A Multidimensional Analysis of Post-Acquisition Performance: The Case of Research and Development in the Pharmaceutical Sector

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Declaration

I declare that the content of this thesis is entirely my own work and has not been submitted for a degree at another university.

Abstract

This thesis provides an additional perspective of the Merger Paradox, namely that mergers and acquisitions (M&A) continue to be transacted when historically their results seem to be disappointing overall.

The thesis shows that when a theoretically sound basis (related to the Resource Based View and expressed as twelve design principles) is used to design a performance measurement framework, then there is no association between a firm's post-acquisition performance and the scale of a firm's previous acquisitions; the thesis then shows, by contrast, that there is a positive association between firms with an above-average level of past acquisitions (by value) and higher financial performance. This divergence provides both a motive and an ability to continue to undertake M&A, despite a lack of association of acquisitions with longer-term operational performance and very strong evidence of diseconomy of scale in the most crucial business process, for the case examined, which is the research and development (R&D) process in the research-based pharmaceutical sector. Additionally, the thesis examines the relative merits of Return on Sales and Return on Assets as financial metrics of performance, and establishes statistically significant differences in the measurement of performance by these two metrics.

The thesis also establishes a contrast between the findings at the level of the firm and at the level of the sector, namely acquisitions considered in aggregate are associated with gains at the sector level, even though this association was not observed when acquisition was considered at the level of the acquiring firm.

The thesis provides a new application of Data Envelopment Analysis and establishes a scale efficiency relationship for the pharmaceutical R&D process. A further empirical contribution is the examination of the statistical distribution of acquisitions in the pharmaceutical sector and confirmation of the consistency of that distribution with a power-law.

Glossary

ADME	Absorption, Distribution, Metabolism and Excretion
BCC	Banker, Charnes and Cooper
CCR	Charnes, Cooper and Rhodes
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
DRS	Decreasing Returns to Scale
IC	Intellectual Capital
ICT	Information and Communications Technology
IND	Investigational New Drug
IRS	Increasing Returns to Scale
KPI	Key Performance Indicator
M&A	Mergers and Acquisitions
MCT	Measure of Central Tendency
Merger Paradox	M&As continue to be transacted when historically their results seem to be disappointing overall
NAIC	North American Industry Code
NDA	New Drug Application

NDV	Normalised Deal Value
p-value	The probability, computed assuming that the null hypothesis is true, of observing a value of a test statistic that is at least as contradictory to the null hypothesis as the value actually computed from the sample data (adapted from Bowerman et al., 2011: 359)
PAP	Post-Acquisition Performance
PMF	Performance Measurement Framework
R&D	Research & Development
R&D (Average)	Average Research & Development expenditure for a firm from 2001 to 2006
R&D (Current)	Research & Development expenditure for a firm in 2006
R&D (Historic)	Average Research & Development expenditure for a firm from 2001 to 2005
RBV	Resource Based View
ROA	Return on Assets
ROE	Return on Equity
ROS	Return on Sales
SDV	Sum of Deal Value
SOA	Sales over Assets

US$	United States dollar. Official currency of the United States of America and several other countries
VRIN	Valuable to the company, Rare, Imperfectly imitable and Non-substitutable
VRS	Variable Returns to Scale

1 Introduction

1.1 Research Aim

Angwin (2007) posits a fundamental question for research into mergers and acquisitions (M&A), which is often termed the 'Merger Paradox', namely why M&A continue to be transacted when historically their results seem to be disappointing overall. That paper goes on to suggest that there are many objectives for M&A and one should not judge a transaction to be a failure on the basis of a particular measure of performance. This thesis examines the Merger Paradox from the stance of measurement rather than from the motive itself (although the two are related), and seeks to demonstrate that differences in the measures used to determine post-acquisition performance (PAP) could explain the continuing popularity of M&A despite M&A not being associated with improved long-term performance in crucial business processes.

The literature review for this thesis has identified PAP literature dating back to 1968 and from the very start the issue of multiple stakeholders and dubious PAP was fully recognised. Over 40 years of research later, across several disciplines, Zollo & Meier (2008) noted the absence of a convergence of findings even within disciplines and identified the use of 12 types of measures of PAP. Despite the variety of measures, in a recent investigation using multiple criteria, Papadakis & Thanos (2010) noted disappointing outcomes in over half of cases, which then leads to the Merger Paradox of why acquisitions remain popular when, in most cases, they seem to be unsuccessful.

It is against this background of voluminous, diverse but pessimistic literature that this thesis adds new contributions by initially focusing on the principles of performance measurement, noting that PAP is an intellectual construct and

taking heed of Venkatraman & Grant (1986) who observe that in strategic management the principle of measurement of a construct is often ignored in favour of content development. In essence, PAP itself can never be considered directly, but only through proxies for PAP expressed in a chosen measure. Given this, the selection of any measure requires a theoretical basis.

The Resource Based View (RBV) of a firm is used here as the theoretical basis for measure selection. Currently, RBV is a long-established approach to strategic management. The *Journal of Management* in September 2011 dedicated a special issue to reviewing resource based theory to commemorate its previous special issue that introduced the theory 20 years earlier; in the most recent special issue, Barney et al. (2011) considered it had reached maturity and was capable of further development to satisfy its critics. The focus of the RBV is on the linkage of competitive advantage to the differences between firms in the same market, as opposed to the factors affecting profitability in the market as a whole (the focus of the Industrial Organisation approach to strategy). The focus of RBV on relating the competitive advantage of a firm to its special factors (some of which will be measurable) has made its literature a natural basis from which to develop a systematic means to identify a set of performance measures that can be related to long-term performance. In the thesis, a performance measure is used to assess the comparative efficiency of key processes of firms in a particular sector and it is used as a measure of relative non-financial performance. This performance measure is then associated with the acquisition history of the firms and used to test a series of hypotheses for mergers in aggregate as well as cross-sector and cross-border mergers. In order to shed new light on the Merger Paradox, the outcome of the analysis is compared with a similar exercise using a common accounting measure.

Finally, the effect of M&A on sector performance and whether particular alternative financial measures provide a consistent view on PAP are examined.

1.2 Choice of Sector and Need for Research

The research-based pharmaceutical sector offers several advantages for this research:

– The resources of a firm, in the RBV sense that includes both inputs and outputs of the research and development (R&D) process, are clearly defined because products cannot be developed without formal regulation and identification, nor can they be sold without marketing approval.

– The R&D process is generic across the whole industry (because of regulatory constraints) and this gives rise to a comparable process that allows efficiency to be measured.

– Data on the industry are widely available.

These characteristics do not apply to all research-based industries, for example the Information and Communications Technology (ICT) sector has diverse R&D processes.

Furthermore, the research-based pharmaceutical sector offers compelling public policy reasons to undertake research: rising healthcare costs are a feature of the economies of the developed world and the ethical pharmaceutical sector is both a cause of, and a potential solution to, these costs; yet there is concern that it is facing a productivity crisis, for example Cockburn (2006), and a rising cost per new compound, for example DiMasi et al. (2003).

1.3 Research Approach

Firstly, because the focus of the research is on how the assessment of PAP depends on the choice of measure, it is necessary to first develop a systematic and rigorous way to select performance measures; as indicated in Section 1.1, this is based upon the RBV. The selection process leads to a vector of measures that can be used to measure R&D efficiency.

Secondly, having defined a vector of measures, a number of Data Envelopment Analysis (DEA) models were built with the selected measures to measure comparative efficiency of the R&D process between firms, in order to establish relative performance; in order to do this it was necessary to test for returns to scale, after populating the models with data on the inputs and outputs to the process. The different models had different selections of inputs that gave rise to different assessments of efficiency.

