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KNOWLEDGE BASED STRATEGIC ALLIANCES AND VALUE CREATION: A STUDY OF BIOTECHNOLOGY FIRMS QUOTED ON THE LONDON STOCK EXCHANGE

Peter McNamara*

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Introduction

Societies and economies are continuously transformed by the creation, integration and exploitation of new knowledge. In delivering new knowledge intensive products, there is a key question of how firms should organise to achieve success. There is increasing dissatisfaction with the operations of the large hierarchical organisation, which appears to be unable to respond to the need not only for efficient and fast delivery of products in the global marketplace, but also the creation, integration, and exploitation of new knowledge to create totally new, or significantly improved, products. It is here that new organisational forms have arisen, particularly the knowledge based organisational network which links smaller firms with each other and with much large enterprises and institutions. At the heart of this network are a form of alliance, which I refer to as a knowledge based alliance. This form of alliance differs from many of its historical ancestors. In these alliances, it is knowledge and intellectual property rights (IPRs) which are exchanged or co-developed and exploited. In contrast, historic alliances emphasised access to markets for products and services, or the supply of downstream production and delivery systems.

A study of knowledge based alliances allows us to appreciate the role of these new organisational forms, and to test the validity of the knowledge based theory of the firm. This theory has arisen is response to the failure of other strategic theories to capture

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the richness of the process of corporate value creation. The knowledge based theory of the firm is currently a vogue in the strategy literature, spawning a host of articles in the *Harvard Business Review* (e.g. Hamel and Prahalad, 1990, Nonaka, 1991), the *Strategic Management Journal* (e.g. Spender and Grant, 1996), and *Organisational Science* (e.g. Kogut and Zander, 1992; Nonaka, 1994; Grant, 1996; Foss, 1996). Most of the writings are conceptual, but some have managed to advance to discussions of simple examples. With notable exceptions, this is particularly true in the alliance field. These exceptions include a number of articles on why biotechnology firms are engaging in alliances both amongst themselves and with pharmaceutical firms (Kogut *et al.* 1992; Lane and Lubatkin, 1997; Powell *et al.* 1996; Senker 1996; Shan *et al.* 1994).

This paper is unusual in that it is an attempt to make a direct assessment of the value of knowledge based alliances in terms of share performance. An event study by Das *et al.* (1998) focused on the effects of technological, R&D alliances versus marketing alliances on firm performance. This paper will differ from Das *et al.* (1998) in that it will not employ a conventional event study method and will concentrate on a single sector, namely UK therapeutic (drug) biotechnology firms. Other empirical studies in the strategy literature which have addressed the issue of knowledge based strategic alliances have tended to focus on variables such as degree of knowledge transfer (Inkpen 1996; Mowery *et al.* 1996) and longevity of alliances (Barkema *et al.* 1997; Parkhe 1991).

UK therapeutic biotechnology firms they are good examples of pure knowledge based organisations. To illustrate the extent of their knowledge intensity one can observe the following. In 1997 of the top nine European therapeutic biotechnology firms in Europe in terms of R&D spend per employee only one had a lower ratio than the top European pharmaceutical firm in terms of that ratio (Ernst and Young 1998). The top biotech company, Celltech had an R&D spend of 141,900 ECUs per employee compared to only 44,500 ECUs for the top pharmaceutical firm, Astra. It is not unusual for over half of the employees of these firms to hold higher degrees, most of which would be doctorates.

Case work underpinning this paper confirmed that the heart of a UK biotechnology firm is its knowledge, often firm specific, about the drug discovery and development process (Mc Namara 1998; Mc Namara and Carlisle 1998; Mc Namara *et al.* 1997). This process can take seven to twelve years from initial concept through to an approved drug, and consume between $200–$350 million (BIO 1998). Therapeutic biotechnology firms have existed in the UK since 1980, however only one, Chiroscience, has had a drug which it discovered and developed approved for marketing. The value of these firms is quintessential: employees and the knowledge that they generate (in terms of patents, IPRs and promising new drug candidate leads) is their principle asset. The other resources which such firms possess, such as computers, software, and the basic scientific equipment are available on the open market.

A brief case may help to illustrate. At its height over the three year period

December 1995 to December 1998 British Biotechnology was worth 2,529 million ECUs (in May 1997). At its low (in October 1998) it was worth only 282.6 million ECUs. During that three year period the firm's value rose 164% to May 1997, only to fall 86.7% from then to December 1998. What triggered these price changes primarily revelations about the conduct and performance of clinical trials of drugs based on the firm's core knowledge base. These revelations challenge the true value of the scientific and managerial knowledge embedded in the firm's research teams and organisational systems. In the case of British Biotechnology, this knowledge process had taken blue skies research into Matrix Metalloproteinases (MMPs) and converted it into two drug candidates, Marimastat and Batimastat. Unfortunately, after an investment of many millions of ECUs, and almost a decade of R&D, its bet on this technology appeared to be in serious trouble, with the abandonment of one of its key trials of the Marimastat drug in December 1998. Nevertheless, were a rival to try to imitate British Biotechnology's capabilities it would be faced with the problem of identifying and understanding the many complex interactions between the knowledge of the firm's individual scientists and that embedded in its organisational systems. Such a task would be costly and consume many man years.

