate learning in corporate acquisitions: post-acquisition strategies and integration capability in U.S. bank mergers. ***Strategic Management Journal***, 25: 1233-1256.

TABLE 1
Sample firm characteristics

Case	Deal characteristics				Acquirer characteristics				UK target characteristics		
	Year of Deal	Deal Value	Assets acquired	Reasons to Sell	Country of incorporation	No of Employees	Year of foundation	R&D ($ 2005 million)	No of employees	Year of foundation	Total funding raised (in million GBP)
1	2006	15.4	• ADME technology and expertise • Data library	• Exit for investors	Belgium	201	2003	8.3	17	2001	48
2	2010	8.4	• Drug programmes in Phase I and Phase II • Stem cell research	• Exit for investors • Restructuring of target	USA	300	1992	unknown	70	1999	16
3	2008	18.8	• Two Phase II drug programmes	• Access to resources for further development of drug programmes	Germany	53	2000	12.3	13	1999	40
4	2009	9.1	• Two pre-clinical drug programmes • Site and expertise in UK	• Access to complementary skills for drug development • Investment in further clinical development of programmes	Australia	70	1986	21.9	17	1999	15
5	2009	95 plus 35 against milestones	• Diagnostic kit / product and underlying platform technology	• Access to resources and capabilities to scale up manufacturing and distribution	Germany	3495	1985	94.0	120	2001	3.2
6	2007	30.1	• Two Phase II drug programmes • Platform technology	• Exit for investors • Investment in developing drug programmes	UK	72	1999	33.0	30	2002	29

a. Data obtained from target and acquirer press releases.
b. Data obtained from DataStream and Fame databases as of 2010 (except R&D expenditure).

TABLE 2
Interviews with target and buyer firms

	Target firm interviews		Acquirer firm interviews	
Case	Nr. of interviews	Position of interviewees	Nr. of interviews	Position of interviewee
1	3	SVP Drug Discovery, CFO and Team Manager	1	SVP Corporate Development
2	3	Founder and CSO	1	SVP R&D
3	1	CSO	1	Founder and CEO
4	1	CSO	1	VP Research
5	4	Founder and CSO	2	Head of Integration and CSO
6	2	CSO and Founder/ executive director	1	SVP Commercial Development

Note: CEO: Chief Executive Officer; CSO: Chief Scientific Officer; CFO: Chief Financial Officer; SVP: Senior Vice President; VP: Vice President; R&D: Research and Development

TABLE 3
Acquirer and target patent activity

Case	Acquirer patents (5 years)	Target patents (5 years)	Technology similarity	Technology complementarity
1	58	24	0.73	0.13
2	2	6	0.00	0.00
3	8	2	0.00	0.90
4	8	6	0.49	0.27
5	119	2	0.11	0.23
6	19	5	0.74	0.13

TABLE 4
Classification of case studies

Case	Technology	Discovery and development capabilities
1	Similar Similar service offerings, ADME services from target filled a gap in buyer's services	Complementary Target's safety and efficacy testing filled gap in buyer's services offering
2	Similar Buyer and target both involved in cellular therapies of wound care; technology used to produce cell component similar, technology to produce delivery of drug different	Similar Activities of target and buyer similar, buyer was one out of four or five companies in the world that could pursue the technology of the target without the target's expertise
3	Complementary Different therapeutic fields: target's field pain/sedation, buyer's field stroke Acquisition broadened buyer pipeline in intravenous, hospital drugs	Similar Activities of target and buyer similar but target 'ran in light mode'
4	Complementary Different therapeutic fields: target's field anti-bacterials, buyer's field anti-virals Acquisition broadened buyer pipeline in anti-infective drugs	Complementary Buyer had infrastructure including internal chemists, through acquisition target gained access to complementary assets to do in-house clinical testing
5	Similar Technological platforms were similar, similar methods for doing molecular biology	Complementary Through acquisition buyer gained access to target's collaborations with large pharmaceutical firm and expertise with European and US regulation
6	Similar Target and buyer used same delivery system but for vaccines for different types of cancer	Similar Firms carried out similar activities in the drug development value chain, including safety and efficacy testing and clinical trials

TABLE 5
Investment in acquired technology assets

	Case	Preservation of target	Target staff retention/ redundancy	% of patent assignees from target remaining after acquisition	Target research and/or development continued	% of R&D budget of combined entity invested in target's projects
Further *research and development* in acquired technological assets in host country	3	Established UK subsidiary through target	Retained full scientific and technical staff of target	100	Yes Advancement of target's drug programme from preclinical to Phase II	50
	4	Established UK subsidiary through target	Retained full scientific and technical staff of target	100	Yes Advancement of target's early phase drug programmes	30
Further *development* in acquired technological assets in host country	5	Established an additional UK subsidiary through target firm	Retained full scientific and technical staff of target Increased scientific staff working on product development Increased manufacturing staff	20	Yes Investment in facilities and equipment	3
	1	Target staff transferred to buyer's UK subsidiary	Retained full scientific and technical staff of target 5 original staff from target left to spin out new business	26	Yes Investment in facilities and equipment	0
***No further research or development* in acquired technological assets in host country**	2	No	All staff made redundant Key scientist retained temporarily as a consultant	0	Yes Feasibility investment in one of the target's drug programme Investment in R&D shifted to home country of acquirer	20
	6	No	All staff made redundant Key scientist and IP manager retained temporarily to transfer documentation	0	No	0

TABLE 6
Knowledge base combinations and effects on post-acquisition investment

Technology	**Discovery and development capabilities**	
	Complementary	Similar
Complementary	**Technology- and capabilities-enhancing** ***Expansion of R&D in host country***	**Technology-enhancing** ***Expansion of R&D in host country***
Similar	**Capabilities-enhancing** ***Continuation of development operations (D but no R) in host country***	**Non-technology- and non-capabilities-enhancing** ***Interruption/shift away of R&D from host country***