Thirdly, data on acquisitions of the major pharmaceutical firms were collected and the deals were also classified according to whether the acquisition involved diversification into different nations or sectors. The data on M&A values were summated for each of the firms and also normalised by dividing by the cost of sales of the firm to relate the deals to the size of the firm.

Fourthly, this acquisition history of the firms was associated with their efficiency as measured by DEA and used to test three merger-related hypotheses relating to: acquisitions in total, acquisitions of new product resources, and acquisitions of new market resources. This was done for more than one DEA model and the differences in outcomes were related to typical behaviours following a merger.

Fifthly, the financial efficiency of the firms was measured by Return on Sales (ROS) and Return on Assets (ROA), for the same firms and this was used to test the same three hypotheses. This was then compared with the outcomes of the hypothesis tests using the DEA methods and this led to a further explanation of the Merger Paradox.

Sixthly, the acquisition statistics on mergers of the firm were analysed without the application of a normalisation factor to examine the effect of mergers on efficiency at the sectoral level; this was done in order to compare the outcome with financial methods of analysis in which differences are observed for the PAP of the shareholders acquiring the firm alone and the shareholders of the acquiring and acquired firm together.

Seventhly, the statistic Sales over Assets (SOA) was tested in order to understand if the acquisition process had an effect on common financial metrics that could be used to measure PAP and an effect was detected.

Some of these steps required hypothesis testing. The research hypotheses are described in the next section (1.4). The research hypotheses were developed after consideration of the literature on PAP and will be related to the literature in the final chapters of the thesis.

1.4 Research Hypotheses

The hypotheses are based on testing the difference in a measure of central tendency (MCT) between two samples, using both a parametric and a non-parametric test. All the hypotheses follow a conventional format, whereby the null hypothesis represents the case of no difference between the means of two samples; the alternative hypothesis is therefore that there is a difference between the means of the two samples and it is the alternative hypothesis that

is tested to establish a statistically significant difference between the means of the two samples.

In the case of the first set of hypotheses, there is a single null hypothesis that scale does not vary with size: constant returns to scale (CRS) exist for a process. The alternative hypothesis is that there are variable returns to scale (VRS) and this is tested by examining whether statistically significant differences in size exist between two groups comprising firms with above-median and below-median efficiency scores.

The second set of hypotheses (a set of three) examines technical efficiency. The null hypothesis is taken to represent the situation that a history of M&A transactions, normalised for the size of the firm, is not associated with a change in efficiency. The alternative hypothesis is that efficiency does change as a result of M&A and as the objective is to test the Merger Paradox, the statistical test is one-sided: M&A is associated with lower technical efficiency.

A similar test is undertaken for a third set of three hypotheses that examines financial efficiency (as measured by both ROS and ROA), except that the direction of the alternative hypothesis is that M&A is associated with higher ROS and ROA that would provide a financial motive, or at least a qualifying factor, for the deal.

A fourth set of three hypotheses considers the association of acquisitions in total, without normalisation for the size of the firm, with technical efficiency. These hypotheses follow a similar format to those in the second set.

Finally there is a fifth set hypotheses that examines different financial metrics. The null hypothesis is that SOA is unchanged, and the alternative hypothesis is that M&A is associated with lower SOA, as additional intangible assets

become recognised in the M&A process. A fourth hypothesis is added to this set, a non-directional hypothesis, to clarify one of the findings.

There are therefore 14 hypotheses in all.

1.5 Technical Challenges and Contributions to Knowledge

1.5.1 Measurement of Intangibles

The difficulty in quantifying intangibles has posed various challenges to this research. One example of an intangible factor is the nature of the output of the R&D process, however, the sector was chosen so a regulatory process circumvented the difficulty of recognising the worth of an output. A further aspect relates to the attempts to measure diversification, for example M&A deals have been categorised in order to examine the effects of diversification, however in order to do so there needs to be a measure of relatedness. A measure of relatedness was achieved by identifying whether the acquired company was located in the same country or had the same industrial classification as the acquiring company; nonetheless it is recognised that these simple classifications do not account for a more nuanced situation.

1.5.2 Longitudinal Nature of R&D Pipeline

The use of DEA to measure the comparative efficiency of the pharmaceutical R&D pipeline between firms in the M&A context is novel[1]. One possible reason is because of the difficulties presented by the longitudinal nature of the pharmaceutical R&D pipeline, whereby outputs in the current time period depend on inputs in the previous time periods. This research has sought to address this problem by collecting input data that cover the majority of the

[1] It has however been used as a means of R&D productivity measurement in other sectors, unrelated to M&A, for example in selection of projects within a portfolio of a firm (Oral et al., 1991; Eilat et al., 2006).

duration of the multiphase R&D pipeline and which exceeds the duration of any single phase of the multiphase pipeline.

1.5.3 Variety of Outputs

Earlier literature on measurement of R&D efficiency has used a wide variety of examples of potential outputs from the R&D process, including revenue, patents and New Drug Applications (NDAs). This variety of outputs has contributed to the diversity of findings.

The advantage of DEA is that multiple outputs can be considered, so that an arbitrary choice between potentially valid output parameters does not have to be made. The selection of the multiple output parameters is undertaken using the 12 Design Principles (the model design is discussed further in Section 4.2).

1.5.4 Types of Contributions to Knowledge

The research has produced the following contributions:

- Two theoretical contributions by offering:
    - additional insight into the Merger Paradox, based on the divergence of outcomes when PAP is measured in different ways;
    - a theoretically based approach to the selection of multiple performance measures.
- A methodological contribution by introducing a novel means of assessment of PAP, combining a longitudinal view of M&A history and a cross-sectional view of comparative efficiency (that itself accounts for

the longitudinal nature of the R&D pipeline and the multiple outputs of the R&D process).

- Three empirical contributions regarding:
    - scale factors for the R&D pharmaceutical pipeline;
    - the statistical distribution of M&A in the pharmaceutical sector;
    - differences in measurement of PAP exhibited when ROA and ROS are used as measures of financial efficiency.

To these can be added a confirmation of a further aspect of the Merger Paradox, namely that although M&A does not seem to be associated with higher performance to the acquiring firm, M&A value in total is associated with more efficient firms (possible reasons for this are elaborated upon later in the thesis).

2 Overview of Pharmaceutical Sector

2.1 Introduction

This chapter provides an overview of the research-based pharmaceutical sector, highlighting the unique characteristics of the R&D process and relating them to the research methodology.

The R&D process, which is common to all research-based firms in the sector due to the regulatory environment, is defined. The market structure of the sector that existed at the time of the analysis (2006 and the preceding decade) is then summarised. Finally, a review of the merger activity follows, including expert industry opinion on the motivations of the mergers and their consequences to the sector and the firms involved, as recorded in published reports accessed from the University databases.

2.2 R&D Processes

The pharmaceutical R&D process is unusually well-defined and recorded. This is because of the need to be confident of the safety of future compounds by undertaking tests on the human population. This has a dual advantage for this research in that well-defined R&D processes allow measurement of comparative efficiency and the metrics used in the measurement are publicly available.

Sweeny (2002: 4) provides a full summary of the pipeline:

– *Discovery/Basic Research: Synthesis and Extraction – the process of identifying new molecules with the potential to produce a desired change in a biological system; Biological Screening and Pharmacological Testing*

– studies to explore the pharmacological activity and therapeutic potential of compounds.