This story also illustrates the power of alliances or the lack thereof. As we shall see British Biotechnology is one of the firms in this paper's sample which did not pursue a strategy of alliances. Thus when investments into a knowledge intensive drug failed the firm bore both the full financial cost and managerial responsibility. This was reflected in both the severe decline in the firm's market value and the resignation of its CEO in 1998.

This paper uses stock market price movements to assess whether knowledge based alliances really do provide value[1], and thus provides an opportunity to assess the value added of the so called knowledge based theory of the firm. My fundamental and tentative conclusion is that the behaviour of the London Stock Market implies that R&D, knowledge based, alliances in the biotechnology sector can convey unique value added by the transfer, or combination, of knowledge which will be subsequently integrated and exploited. The conclusion is tentative, because this paper is an interim outcome of a stream of on going research. It is fundamental, because this paper enables us to move much closer to providing an outline framework for testing the knowledge based theory of the firm.

This paper is divided into two main parts. First, I will briefly outline some arguments for and against the value adding nature of inter-organisational alliances. Second, a knowledge based view of the firm is illustrated with an analysis of nine UK biotechnology firms focusing on their alliance making, drug trial results and stock market performance over a 16 month period. These firms are: British Biotechnology, Cantab Pharmaceuticals, Celltech, Chiroscience, Cortecs, Oxford Molecular, Peptide Therapeutics, Proteus International, and Scotia Holdings.

Knowledge-based alliances and wealth creation

A knowledge based alliance can be defined as:

> ...an inter-organisational relationship short of full integration of direction and routines in which final products are not traded, but the organisations combine and share knowledge bases and trade intellectual property rights.

How should we view knowledge based alliances? The traditional view of alliances stress that many end in failure; like mergers, they are an uncertain way of achieving advantage (Hamel, 1991 and Bleeke and Ernst, 1991). Thus, according to this view a knowledge based alliance should not *per se* lead to added shareholder value. There are a number of reasons why this may be so. First, some alliances go onto succeed, while later the firm collapses. Second, knowledge based alliances might not always be seen positively by shareholders: they typically require the initiating (biotechnology) firm to sell property rights on future income streams in exchange for cash. In general, shareholders prefer firms not to sell call options of future earning streams (as this is exactly what a share is supposed to represent). Actions such as this may appear to be in the interests of management, but not necessarily of shareholders. Selling rights to other firms can be seen as a rival to the stock market.

Third, the market may view knowledge based alliances less favourably due to the great difficulty in valuing them when compared to alliances focused around resource sharing and access to markets. The experience of the market in valuing Mergers and Acquisitions makes it well prepared for analysing the value added from resource sharing and access to complimentary or expanded distribution and marketing channels. The market even offers some experience in the valuation of enlarged opportunities for internal knowledge creation and application that a Merger may offer. The market is much less familiar with the valuation of alliances centred around the highly uncertain and often intangible tasks of joint knowledge creation and application. These tasks occur across independent organisational hierarchies and control systems, where integration of systems may be less viable. How intangibles, never mind inter-organisational intangibles, are valued is an area in which the analytic skills of the stock market are more difficult to apply.

An announcement of progress along a route to success, such as the discovery of a new drug, or even that the drug has passed a critical trial is traditionally viewed as a valuable announcement. Such announcements contain significant information, it is generally argued, and they reduce uncertainty.

> *Hypothesis A: According to traditional transactions styled theories, the announcement of a knowledge based strategic alliance where intellectual property rights are sold in exchange for cash are less likely to be as highly valued as an announcement relating to a significant discovery or progression of discoveries.*

In the knowledge based view of the firm, we have a slightly different result. Here the

alliance between firms represents the key input to the process of success. This is because, without the alliance, knowledge may not be easily recreated or acquired. Grant and Baden-Fuller (1995) develop a theoretic argument which stresses that a knowledge based alliance will significantly increase the value of the firm. Hypothesis B of this paper concurs with this view. Moreover, one would expect such alliances to require significant risk sharing, each firm will typically trade some IPRs in exchange for access to the partners complimentary scientific knowledge, organisational capabilities (e.g. the management of large scale clinical trials) and financial resources. This would not be viewed as running against the shareholders' interests. Because the theory is concerned with the quality of the knowledge, the standing of the partner is critical.

The knowledge based theory would also stress the signalling value of the alliance announcement. The theory stresses that much of the firm's assets are tacit. The announcement of an alliance could represent a significant statement about the value of these tacit knowledge bases and routines.

> *Hypothesis B: According to the knowledge based view, the announcement of a knowledge based strategic alliance where intellectual property rights are exchanged is likely to be viewed as equally, or more significant, an action by the market than the announcement of a discovery or critical advance in R&D. Moreover, the greater the knowledge base of the partner firm, the greater the likely value of the alliance.*

Data Sources and Sample

In developing the ideas in this paper the researcher drew upon two sources of data. The first was a series of case studies of three UK biotechnology firms[2] (Mc Namara, 1998; Mc Namara and Carlisle 1998; Mc Namara *et al.* 1997). These three firms span the breadth of the sector. Celltech had a portfolio of five drugs in development and is the oldest firm in the sector. Oxford Molecular provides software to aid in molecular modelling and also offers collaborative discovery services which bring together and manage projects involving biotechnology and pharmaceutical firms and universities. It is a mid-aged company having been listed since the mid 1990s. PolyMASC specialise in R&D of drug delivery mechanisms and was the newest biotechnology company to obtain a listing at the time of the study.

From the case work it became apparent that managers inside biotechnology firms view the formation and maintenance of knowledge based alliances with pharmaceutical firms as crucial. The more prestigious the partner the more highly prized was the alliance. Their logic was a mix of the following: to validate the commercial potential of their knowledge base in the eyes of shareholders; to gain access to critical, and often competing, discovery capabilities and patents; to reduce the firm's cash burn (the ratio of cash in the bank divided by operating losses) through cash payments by the partner;

and access to development and marketing capabilities, thus enabling access not only to world class capabilities but also a reduction in the cost of maintaining full development and marketing capabilities internally. What remained unclear from the cases was whether alliance activity was actually rewarded by the shareholders in terms of market value and whether it was more highly ranked than clinical advances.

The second source of data was a financial analysis of company accounts and stock market data on nine firms listed on the LSE in 1995[3] over a sixteen month period. During this period these firms lead the wider UK biotech sector in terms of raising capital, establishing competent managerial and scientific teams with a proven track record, collaborating with leading pharmaceutical firms, and taking drug candidates into clinical trials. Their combined market capitalisation was about £ 3.6 billion. Their R&D spend was over £ 100 million per year. They were engaged in about 30 R&D collaborations with pharmaceutical firms and universities. Their combined research portfolio included more than 40 drugs in clinical trials, 3 of which were in phase III, with two having recently passed phase III. These nine firms had drug candidates focused on about 100 clinical targets (illnesses) and employed more than 1,500 people – the majority of which were scientists.

Although these firms are only a small part of the global industry, they are significant. An industry periodical recently reported that in the USA there were 280 biotechnology products under FDA review, 65 at phase III (Genetic Engineering News 1997).

Table 1 shows some key data for the sample. This table documents the principle areas of interest for each firm and the rough stage of clinical development. This data acts as a rough proxy for the depth of each firm's stock of knowledge. The greater the number of clinical trials in advanced stages the greater the likelihood that one will succeed and become a marketable drug. One of the nine firms is not strictly a drug firm. Oxford Molecular develops software for use in drug research. Where possible, this firm is included in the analysis, but at the key point of valuing alliance making strategies it is excluded because of non-comparability.

Analysis

The nine biotechnology firms followed different strategies. In particular, some undertook a wide variety of alliances where as others undertook very few. In addition, those firms which did undertake alliances differ in how they approached their choice of partners. This diversity of approach provides researchers with an opportunity to assess the value of knowledge based alliances, because one can compare firms strategies, and look at strategy announcements and stock market reactions.

Table 2 provides detailed information on the R&D alliances of the nine firms in the sample. These alliances are chosen because from the case work it became apparent that managers view these as the most value added form of alliances in their portfolio.