- *Preclinical Testing: Toxicology and Safety Testing – tests to determine the potential risk a compound poses to humans and the environment involve use of animals, tissue cultures or other test systems; Pharmaceutical Dosage Formulation and Stability – the process of turning an active compound into a form and strength suitable for human use.*

- *Regulatory Review: Application to regulatory authority to use compound in human testing. In the USA the compound is then called an Investigational New Drug (IND).*

- *Phase I Clinical Trials. Testing of a new compound in 20–80 healthy human volunteers to determine tolerance, pharmacological effects, and absorption, distribution, metabolism and excretion (ADME) patterns.*

- *Phase II Clinical Trials. Trials in 100–300 patients with the targeted condition to determine effectiveness in treating disease or medical condition and short-term risks.*

- *Phase III Clinical Trials. Trials on 1000–5000 patients to determine clinical benefit and incidence of adverse reactions.*

- *Process Development for Manufacturing and Quality Control. Engineering and manufacturing design activities to establish capacity to produce in large volumes and to ensure stability, uniformity and overall quality.*

- *Bioavailability Studies. Use of healthy volunteers to show that formulation used in trials is equivalent to product to be marketed.*

– *Regulatory Review: NDA. Application for approval to market a new drug. In the USA this is called a NDA.*

– *Phase IV. Post-marketing trials to identify undetected adverse effects and long-term morbidity and mortality profile.*

This process is universally called the ‘pipeline’ and compounds move through the pipeline in stages. Measurement of a drug in the pipeline can occur at the following stages: Preclinical, Phase 1, Phase II, Phase III and Awaiting Approval (i.e. the Phase III trial has been successively completed but Marketing Authorisation for the NDA has yet to be given).

In practice the pipeline resembles a funnel, with many compounds entering the start and fewer emerging because the remainder fail to clear the hurdles of clinical trials. The management of the pipeline is a ‘race against time’. The patents on which the compound are originally based generally have a 30 year life, after which any company can produce the drugs on which the patent is based, in other words it becomes ‘generic’ in the lexicon of the industry. The longer a compound stays in the pipeline the shorter the exclusive manufacturing and marketing period; this leads to a considerable loss of income.

These time factors can lead to variations in approaches to management of clinical trials. A trial is focused on the use of a compound for a particular ‘indication’: treatment of a condition. Some companies choose to proceed with trials for as many indications as possible in the hope of gaining multiple marketing approvals early in the patent lifetime. However, this is also an expensive strategy because clinical trials are expensive; an alternative approach is to proceed with trials for major indications only.

The timing and technology of the clinical trial part of the pipeline has tended to remain relatively static, with the increase in terms of the reporting requirements being offset by advances in ICT. However the preclinical stages of the pipeline have benefited from major technological changes on two fronts:

– product technology, moving from traditional 'small molecule' chemical compounds to biotechnology, where the compounds are large molecules, derived from biological processes;

– process technology, which has allowed increased productivity in the screening of potential drug candidates prior to clinical trials.

The latter change has implications, discussed later, for the relevance of examining R&D inputs to the process in the low productivity era.

2.3 Market Structure and Acquisition Activity

Two industry surveys, Sykes (1999) published near the start of the period of examination of M&A activity within this thesis and Hamilton (2005) published near the end, summarise the main issues facing the industry in this period.

Sykes (1999) specifically considers merger waves in the industry, correctly identifying the start of the third wave which is the focus of this study. M&A activity frequently follows waves as noted by Schoenberg & Reeves (1999) who proposed five factors that may affect acquisition activity: industry profitability, industry growth, industry concentration, capital intensity and industry deregulation; such factors have been observed in the pharmaceutical sector, as discussed below. The first M&A wave occurred in 1988–89 and led to the consolidation of a number of middling companies into top-tier firms. The second M&A wave focused on 'mergers of equals' or horizontal mergers intended to reduce fixed costs and increase funds available for R&D. Three

drivers of M&A activity were apparent: improved R&D, improved sales and marketing cost reduction, and the desire to preserve independence. Companies were also identified as having different views on M&A, classified as merger-bent, merger-averse and merger-resistant, the last group preferring co-licensing deals to full-blown acquisition. As Sykes (1999) was going to press, the third wave commenced, with mergers involving Astra and Zeneca, Sanofi, and Aventis. Hamilton's (2005) study was written at the end of this merger wave that left the industry in a challenged state: *"the pharmaceutical industry continues to experience problems in all aspects of its business"*. R&D productivity had declined and some major drugs had been withdrawn from the market following safety concerns. At that time, the major opportunities were seen to be the emerging markets of China and India, and growing ageing and obese populations across the globe. The importance of linking the R&D strategy to commercial priorities was also emphasised, rather than focusing on exploiting new development technologies as had occurred previously.

2.4 Key Metrics

The performance of the pharmaceutical industry is measured by financial metrics similar to those used in other sectors; however, there is one particular metric that is given universal prominence in the sector, namely R&D expenditure as a proportion of revenue. For example Pharmaceutical Research and Manufacturers of America (2010) cites the statistic on its opening 'Key Facts' page, and the synopsis of the sector provided by the Association of the British Pharmaceutical Industry (2010) remarks: *"Research and development lies at the heart of the pharmaceutical industry. It invests 30 per cent of its sales in research…"* and then goes on to tabulate R&D as a proportion of sales over time for the sector and to compare the statistic between sectors.

At the firm level, the metric R&D as a percentage of sales is frequently used to rank companies by their long-term potential, on the presumption that higher R&D expenditure leads to greater prospects of future success at the preclinical stage.

3 Literature Review

3.1 Introduction

The literature review for this research encompasses:

– the PAP literature from 1968 onwards, including DEA-related literature;

– the RBV, which is the theoretical basis for the selection of performance measures;

– multidimensional measurement, especially as regards the measurement of intangibles;

– the application of the RBV in the pharmaceutical sector;

– the small subset of the large DEA literature that considers M&A, R&D or the pharmaceutical sector.

On analysing the literature it becomes apparent that many topics themselves are multidisciplinary. M&A in general and PAP in particular have been considered differently by different academic disciplines; performance management itself is multidisciplinary, as made clear by an extensive literature review in Neely et al. (1995). Given this, the literature review concludes with a synthesis of the various strands of literature as they relate to this thesis.

3.2 PAP

3.2.1 History

The academic literature on PAP has been accumulating for the past four decades. Weston & Mansinghka (1971) were one of the first to publish on the performance of conglomerates and were able to cite only three prior papers.

This paper and the references set the tone for the subsequent decades. The paper found that in a sample of 63 firms, active acquirers had lower profitability than a random sample. Of the prior papers, Reid (1968) found active acquirers scored higher on criteria related to managers' interests than owners' interests. Smith & Schreiner (1969) found that investment companies were better at portfolio management than corporate acquirers. Lorie & Halpern (1970) examined if 'deception of investors' in the acquired firm took place but found the concerns to be unfounded with above-index returns to shareholders of the acquired firm. Therefore from very early on in the M&A literature the issues of multiple stakeholders and dubious PAP, at least for the acquiring firm as distinct from the acquired, were fully recognised.