TABLE 1: Research Activity in Nine LSE Quoted Biotechnology Firms

Company Name	Major Areas of Interest	Rough Stages of Clinical Development (publicly reported)	R&D Spend	Number of Staff	R&D per Employee
British Biotech	Cancer, Inflammation, Virology.	1 recently passed phase III. 15 clinical trials across 6 products (1 at phase III). 3 pre-clinical trials.	29.1 (millions)	350	83,143
Cantab	Cancer, Inflammation, Infectious Disease via immunotherapeutic vaccines.	3 clinical trials with more in the pipeline.	6.3	91	69,231
Celltech	Cancer, Inflammation, immunomodulation.	4 clinical trials (1 at phase III). 1 recently failed phase III. 5 pre-clinical studies.	17.4	200+	87,000
Cortecs	Oral Drug Delivery Systems. Incorporating research in Chronic Lung Disease, Diabetes, Helicobacter Pylori, Male Hormone Deficiency, Microbial Antigens, and Osteoporosis.	4 clinical trials (1 at phase II/III). 4 pre-clinical studies.	12.1	166	72,892
Chiroscience	Chiral compounds (R&D includes RNA virus infections. e.g. Hepatitis C, Cancer, local anaesthetic).	1 recently passed phase III. 4 clinical trials (1 at phase III). 12 candidates in development.	5.9	170	34,706
Oxford Molecular	Software and services to support the Drug Design Process.	1 pre-clinical trial. 1 set of tools for chemical data analysis in development with Glaxo-Welcome. 2 computer software products.	8.0 (95 admin)	97	82,474
Peptide Therapeutics	Allergy, Meningitis, Rheumatoid Arthritis, Veterinary.	3 clinical trials. 6 pre-clinical trials.	2.1 (95)	64	32,812
Proteus International	Immunotherapeutics (control of sex hormone dependent tumours), DNA binding, Enzyme Inhibitors (HIV, Blood Clotting), Inflammation (arthritis), BSC diagnostics.	1 phase II trial being conducted by a collaborator. 1 future BSC testing product.	5.5	65	84,615
Scotia Holdings	Lipid Technology, Cancer, Dyslexia.	5 clinical trials. recently encountered difficulties at phase III). 16 pre clinical candidates. Some products on the market but not via FDA/EMEA	16 (95)	340	47,059
Total		2 passed phase III. 43 clinical trials, 3 at phase III. 47 pre-clinical trials	102.4	1,543	66,364

Sources: Annual Reports; Extel Company Reports.

They are central to the management of biotechnology firm's core knowledge base, namely the discovery and development of novel drugs. In most cases these alliances embrace not only a sharing of patents and discovery leads within a defined scientific area, but also drug development and marketing agreements. Other alliances within these company's portfolio occasionally including contract manufacturing and licensing deals. These alliances are excluded from this study on the basis that they do not involve a sharing of knowledge and IPRs, but a purchase thereof.

The collaborative strategy of each firm is judged according to two factors: the stated collaborative position of the firm in their annual report, and the number of significant alliances. These data sources were checked with other public data. It was found that the sample could be divided into two groups: Go-it-alone and Alliance Makers.

Go-it-alone: Two firms British Biotechnology and Scotia Holdings engaged in one R&D alliance each (Glaxo-Welcome for Asthma and Astra Pain Control for Anaesthetics) which is small in comparison to the number of products they were working on in the clinic (15 and 5 respectively) and in pre-clinical development (3 and 16 respectively). These two firms are labelled as "Go-it-Alone" because their stated intentions and/or practice[4] suggests that they avoid partnerships for the majority of their core research (neither Asthma nor Anaesthetics is core to these firms).

Alliance makers: Six firms appear to engage in many alliances to aid drug discovery and development. From the data the collaborative strategy of each firm can be further divided into one of two categories: prestige or regional. Prestige collaborations are R&D collaborations with major global pharmaceutical firms. Regional collaborations are R&D collaborations with research institutions or regional rather than global pharmaceutical players. Only two firms have consistently engaged in prestige alliances: Celltech and Cantab. The other firms appear to have focused on regional alliances.

The financial needs and sources of capital for the firms

Is there a clear relationship between the effectiveness of developing biotechnology knowledge, the alliance strategy, and the value of the firm? The case work suggests that biotechnology executives believe that it is from the firm's stock of knowledge that it develops novel drug candidates which attract the eyes of both collaborative partners and financiers. They say that a collaborator brings many benefits. First there are clear financial rewards in terms of milestone payments from the collaborator. They say that a major pharmaceutical partner also validates the potential of a biotechnology firm's knowledge base in the eyes of the financial markets5. This strengthens the firm's ability to raise further funds from the capital market, hence strengthening its financial value. Both these factors increase the biotechnology firm's ability to invest in additional knowledge, thus strengthening its key source of competitive advantage. A virtuous cycle can develop.

TABLE 2: Some Collaborative Arrangements of Nine LSE Quoted Biotech Firms (Bold indicates formed between December 1995 - April 1997)

Company	R&D Alliance (29 in all)[1]	Collaborative Strategy [2]
British Biotech. 1 phase III passed drug, 15 clinical trials, 3 pre clinical.	One alliance: Glaxo-Welcome (P) (Asthma).	Go-it-alone
Cantab Pharmaceuticals 3 clinical trials	Two alliances: Glaxo-Welcome (P) (Herpes vaccine); SmithKline-Beecham (P) (Genital warts vaccine).	Prestige
Celltech 4 clinical trials; 5 pre clinical trials.	Six alliances: American Home Products (P) (leukaemia); Bayer (P) (septic shock; arthritis; inflammatory bowel disorders; Crohns) Merck (P) (Asthma); Schering-Plough (R) (Asthma); Stanford Uni (P) (antigen blockers); Zeneca (R) (Cancer and Arthritis).	Prestige
Chiroscience 1 phase III passed drug, 4 clinical trials; 12 pre clinical	Three alliances: Knoll (R) (cardiovascular); Laboratorios Menarini (R) (arthritis); Medeva (R) (attention deficit).	Regional
Cortecs 4 clinical trials; 4 pre clinical trials.	Six alliances: Cambridge Uni (P) (microbial antigens); CCBR (R) (clinical trials on Osteoporosis); Exocell (R) (diabetes control); Osteometer (R) Uni of Canberra (R) (vaccine); Uni of Singapore (R) (H.Pylori).	Regional
Oxford Molecular 1 clinical trial, 3 products.	Four alliances: Alizyme (R) (obesity); Glaxo-Welcome (P) (On-line library); Prolifix (R) (Molecular Modelling); Yamanouchi Pharmaceuticals (R) (Identification of Small molecules).	Regional
Peptide Therapeutics 6 clinical trials; 6 pre clinical trials.	Five alliances: Alizyme (R) (libraries); Dr. Fooke Laboratorien GmbH (R) (Arthritis); SmithKline Beecham (P) (vaccines); Uni. of Bristol (R) (arthritis); Uni. of Nottingham (R) (allergies)	Regional
Proteus International 1 clinical trial; 1 pre clinical trial.	Three alliances: Janssen Pharmaceutica [J&J] (P) (Animal Healthcare); M.L. Laboratories (R) (oncology) University College Dublin (R) (BSE Diagnostic)	Regional
Scotia Holdings 5 clinical trials; 16 pre clinical.	One alliance: Astra Pain Control AB (R) (anaesthetics)	Go-it-alone

[1] Signifies the type of collaborator. P = prestige. A firm that ranks in the Fortune Global 500 or has a global market share of over 1% (Fortune 1996; Bogner and Thomas 1996). R = regional. All other pharmaceutical firms.

[2] A firm is classified prestige if 50% or more of its collaborators are prestige firms. They are classified go-it-alone if their predominant strategy is to develop drugs without alliances

The importance of alliances as a way of raising cash can be seen from Table 3. We can see that payments from collaborative partners represents a considerable source of funds. British Biotechnology, Cantab Pharmaceuticals, Celltech, and Proteus International all obtain milestone payments in the millions. Over half of Chiroscience's turnover came from a manufacturing contract, while much of the remainder came from technical support services and milestone payments. In the case of the remaining three firms substantial turnover was obtained from sales of intermediary and final products. Cortecs obtained turnover from sales of testing kits with collaborators and milestone payments. Oxford Molecular had a growing business in the sale of software to support drug discovery and development. Scotia was the only firm with sales of final drug products. Most of these sales came from its small portfolio of dermatological and pain control products. The other columns show each firm's cash burn, how much money has been raised from the market and the firm's net cash flows before financing from the stock market.

Market Performance of UK Biotechnology Firms

The LSE is the second largest equity capital market in the world after the New York Stock Exchange. For the purposes of data analysis this paper assume that the semi-strong form of efficient capital markets theory applies to the LSE. This theory states that all publicly available information should be fully reflected in a firm's share price (Fama 1991). It is therefore assumed that public announcements on a firm's activity should be reflected in the firm's share prices. Annual returns to investors are calculated as being: (Final trading day price – first trading day price + dividends) / (First trading day price). A more normal method of calculation would have been daily log returns, however due to the high volatility of this shares this method proved impractical. Annual returns were calculated based on daily share price movements from December 1995 to April 1996 (16 months). This was the first period during which all nine firms were simultaneously quoted on the LSE.

Table 4 outlines the mean returns on an annualised basis for the sample. First, one can see that there is a clear group of winners and losers. Cantab, Peptide, Oxford Molecular and Chiroscience outperform the FTSE All-Share and the FTSE-Pharmaceuticals by a considerable amount. British Biotechnology, Celltech and Scotia yield positive returns, but not significantly above that of the market. Cortecs and Proteus both destroy, rather than create value. The minimum and maximum ranges indicate just how much can be won and lost for short term investors in these firms. Losses range from as much as 70% in Proteus International to gains of 117% from Cantab.