3.2.2 Meta-Analyses

It is now recognised that PAP is an intellectual construct subject to a variety of interpretations, and for the past decade there has been an emerging sense of the need for integration of the literature seeking to unite at least some of the several theoretical perspectives. Larsson & Finkelstein (1999) seek to do this by using a structural equation model to assess how synergy realisation is affected by combination potential, organisation integration and employee resistance. Nonetheless they recognise that the synergy realisation measure is less objective than financial or accounting measures. This search for an integrative approach has also encompassed performance measures specifically: Zollo & Meier (2008) examined some but not all aspects of this construct (the 'Performs for whom?' question was not posed) when they undertook a meta-analysis of 87 academic articles on M&A. These papers have been subject to further analysis as discussed later. This meta-analysis revealed three broad academic disciplines: strategic management, corporate finance and organizational behaviour. The 87 studies in the meta-analysis

used 12 different types of performance measures. The largest group (41%) of the total used a short-term window financial event-study approach, a method that typically relies on stock market measures, as do the long-term window studies (18%) that are finding increasing application in finance journals. The next most frequent type of measure is the accounting measure (29%), which is found in the strategic management and organizational behaviour journals, whose analysis term is a matter of choice but comprises one or more years. Other approaches attempt a more general assessment of acquisition performance, including subjective surveys and panels (14%); none of the remaining approaches total more than 7% of the total. Three broad categories of measures are therefore observed: finance (short- or long-term window, 59%), accounting (variable term, 29%) and subjective surveys (14%).

Zollo & Meier (2008) add further dimensions to their meta-analysis; firstly they consider the time dimension by using a two-way taxonomy of short and long term, acknowledging that acquisitions may be a response to immediate incentives but whose long-term effect is uncertain. In a second dimension, Zollo & Meier (2008) also propose a three-level taxonomy: firstly, tasks involved in the acquisition, secondly the acquisition itself and thirdly the longer-term performance of the acquiring firm. Considering this three-by-two classification of measures, Zollo & Meier (2008) then provide plausible scenarios where the measures of performance may diverge: they establish that different measures may measure different aspects of the PAP construct and can be expected to diverge under certain circumstances.

Many of the 87 papers considered multiple measures and 13 examined accounting performance and one other parameter, as this thesis does; however, in no case were both accounting and operational efficiency measures for intangibles considered, which is the subject of this thesis. This

preference for multiple measures in the literature is an indirect endorsement of the benefits of multidimensional performance measurement and later in this review specific literature that confirms the benefit is identified.

Table 3.1 provides a chronological analysis of the Zollo & Meier (2008) papers (this analysis was not presented in the original paper) and displays the types of measures used, with some papers considering up to three measures.

Table 3.1 Choice of Measures in Acquisition Meta-Analysis 1983–2006

Author	*Year*	*First Measure*	*Second Measure*	*Third Measure*
Eckbo	1983	S		
Jensen and Ruback	1983	S		
Wansley et al.	1983	S		
Buono et al.	1985	I	O	
Kusewitt	1985	A	L	
Chatterjee	1986	A	S	
Montgomery and Wilson	1986	V		
Lubatkin	1987	L	S	
Ravenscraft and Scherer	1987	A		
Singh and Montgomery	1987	L		
Travlos	1987	S		
Amit and Livnat	1988	A		
Capon et al.	1988	A		
Morck et al.	1988	A		
Shelton	1988	S		
Walsh	1988	E		
Fowler and Schmidt	1989	A	L	

Walsh	1989	E		
Datta and Grant	1990	O		
Hunt	1990	I	O	
Lahey and Conn	1990	L		
Seth	1990b	S		
Chatterjee	1991	S		
Datta	1991	I	O	
Franks et al.	1991	S		
Harris and Ravenscraft	1991	S		
Harrison et al.	1991	A		
Hitt et al.	1991	V		
Schweiger and Denisi	1991	E		
Slusky and Caves	1991	S		
Chatterjee	1992	L		
Chatterjee et al.	1992	S		
Shanley and Correa	1992	I	O	
Travlos and Waegelein	1992	S		
Agrawal et al.	1992	L		
Cannella and Hambrick	1993	O	A	
Hambrick and Cannella	1993	E		
Hoskisson et al.	1993	A	L	
Bruton et al.	1994	O		
Clark and Ofek	1994	A	L	
Markides and Ittner	1994	S		
Pennings et al.	1994	V		
Berger and Ofek	1995	S		
Brush	1996	A	M	

Chang	1996	A		
Hitt et al.	1996	A	V	
Vermeulen and Barkema	1996	V		
Weber	1996	I	A	
Anand and Singh	1997	A		
Barber and Lyon	1997	L	S	
Covin et al.	1997	E		
Hayward and Hambrick	1997	S		
Holl and Kyriazis	1997	S		
Krishnan et al.	1997	A		
Kroll et al.	1997	S		
Loughran and Vijh	1997	L		
Lubatkin et al.	1997	L	S	
Ramaswamy	1997	A		
Hitt et al.	1998	A	V	
Morosini et al.	1998	A		
Bresman et al.	1999	I	K	
Capron	1999	I	O	
Haleblian and Finkelstein	1999	S		
Larsson and Finkelstein	1999	I	O	
Thakor	1999	Y		
Palich et al.	2000	A	L	S
Walker	2000	S		
Ahuja and Katila	2001	N		
Bergh	2001	V		
Krug and Hegarty	2001	E		
Beckman and Haunschild	2002	S		

Capron and Pistre	2002	S		
Hayward	2002	O	S	
Heron and Lie	2002	A		
Seth et al.	2002	S		
Carow et al.	2004	L	S	
DeLong and DeYoung	2004	A	S	
Feea and Thomas	2004	A	S	
Moeller et al.	2004	S		
Pangarkar	2004	S		
Zollo and Singh	2004	A		
Harrison et al.	2005	L	S	
Shahrur	2005	S		
Zollo and Reuer	2005	A	L	
Homburg and Bucerius	2006	O		
Puranam et al.	2006	O		
Kapoor and Lim	2007	N		

Key to columns 3, 4 and 5:

I = Integration process performance; O = Overall acquisition performance; E = Employee retention; A = Accounting performance; L = Long-term financial performance; S = Short-term financial performance; V = Acquisition survival; N = Innovation performance; K = Knowledge transfer; Y = Systems conversion; M = Variation in market share.

Table 3.1 shows some trends in scholarship in the examination of PAP. For the first five years, there are 2.2 papers per year and an average of 1.36 measures per paper. In the next five years output increased to 4.8 papers per

year but with an average of 1.2 measures per paper (i.e. adopting a one-dimensional view of merger performance). In the past ten years we see a steady 1.4 measures per paper and an average output of 3.2 papers per year. Over time therefore the intensity of research has slightly declined but there has been a greater effort to obtain a multiparameter view.

Another recent meta-analysis of performance measures in PAP is Papadakis & Thanos (2010), which extended work by Schoenberg (2006) and generally confirmed its results, showing merger success rates below 50%. Schoenberg (2006) found no correlation between accounting measures, financial returns and managers' subjective assessments, whereas Papadakis & Thanos (2010) found a correlation between accounting-based measures and managers' subjective assessments. However, the possibility that the latter (received in a single semi-structured interview) may have been influenced by the former was not discussed in the paper. That paper considers case studies explicitly, although these can be considered a variation on a survey of subjective assessments, with a sample size of one, with the justification that each merger is so unique that any attempt at categorisation of findings into measures would risk distortion.

Another recent meta-analysis by King et al. (2004) considered whether the acquisition was by a conglomerate, whether it was related by sector, method of payment and prior experience; it also established the relative popularity of accounting measures: 29 studies using ROA, 14 using Return on Equity (ROE) and 9 using ROS. This confirms the preference of ROA to ROE as a measure of capital efficiency because it does not depend upon the capital structure of the firm. The relative merits of ROA and ROS as a measure of financial efficiency are considered later.