Market Performance and Knowledge Stocks

The events upon which this study focuses are announcements of new R&D alliances, or alliance termination, and announcements of progress in clinical trials. These are viewed

TABLE 3: Relative Strength of Financial Stocks

Company Name	Raised by milestone payments or turnover 1996 £ millions*	Cash Burn[1]	Raised from Equity & Major Asset Sales Since LSE Listing (millions)	Net Cash Flows before financing
British Biotech.	8.0 (milestones)	2.8 years	389.5	-22.2
Cantab Pharm.	7.0 (milestones) 3.1 (licence fees)	8.1 years	55.9	Not Available
Celltech	2.8 (milestones)	5 years[2]	170.0	+21.1 (due to asset sale)
Chiroscience	11.5 (turnover)	1.5 years	91.6	-21.1
Cortecs	8.03 (turnover)	6 years[3]	58.0	-4.6
Oxford Molecular	9.8 (turnover)	4.7 years	78.5	-21.1
Peptide Therapeutics	0.2 (turnover)	4.5 years	56.6	-3.0
Proteus International.	1.1 (milestones)	0.4 years	43.0	-3.5
Scotia Holdings*	16.5 (turnover)	1.8 years	83.8	-19.1
Total	68.0		1026.9	

* Where milestone payments were not separated out from turnover the turnover is offered in this table.

[1] 1996 annual report data (except Cortecs).
[2] Excluding extraordinary profit from sale of contract research firm. This amounts to £ 12.2 million and turned a loss of £ 9.2 million into a group profit of £3.0 million. Sources of Data: Extel Financial Services, Annual Reports; London Stock Exchange Year Book.
[3] Based on six month data annualised (Cortecs December 1996 interim six month financial report).

as proxies of performance in terms knowledge management. The effect of these events is then related to the relative ranking of the sample firms in terms of stock market performance. This paper does not employ a traditional event study methodology, which is the subject of a later paper6. Rather it takes a more simplistic and global perspective. Instead of assessing the effect of single announcements on the share price of a firm in a narrow window the paper assesses the cumulative effect of announcements over the total 16 month time horizon. The question this method seeks to address is whether there is a simple hierarchy of announcements which can rank the relative performance of the

TABLE 4: Average Annual Returns of Eight London Stock Exchange Biotech Firms

	Mean Annual Return	Standard Deviation	Minimum Return	Maximum Return	Range
British Biotech	18.75**	13.74	-2.35	104.46	102.11
Cantab Pharm.	84.56**	14.01	43.40	116.67	73.27
Celltech	7.17**	19.45	-19.78	37.81	57.59
Chiroscience	23.76**	27.43	-14.15	76.23	90.38
Cortecs	-2.15	10.78	-29.96	29.64	59.61
Oxford Molecular	37.60**	6.75	16.08	52.12	36.04
Peptide Therapeutics	34.93**	35.90	-17.73	88.63	106.35
Proteus International	-21.16**	49.06	-70.78	116.21	186.98
Scotia Holdings	6.48	18.94	-38.17	33.33	71.51
FTSE All Share	13.16**	2.26	8.61	18.95	10.34
FTSE Pharm.	19.69**	8.18	9.23	38.97	29.74

* Significant at 95% level.
** Significant at 99% level.

sample companies against one another over 16 months. As we shall see such a hierarchy does seem to exist. Its existence may have powerful implications both for managers within these firms and for the knowledge based theory of the firm.

Regular announcements are made in the *Financial Times* regarding the sample firm's progress in drug discovery, clinical trials and alliance deals. During the sixteen month period of the data set 154 *Financial Times* articles referred to these eight firms. As said before, Oxford Molecular was excluded from this portion of the analysis since its business does not focus on drug discovery and development *per se*, but rather on the provision of software and services to support such activities in other firms.

There were 49 articles referring to the sample firms, or 32% of the total, from which 40 relevant events announcements were identified. These 40 events were divided up as follows: 19 were announcements about drug trial progress; 7 were announcements casting doubt on technical progress (usually considered important information in this sector); 14 were announcements on alliances. The remainder of the articles announced interim and year-end financial results (17.5%), equity issues and acquisitions or

disposals (8%), changes in staff (6.5%), or other issues (36%). The other category includes general articles on the sector, in which one or more of the companies was mentioned.

Table 5 reports the announcements analysed by type and relates it to investor returns. This table shows the stock of knowledge, in terms of alliances and drugs in clinical trials, which each firm had at the start of the study and the change in that stock over the period of the study. To test the hypothesises changes in knowledge stocks are linked to the rank order of performance of each stock. Firms who have improved their overall stock of knowledge should have a higher level of performance than others. This finding would add weight to the knowledge based view of the firm. For hypothesis B to hold then firms who improve their stock of alliances should have superior performance to firms who improve their stock of drugs in clinical trials only.

From Table 5 one can observe a clear hierarchy of performance and announcements which matches the consideration of knowledge in the biotechnology sector outlined above. The hierarchy of announcements can be seen by reading Table 5 right to left. Prestige alliances are the most important announcements, while advances in clinical trials yield lesser value. Cantab ranks first in terms of annual returns, with Peptide second. Cantab entered into two prestige R&D alliances during the sixteen month period, while peptide entered into one. The market appears to view these alliances as the most valued events amongst the options in Table 5, hence firms who gain prestige alliances are the biggest winners in terms of performance, while the Proteus which lost two prestige alliances is the biggest loser.