Having established that there are four approaches to the measurement of PAP (or three, if a case study is regarded as a subjective survey with a sample size of one) and there is little or no correlation between them, it only becomes possible to choose between them by considering the purpose for which the measures are being applied. For this thesis, one objective is to examine the Merger Paradox, namely why M&A continue to be transacted when historically their results seem to be disappointing overall. The major references and the strengths and weakness of each method are summarised below so that judgement can be subsequently made on the most appropriate method for examination of the Merger Paradox.

3.2.3 Summary of Main Approaches

The theoretical foundation for financial performance is provided by Fama et al.'s (1969) definition of the event study and Fama's (1970) definition of the efficient capital market hypothesis. Forty years later the validity of the hypothesis is still much discussed, however it has since become the cornerstone of modern corporate finance theory. The 'strong' version of the hypothesis states that prices reflect all information on a company, whether the information is public or not. If the hypothesis is true, then the 'abnormal gains' of share prices following a merger announcement can be considered the best possible judgment on its future performance, as expressed as the best estimation of the value created by that merger. The advantage of the method is that data are publicly available and the sample sizes are large. Several studies have suggested that mergers 'create value', for example Jensen & Ruback (1983), Seth (1990b) and Singh & Montgomery (1987). However, other studies indicate that it is the shareholders of the acquired companies who have the most consistent gains, for example Chatterjee (1986), Datta (1991), Datta et al. (1992), Seth (1990a), Singh &

Montgomery (1987) and Sirower (1997). There are however two difficulties with the approach. The first is that the efficient capital markets hypothesis is still a hypothesis, especially in its strong form (the weak form states only that prices reflect public information). The second is more fundamental, namely whether a gain in wealth by the shareholders by the acquired firm (the only consistent observation) represents a genuine creation of economic value or is simply a case of overpayment, which will subsequently burden the merged firm. This raises the multistakeholder question of 'performance for whom?'

Regarding accounting measures, these also use publicly available data and large sample sizes are available, and it is possible to monitor performance over an extended period of time. The use of accounting measures does, however, have its critics, for example it ignores risks, it treats the cost of equity and debt finance differently and the measures are historical but not forward looking, as noted by Montgomery & Wilson (1986). Notwithstanding these shortcomings, accounting measures are used by managers for decision making on the future of the firm, including decisions on acquisitions, and by financial analysts to inform forecasts that affect share prices.

The use of surveys, whether of expert panels or managers, faces the generic strengths and weaknesses of this approach. Perhaps the greatest strength is that it is possible to account in the survey for the original motives of the merger against which to assess success or failure, and Angwin (2007) stresses the importance of motive in explanation of merger decision making. Set against this is the potential for subjectivity and selectivity in survey design and tactical responses to survey questions. The case study reflects an extreme example of a survey, able to take account of the unique nuances of each acquisition and its motives, however, it is very susceptible to subjectivity and difficulties in

generalisation. Examples of this research approach include Haspeslagh & Jemison (1991), Marks & Mirvis (1998) and Shanley & Correa (1992).

From the preceding discussion on the strengths and weaknesses of measurement methods and the earlier discussion on meta-analyses of studies in assessing PAP and the Merger Paradox, two important themes emerge. The first is to understand what those who initiated the merger expected from it and the second is the need to understand what happened over a significant period of time.

3.2.4 Motive and Synergy

Brouthers et al. (1998) established that the top three motives for M&A were to 'pursue market power', 'increase profitability' and 'marketing economies of scale' in that order. These three motives have guided the design of this research. Firstly, the reference to 'profitability' suggests that accounting measures are paramount in managers' minds, and analysis of accounting performance has been used to illuminate further the Merger Paradox (significantly 'profitability' rather than 'shareholder value' was mentioned in the top three motives, possibly because the latter is seen as being influenced by exogenous factors); in this thesis, profitability has been measured by both ROA and ROS. Secondly, regarding 'market power' and 'marketing', in the pharmaceutical sector this is tightly coupled with the R&D process because authorisation for particular markets or applications of compounds can only be obtained through successful completion of the clinical trial process. Therefore in this thesis, efficiency of the R&D process has been selected for examination of the PAP.

Furthermore 'market power' is synonymous with 'collusive synergy', one of three types of synergy (the other two being operational synergy and financial

synergy) and the RBV provides a theoretical base for the examination of synergies. Overall, synergies should be positive for an acquisition to proceed and Penrose (1959) (the earliest RBV-related paper) noted the initial presumption should be that synergies are negative unless there is a special reason otherwise. However, Rumelt (1984) notes the presence of synergies where companies diversify into areas where there are common factors. However, the potential for synergy may not always be realised, and Angwin & Vaara (2005) suggest there is an appreciation of the need to examine the degree of integration or connectivity with the firm.

Notwithstanding the multiple motives that are possible for a deal, Ambrosini et al. (2010) have found that acquirers that opted for a single value creation strategy, for example consolidation of costs or leverage of resources across a larger firm, experience higher PAP than those which pursue multiple strategies. In the pharmaceutical sector this has been confirmed by Higgins & Rodriguez (2006) who noted positive financial returns to companies that sought to outsource R&D through the use of M&A to acquire technological resources.

3.2.5 Diversification Literature

The diversification literature considered synergies in more detail. Chatterjee (1986) concluded in the Abstract: "*collusive synergy is, on average, associated with the highest value. Further, the resources behind financial synergy tend to create more value than the resources behind operational synergy*".

This observation is highly pertinent to the comparison between the financial efficiency (ROA and ROS) scores, which include all three synergies, and the technical efficiency (DEA) scores, which consider operational synergies alone.

Examining the diversification literature more generally, there is a strong similarity with the acquisition literature. A lengthy period of research, mostly based on cross-sectional studies, has given rise to conflicting results that are now the subject of meta-analyses noting the evolution of the research. For example Martin & Sayrak (2003) note there was initially a view that there was a discount associated with diversification, there then followed a phase where it was accepted that a discount existed but that it could be accounted for by other factors, with the final conclusion that there may actually be a premium associated with diversification but there is a problem with 'noisy proxies' used to measure diversification, that is the principles for the measurement of diversification are being queried.

Some authors suggest that relatedness improves performance: Kitching (1967), Elgers & Clark (1980), Kusewitt (1985), Singh & Montgomery (1987), Shelton (1988) and Healy et al. (1997). However, as remarked previously, in some cases the 'gains' have included gains to target shareholders and this may simply reflect overpayment. Therefore there seems to be a consensus that some relatedness may be beneficial to the extraction of synergy, even though the earlier view that diversification lowered value is now being questioned.

Regarding cross-border diversification specifically, Seth et al. (2000) estimated total gains to be 7.6% of pre-acquisition value (i.e. including gains to target shareholders), which is comparable with the Bradley et al. (1988) figure for domestic acquisitions (i.e. there is no special advantage for cross-border acquisition) and indeed less than that observed in Eun et al. (1996), although this research did find positive total gains for cross-border deals.

3.3 RBV

3.3.1 Early Definition of the RBV

Although Penrose (1959) and Rumelt (1984) are now considered to be part of the RBV literature, the modern variant of the RBV was launched by Wernerfelt (1984) who defined resources as any factor that was a strength or weakness of a firm. Some examples are given of attractive resources: Machine Capacity, Customer Loyalty, Production Experience and Technological Leads. These particular examples have the characteristics of assets and refer to both tangible and intangible assets; these parameters are potentially measurable.

Rumelt (1984) highlighted the need to consider 'isolating mechanisms' that hinder the imitation of resources and cites ten factors: Causal ambiguity, Specialised assets, Switching and search costs, Consumer and producer learning, Team embodied skills, Unique resources, Special information, Patents and trademarks, Reputation and image, and Legal restrictions on entry.

Isolating mechanisms complicate the task of the external evaluator: it is not sufficient to identify and measure a resource, or even to compare this measurement with that of another organisation (e.g. as occurs in competitor benchmarking), but one has to anticipate the potential for imitation.

The RBV was interpreted for practitioners by Prahalad and Hamel (1990) who proposed the concept of a 'core competency': defined as an entity that provides access to a wide variety of markets, and `makes a significant contribution to perceived customer benefits and is difficult for a competitor to imitate.

3.3.2 Qualification of Resources

In the mature phase of the RBV, the perspective moved beyond proposing candidates for resources to establishing that resources had to have particular qualities if they were deliver competitive advantage. Barney (1991) proposed four essential characteristics of resources: Valuable to the company, Rare, Imperfectly imitable and Non-substitutable (VRIN). These qualities can be used to screen potential candidates for their relevance to performance measurement.

Peteraf (1993) provided an alternative set of qualifying factors for resources when she cited the 'four cornerstones' to the RBV:

- the heterogeneity of firms, noting that unique resources allow firms to earn economic rent as opposed to break even;
- ex-post limits to competition that limit competition for rents once resources have been acquired;
- imperfect mobility of resources, in terms of their trade;
- ex-ante limits to competition, namely that there is limited competition for resources prior to their acquisition, so as to avoid the potential profits from being competed away by bidding for the resource.

These economically orientated factors are especially relevant to the selection of measures because they translate the qualitative concept of competitive advantage into a quantitative concept of economic rents. This is also highly relevant to the pharmaceutical industry that can be viewed as earning an economic rent on intellectual property, namely patented and approved compounds.

3.3.3 Dynamic RBV

In the evolution of the RBV it was becoming recognised that having a stock of resources may be necessary for competitive advantage but it was not sufficient because resources needed to be deployed: there must be a corresponding flow, or use, of the resources for some purpose, as Dierickx and Cool (1989) noted. Amit and Schoemaker (1993) provided a linkage between the emerging RBV and the earlier Industrial Organisation perspective framework, and introduced the concepts of 'capabilities' that were defined as the capacity to deploy resources.

The introduction of the concepts of stocks and flows into the RBV is of direct relevance to performance measurement. One can measure both a stock and a flow but care must be taken in mixing the two when building a model to evaluate efficiency.

Teece et al. (1997) highlighted the role of routines and skills in the firm in regards to the effective deployment of resources, although these factors may pose a particular challenge to measurement, especially for an external evaluator.

3.3.4 Critiques of the RBV

There have been a number of critiques of the RBV, for example Foss (1997) and Williamson (1999), and also a dialogue between Priem & Butler (2001a, b) and Barney (2001), regarding the Barney (1991) paper. The criticisms include: the RBV is tautological (instead of explaining how resources lead to competitive advantage, it assumes the point) and this makes it difficult to verify, and the RBV does not link resources to value nor does it consider the causality of how resources lead to competitive advantage.

This thesis addresses this weakness directly. Beginning with the observation that for a company to be in the top 50 by turnover, it must *de facto* be competitive, it then derives the resources that contribute to this success and uses this as a basis for a performance measurement framework (PMF).

A reassessment of the RBV was also provided by Foss & Knudsen (2003) that considered the papers of Barney (1991) and Peteraf (1993) as the core foundations of the RBV, providing the strategic management and economic bases respectively. However, these two bases were not entirely consistent, furthermore there were only two necessary conditions for sustainable competitive advantage: uncertainty and immobility. Peteraf & Barney (2003) replied, stating in the abstract that: *"Unless Resource Based Theory is understood as a resource-level and efficiency orientated tool its contribution cannot be understood fully"* and suggest a narrower definition of competitive advantage that focused on intra-industry advantage. This reply is entirely in sympathy with the approach taken in this paper, where the focus is on resource-level measurement to assist in the quantification of performance relative to competition within a single industry.

In conclusion this research accepts the limits to RBV proposed by its founders: its focus on intra-industry efficiency analysis. In addition, this research seeks to develop a new perspective for RBV: establishing the causality of resource possession and competitive advantage. This research is also supported by the finding in Crook et al. (2008) of a positive association of measures and performance when those measures are selected by the criteria laid out in the RBV.

More recently, Kraaijenbrink et al. 2010 identified eight criticisms of which three were considered to merit further attention; these three were two basic

concepts that resource and value required a more detailed definition and there was a narrow view taken of competitive advantage.

3.3.5 Recent Retrospective on the RBV

As noted previously, the *Journal of Management* in September 2011 dedicated a special issue to reviewing resource based theory to commemorate its previous special issue that introduced the theory 20 years earlier; in the most recent special issue, Barney et al. (2011) considered it had reached maturity and was capable of further development to satisfy its critics.

The topic of measurement was also specifically addressed by Molloy et al. (2011) who examined empirical tests of the RBV and found a lack of theoretical justification for the selection of the measures chosen, noting in the opening paragraph:

> *Resource-based theory (RBT) indicates that intangible resources, or intangibles, underlie value creation (Penrose, 1959). A paradox of RBT is that these very resources that underlie value creation elude examination (Barney, 2001). Indeed, since intangibles are immaterial, scholars cannot easily isolate, observe, or measure them (Lev, 2007). How then are scholars to advance RBT through empirical research that examines intangibles?*

Molloy et al. (2011) propose a multidisciplinary assessment process that draws on the strengths of both economics and psychology. This thesis adopts an alternative approach of identifying factors relevant to competitive advantage that are accessible to an external evaluator.

3.3.6 Summary of Key Issues for Performance Measurement

Later in this thesis a set of Design Principles and a Construction Process that have been derived from the RBV is described, and as a prelude the contributions made by the main authors of the RBV to the measurement of resources is summarised in Table 3.2 following their original definition.

Table 3.2 Contributions of the Major RBV Authors to Performance Measurement

Phase	*Author*	*Contribution to Measurement*
Early	Wernerfelt (1984)	a) Resources are the differentiating factors
	Rumelt (1984)	b) Isolating mechanisms with examples
Consolidation	Barney (1991)	c) VRIN tests: Valuable Rare Imperfectly imitable Non-substitutable
	Peteraf (1993)	d) Link to value and rent generation
Dynamic	Dierickx and Cool (1989)	e) Importance of deployment as opposed to possession (prelude to process)
	Amit & Schoemaker (1993)	f) Capabilities (recognition of intangible aspect to resources)
	Teece et al. (1997)	g) Paths, Positions and Processes
Reassessment	Peteraf & Barney (2003)	h) Efficiency perspective

We now discuss the topic of performance measurement in more detail, beginning with consideration of the benefits of additional multiple measures.

3.4 PMFs

3.4.1 Theoretical Benefit of Additional Information

The benefits of multiple parameter measurement for business management are considered in the next section but first we summarise the theoretical evidence. Blackwell (1951) reports that multiparameter measurement could be no worse than single-parameter measurement (although this presumed additional information was costless) but there was no view on the scale of the additional benefit. Further support comes from Holmström (1979) who considered the role of asymmetric information in a principal–agent relationship, and found that any additional information, no matter how noisy, would have a positive value. In the case of a PMF, the user of the PMF could be considered an agent, and this finding suggests that any additional information could be beneficial to either an internal or external evaluator.