The next most valued events appears to be successful completion of phase III clinical trials. Chiroscience ranks third in terms of mean annual returns, having taken a drug successfully through phase III with no reported question marks on performance. The firm also has a pipeline of other drugs in clinical development. British Biotechnology comes fourth with a drug passed phase III, a number of other drugs in the pipeline, but two question marks on its clinical progress in one of its main drugs (Marmistat which was in phase III). Celltech comes fifth, with one drug entering phase III, a number of other drugs in the pipeline, and no question marks on clinical progress (though in May 1997 the phase III drug failed and almost 50% was wiped off the firm's market value). Scotia Holdings came sixth, with one drug passed phase III. However, during the period of study, this drug was under heavy criticism by some medical authorities and it seemed likely have to undergo a new battery of tests, thus delaying time to market, or be rejected by regulatory authorities. This is reflected in the four question mark articles on the firm's clinical performance. Cortecs ranks seventh, with no drugs entering phase III in the sixteen month period and no new Prestige alliances.

It can be concluded from this analysis that the most highly valued announcement was that of a Prestige Alliance, next came the announcement of a success in Phase III trials, and third were other announcements such as regional collaborations or other drug trial successes in Phase I or II.

TABLE 5: Relative Strength of Knowledge Stocks: Reported Activity in Trials and Alliance December 1996 - April 1997

Company		Regional R&D Alliance	Drug Enters Trials	In phase 1/2	In Phase 3	Passes Phase 3	Question Mark on Progress	Prestige R&D Alliance	Ranked Annual Return[1]
Cantab	PROGRESS DEC 1995	0	+0	+0 4	+0	+0	+0	+2 0	1 (85%)
Peptide Therapeutics	PROGRESS DEC 1995	+0 4	+0	+0 3	+0	+0	+0	+1	2 (35%)
Chiroscience	PROGRESS DEC 1995	+1; -1 2	+1	+0 4	+1	+1	+0	+0 0	3 (24%)
British Biotechnology	PROGRESS DEC 1995	0	+1	+2;-2 14	+1 0	+1	2	+0 1	4 (19%)
Celltech	PROGRESS DEC 1995	+0 0	+1	+1 3	+1; -1 1	+0	+0	+0 6	5 (7%)
Scotia Holdings	PROGRESS DEC 1995	+1; -1 0	+0	+1 4	+0	?=1	-4	+0 1	6 (6%)
Cortecs	PROGRESS DEC 1995	+2 4	+0	+2 2	+0	+0	+1	+0 0	7 (-2%)
Proteus International	PROGRESS DEC 1995	+1 1	+0	+1	+0	+0	+0	+1; -2 0	8 (-21%)

1 These ranks are calculated using Table 4. The largest mean annual return obtained a rank of one while the worst obtained a rank of 8. Oxford molecular is excluded from the analysis for reasons outlined in the text.

Source: Financial Times December 1995 - April 1997; Company Annual Reports and Extel Company Reports.

Discussion and Conclusion

In drawing these conclusions, it is recognised that this is a simple analysis of share performance. While a rank order within the sample is obtained the relative effect of each event was not assessed. The data in this paper does, however, appear sufficiently clear to draw the tentative conclusions outlined below, and to justify pursuit of future research to assess the relative impact of each type of event on the share performance via an event study.

Recalling that the hypothesis were:

> *Hypothesis A: According to traditional transactions styled theories, the announcement of a knowledge based strategic alliance where intellectual property rights are sold in exchange for cash are less likely to be as highly valued as an announcement relating to a significant discovery or progression of discoveries.*
>
> *Hypothesis B: According to the knowledge based view, the announcement of a knowledge based strategic alliance where intellectual property rights are exchanged is likely to be viewed as equally, or more significant, an action by the market than the announcement of a discovery or critical advance in R&D. Moreover, the greater the knowledge base of the partner firm, the greater the likely value of the alliance.*

The data from tables four and five clearly indicate that support for hypothesis A is absent from the data. The relative ranking, in terms of annual returns, between the nine firms shows that announcements of prestige alliances is more valuable than announcements about progress in clinical trials. Neither Cantab nor Peptide reported progress in clinical trials during the 16 month period, yet they are the top ranked firms. This runs counter to hypothesis A.

Hypothesis B seems to have strong support. The top ranked firms are those who announced alliances with powerful partners, who have deep knowledge bases. Thereafter performance can be clearly linked to the relative progress in terms of clinical performance. Those who have passed phase III do next best, with Celltech, who had a drug enter phase III trials coming behind Chiroscience and British Biotechnology. The laggards are Scotia and Cortecs who have both had question marks on their clinical performance and no prestige alliance announcements. Proteus has the lowest ranked performance. It lost prestige alliance partners and had limited progress in terms of clinical performance.