This establishes a mathematical basis for the assertion that additional costless information cannot be detrimental, although it must be borne in mind that there may be a cost associated with the interpretation of the additional information and in comparative efficiency modelling additional parameters in a model can be detrimental, for example by creating the need for a larger sample.

An analogue can also be drawn with the 'mosaic theory' defined by Pozen (2005: 630):

> *… a basic precept of intelligence gathering: Disparate items of information, though individually of limited or no utility to their possessor, can take on added significance when combined*

> *with other items of information. Combining the items illuminates their interrelationships and breeds analytic synergies, so that the resulting mosaic of information is worth more than the sum of its parts.*

Having established the theoretical benefit of additional information, the next issue is how to relate this to the assessment of business performance.

3.4.2 Benefits of PMFs

PMFs are intended to provide a balanced view of the performance of the firm. In this regard there have been positive findings on the usefulness of non-financial information to supplement conventional financial measures, for example Davis & Albright (2004) in a cross-sectional study of bank branches found better financial performance for branches implementing the Balanced Scorecard than others. Ittner & Larcker (2003) showed that a higher ROA was associated with organisations that used PMFs than was the case with those that did not.

Ittner et al. (2003) examined financial services firms and stated (in the Abstract):

> *…we find consistent evidence that firms making more extensive use of a broad set of financial and (particularly) non-financial measures than firms with similar strategies or value drivers have a higher measurement system satisfaction and stock market returns*.

Banker et al. (2000) showed that including customer satisfaction as part of an incentive plan increased customer satisfaction and this led to increased revenues in a hotel chain. This finding suggests that managers can use

measures to influence behaviour and act to improve performance, thus establishing a causal link between PMFs and improved financial performance, as well as an association.

PMFs offer the opportunity to include measures indicating likely future financial performance as well as retrospective financial performance. Ittner & Larcker (1998) reported a statically significant positive relation between customer satisfaction measures and future accounting performance. Furthermore they found evidence that customer satisfaction is a leading measure for financial performance, even when measured from outside the firm. There is further evidence that the benefit of leading measures is not confined to customer-related metrics. Rucci et al. (1998) found that an improvement in employee attitude translated into better customer satisfaction and revenue growth in a retail company, suggesting that the casual link extended from employee to customer to a financial measure.

3.4.3 The Balanced Scorecard and its Evolution

The Balanced Scorecard is a widely recognised form of multidimensional performance measurement proposed by Kaplan and Norton (1992, 1996) who advocated its use as a strategic management system. The Balanced Scorecard is developed by an organisation's management to agree the organisation's goals, to measure and communicate progress, enrich the business plan and feedback performance to adapt strategy. The key features of the Balanced Scorecard include the need for a balanced set of measures as opposed to a single measure (four perspectives are suggested to recognise the multiple stakeholders: finance, operations, customer and employee learning) and for leading measures as well as lagging measures to be included. The relationships between measures should be expressed as a

performance model and the Scorecard should act as a second feedback loop, typically operating at an annual or quarterly period, to supplement the weekly or monthly operational feedback loops. Notwithstanding the remarks on feedback, the Scorecard is intended as a communication tool, intended to assist strategy deployment, not a control tool. Nonetheless some companies cascade the Scorecard down the company, assigning more detailed Scorecards to processes and even to individuals.

The Balanced Scorecard concept is not entirely original; according to Malo (1995), French companies have been using the tableau de bord since 1932. Bourguignon et al. (2004) suggest however that there are differences between the two that reflect cultural differences between French and American society; certainly the Balanced Scorecard is shown to have more theoretical structure, in terms of categories and causal modelling, however this might also reflect that it is the later development, rather than any of the cultural differences suggested. It is perhaps significant that two other reports of the Balanced Scorecard implementation in northern and southern continental Europe, Braam & Nijssen (2004) and Papalexandris et al. (2005), respectively, did not refer to specific national cultures.

The Balanced Scorecard has evolved over time with attempts to define three phases of evolution. For example Speckbacher et al. (2003) see the first phase comprising a multidimensional framework, combining financial and non-financial measures, a second describes strategy using cause and effect relationships, and a third that implements strategy by defining objectives, plans, outcomes and incentives; this conforms quite closely to the original concepts. Lawrie & Cobbold (2004) consider the first phase as comprising the original Kaplan/Norton concepts, for example ‘balance’ and use of leading measures. The second phase is the selection of measures to be applied to

specific strategic objectives and the use of visual documentation of major causal relationships. The final stage involves the use of a 'destination statement' for the company and the development of an 'outcome' perspective to replace 'financial' and 'customer' perspectives, and an 'activity' perspective to replace 'learning' and 'process' perspectives. The last evolutions are intended to make the Scorecard more relevant to the public sector. Most of these are less concerned with the selection of measures than with their presentation and their link to change management.

Finally, in the original Scorecard there is no measure of risk and this was remarked upon by Kaplan (2010) in an interview:

> *If I had to say there was one thing missing that has been revealed in the last few years, it's that there's nothing about risk assessment and risk management.*

Table 3.3 summarises the main lessons for performance management that arise from the Balanced Scorecard.

Table 3.3 Summary of Balanced Scorecard Concepts

Kaplan & Norton (1992)	i) Need for non-financial measures
Kaplan & Norton (1992)	ii) Use of leading measures
Kaplan & Norton (1996)	iii) Causal links between measures
Kaplan (interview 2010)	iv) Need to measure risk

The previous sources considered the benefits of particular measures with an emphasis on establishing that certain non-financial measures were leading measures of performance, however, this is not the only consideration. There is

also the question of populating the PMFs with measures, which is considered below.

3.4.4 Choice of Measures

Malina & Selto (2004) consider the choice of measures from the stance of management control theory and identify eight attributes, the first five being 'design' attributes and the remainder 'use' attributes. Specifically, measures should be: 1) Diverse and complementary, 2) Objective and accurate, 3) Informative, 4) More beneficial than costly, 5) Causally related, 6) Strategic Communication devices, 7) Incentives for improvement and 8) Supportive of improved decisions.

However there still remains the question of which measures should be chosen. Abernethy et al. (2005) proposed the building of causal performance maps to identify Key Success Factors but this is clearly difficult for an external evaluator to undertake. However, the concept of Key Success Factors seems to be closely related to Critical Success Factors that were first defined by Rockart (1979: 85) as: *"the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organization",* which could be assessed by an external evaluator.

Methods for the systematic design of PMFs have been developed, even to the point of the publication of a workbook for the application of a systematic process, as described by Neely (2000). Neely at al. (2002) have developed this further into the 'Performance Prism'. However, in these cases there was a presumption that the designers of the PMF were working with the active co-operation of the firm's management to produce a PMF for their use; we now consider the case of PMFs designed for the use of external evaluators.

3.4.5 External Evaluation of Intellectual Capital

PMFs are also of use to external evaluators, especially for benchmarking purposes. Lebas & Euske (2002: 73) noted that the needs of the internal and external evaluators differ:

> *Performance does not have the same meaning if the evaluator is inside or outside the organisation. The operations management remain a black box for the outsider while the insider operationalizes performance in cooperation with other actors*.