Having obtained some support for Hypothesis B and rejected Hypothesis A on the basis of the analysis of share performance the next step is to conduct a more sophisticated event analysis. In the development of this paper much has been learned. A follow-up event study should seek not only to test these two hypothesis but also to explore two further propositions which have been developed. It is to these propositions which we shall now turn.

Proposition One:

In environments where there are very significant investments in complex knowledge bases, the market will use alliances with prestige collaborators as a proxy measure of the potential value of the independent firm's knowledge stock.

An analysis of the nine firms reveals that all have significant R&D investments which are being funded in large part by equity from the capital markets. None of these firms have significant bank debt as a source of funding. It is clear that the value adding task of these firms flows from commercialisation of their complex knowledge bases. The value and depth of these firms knowledge base is very difficult to determine. Large pharmaceutical firms have considerable amounts of scientific expertise in this field, in addition to experience of getting drugs to market. In the eyes of the market an alliance with one of the biotechnology firms acts as an external validation of the commercial value of that firm's knowledge base. The alliance will over time involve the collaborator becoming intimately aware of the project details. Likewise, should the alliance terminate without the completion of the project then this is likely to be a signal to the market that the knowledge base of the firm is not as valuable as previously thought. What is most surprising is that the stock market views information from alliance making as even more important than that of clinical trials. This is a point on which more research needs to be undertaken.

Proposition Two:

Knowledge based alliances can be an important source of value where the partners key capabilities are complimentary. In this environment the motivation for the alliance is essentially an exchange and combination of resource and capabilities centred around the creation as well as commercialisation of knowledge bases.

It is commonly, but I suggest wrongly, argued that alliances in the biotechnology industry are driven by the fact that biotechnology firms are gifted at the discovery of promising new drug candidates, but lack the capabilities in the later stages of development and marketing. Of course it is true that prestige pharmaceutical firms have strong capabilities in the areas of taking drugs through the later stages of clinical trials and in global marketing and distribution. However, if this was the real value of an alliance, then the announcement of the alliance would have no significant value before the result of the clinical trial. In fact the opposite is the case.

The results of this paper suggest that the real perceived value of alliances is in the sharing of capabilities where the biotechnology firm's discovery capability feeds into the pharmaceutical firm's development capability. The case work which underpinned this research revealed that discoverers often need to work in close conjunction with the development team during critical stages of the process. In this way these alliances clearly create new knowledge which could not be created by the firms individually. The interaction between two firms with differing perspective and capabilities may be critical

to the process of discovery and development.

This paper reports some preliminary work, and so should be treated as such. It has flaws and limitations. It is, however, an attempt to make operational some of the knowledge based theories of the firm, which have become popular in the last few years. In undertaking this empirical work, it has been found possible to use the knowledge based theory of alliances to come up with some testable predictions about stock market reactions to announcements. Despite the limited data, this paper has uncovered evidence that the knowledge based view may be a better depiction of the world than some more traditional views.

Notes

1. It was noted by some participants at the EGOS Colloquium 1997 that there may be a distinction between alliances adding 'true' value to the company as opposed to the perceptions of the stock market that these alliances add value, and hence that stock prices rise. This may well be true, however whether the perceptions of the stock market equate with the reality of value creation in terms of eventual production of a superior drug is a casually difficult matter to assess. At the end of the day the shareholder is the owner of the firm, if they feel that alliances add real value this will be reflected in the share prices. Management, as the agents of the shareholder, ignore the perceptions of the stock market at their peril.
2. These case studies are part of research sponsored by the UK Design Council.
3. The UK biotechnology sector is new to the LSE. Listing rules made it impractical for them to be quoted before 1990. In 1997, 16 firms were listed on the exchange, of them only ten firms were listed in 1995, one of which was a small American firm. The sample of nine firms in this paper is effectively the entire population listed in 1995. As of May 1997 these firms represented about 75% of the total market capitalisation of pharmaceutical biotechnology firms listed on the LSE and a similar amount of that population's R&D expenditures.
4. Scotia Holdings had a stated intention to engage in alliances, however during the period of study had only one regional R&D alliance partner, and no prestige partners.
5. This view point is further strengthened by the comments of Sir Brian Richards who, in a public workshop/seminar at City University Business School, noted the strong validation effect that such alliances have on the standing of biotechnology firms in the market. Sir Richards was the co-founder of British Biotechnology and currently sits on the board, or is a founder of, over eight UK biotechnology firms.
6. For a review of this method the reader is referred to Mc Williams and Segel (1997), or the applied paper Das *et al.* (1998).

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