Where the primary audience for the non-financial measures is external, then the design of a PMF is often considered through the lens of the external reporting of a firm's Intellectual Capital (IC). Marr et al. (2004) first consider why companies should measure IC and conclude that there is a need for more testing of the benefits, especially through longitudinal studies as opposed to cross-sectional studies (echoing similar trends in M&A research where long-term performance is an issue). Marr et al. (2004) then consider how to construct a PMF for IC, noting a sequence of definition in IC over time from Hall (1992) where IC was considered to comprise assets and skills, through Edvinsson & Sullivan (1996), Brooking (1996), Sveiby (1997), Roos et al. (1997), Stewart (1997), Edvinsson & Malone (1997), Bontis et al. (1999), Lev (2001) until Marr & Schiuma (2001) arrive at a view whereby IC is seen as comprising knowledge-based assets located either in relationships or infrastructure. This cannot be considered an entirely linear sequence of thinking (e.g. Brooking and Stewart seek focus on the financial aspects of IC).

The later papers have also sought to produce systematic reporting frameworks, including the IC Index (Roos et al., 1997), the IC Audit Model (Brooking, 1996) and the Intangible Asset Model (Sveiby, 1997).

However the most commercialised framework is the Skandia Model, described by Edvinsson & Malone (1997), which divides Market Value into Financial Capital and IC. IC is divided into Human Capital and Structural Capital, which itself comprises Customer Capital and Organisational Capital, with subsequent subdivisions of the latter. These categories can be used to group resources and act as a basis for measurement, although Roos et al. (1997) propose the aggregation of measurement into a single IC Index.

The previous literature is not sector-specific, although the use of IC frameworks in research organisations was described by Leitner & Warden (2004) and indeed Leitner et al. (2005) experimented with the use of DEA to measure the productivity of Austrian universities, concluding it was a useful consulting tool. However, although IC frameworks provide a basis for classification of measures, they do not assist in the identification of performance measures for the external evaluation of companies in a specific sector for a specific purpose, as required by this research.

There is a major practitioner initiative led by the Enhanced Business Reporting Consortium that has links to the accounting profession. Enhanced Business Reporting Consortium (2006) is a framework for non-financial reporting that has been influenced by the language of the RBV, for example it suggests reporting upon ‘Competencies and Resources’. The next step is to produce industry-specific Key Performance Indicators (KPIs), although this has not yet happened. This work is being undertaken in conjunction with the World Intellectual Capital Initiative.

Extended business reporting is already common in regulated industries where it is used to support comparative efficiency assessments; in the UK, the Water Services Regulation Authority collects extensive non-financial information annually, in the form of the June returns, whose purpose is summarised in OFWAT (2005); some of this information includes intangible parameters, such as quality of service. An example of quarterly reporting of a PMF in the Balanced Scorecard format is the National Rail Monitor, published by the Office of Rail Regulation; the design of the PMF is described in ORR (2004). Also in the UK, the application of extended business reporting principles to the public sector has been supported by the National Audit Office by the issuing of the 'FABRIC' guidelines (Focused, Appropriate, Balanced, Robust, Integrative, Cost Effective), as summarised in H.M. Treasury et al. (2001), and commissioning independent research (Accenture, 2009) on the design of PMFs that comprise both financial and non-financial measures.

Separately efforts have been made to link the non-financial measurement of IC and financial measurement. Financially, IC can be considered the Market Value Added of the company: the difference between the Market Value and net book value of the tangible assets. Stewart (1997) has suggested a parameter termed Economic Value Added as a proxy for this, to be used as a managerial incentive, although Kramer & Pushner (1997) have questioned the evidence supporting this. Economic Value Added was intended to make adjustments to conventional accounting data to rectify some of its limitations of use as a measure, and there is no doubt that these are especially significant as regards accounting for intangibles in the context of mergers, and Canibano et al. (2000) provide a literature review on accounting for intangibles. The main issue is that internally generated intangible assets are not recognised as such, although externally acquired intangibles can be recognised as assets.

Thus an acquisition can lead to the recognition of assets in parameters such as ROA and result in this being a biased indicator for acquisition performance. Boekestein (2009) has already noted the impact of M&A on the valuation of accounting value of assets in the pharmaceutical industry and this thesis explores it further.

To summarise, although various IC initiatives, whether academic or practitioner, may use the language and the concepts of the RBV to assist in their goal for standardised external reporting, they still leave open how the non-financial measures would be selected for a particular sector, for example the World Class Competitive Intelligence forum has yet to produce a draft set of KPIs for the pharmaceutical sector. The contribution of this thesis is to go beyond the use of RBV terminology and to propose a systematic approach to the design of a PMF that can be applied to any sector and then to apply it to the pharmaceutical sector specifically.

First however, we consider how the RBV has been used in the pharmaceutical sector specifically and the lesson this provides for the design of a PMF that is suitable for a comparative efficiency assessment.

3.5 Use of the RBV to Measure Performance in Pharmaceuticals

Yeoh and Roth (1999) defined the relevant resources and capabilities for a pharmaceutical firm: 1) R&D expenditures, 2) Sales force expenditure, 3) Internal R&D efforts, 4) Therapeutic market focus, 5) Approval success and 6) Radical innovations. This confirms the criticality of the R&D process because all factors except sales force expenditure are contributory factors to a single type of output, namely approved compounds at progressive stages in the pipeline, and sales force expenditure itself is only useful when a compound has finally emerged from the pipeline with marketing approval.

DeCarolis & Deeds (1999) examined the effect of stocks and flows of organizational knowledge on firm performance. Table 3.4 shows the various measures that were identified as being relevant to examining the paper's hypotheses.

Table 3.4 Parameters and Metrics Cited in DeCarolis & Deeds (1999)

Parameter	*Metric*
Firm performance	Market value
Location	Munificence of location of corporate HQ, based on factor analysis
Alliances	Number of active alliances
R&D intensity	R&D expenditure as % total expenditure.
R&D pipeline contents	Number of products at each stage
Patents	Number of patents
Citation data	Number of citations by senior personnel

Using these metrics, data from 98 firms were collected and regression models were used to test six hypotheses. The outcome is shown in Table 3.5.

Regarding the 'supported or 'mixed' factors, 'location' refers to being based in a 'geographic cluster' of high performing pharmaceutical companies, as opposed to a national location, and is not relevant to this research. The remaining parameters that are found to be significant are patent citations (but not patents), the number of drugs in the pipeline and R&D intensity (i.e. expenditure). Patents themselves were not found to be linked to performance, possibly reflecting the variety of reasons for taking out a patent (including defensive reasons) and for not taking out a patent (e.g. confidentiality or

expense). However, citation analysis is not without its drawbacks. For example Meyer (2001: 166) notes:

> *First of all, one should be aware of the general limitations of patent citation data…citations establish only a mediated linkage…it is not possible to derive any insight as to the direction of potential knowledge flows*.

Table 3.5 Outcomes of Hypotheses Testing in DeCarolis & Deeds (1999)

Hypothesis	*Outcome*
Location affects performance	Supported
No. alliances affects performance	Not supported
R&D intensity affects performance	Mixed results
No. new drugs in pipeline affects performance	Supported
No. patents controlled affects performance	Not supported
No. citations affects performance	Supported

Furthermore, and most significantly, DeCarolis & Deeds (1999) simply summed the contents of the pipeline from Preclinical to Phase 3, which represents a significant distortion given the attrition rates between the successive stages of the pipeline, which means that compounds in the later stages have a higher value than compounds at an early stage in the pipeline.

DeCarolis (2003) also examined firm performance. The metrics used are shown in Table 3.6.

Table 3.6 Parameters and Metrics in DeCarolis (2003)

Parameter	*Metric*
Firm performance	Return on Assets Market-to-Book Value
Technical competence	A measure calculated as follows: the firm issues N patents in a given year and within two years M patents had cited these N patents and of these M citations, X were self-citations. The ratio of X/N is the measure of competence.
Imitability	A measure calculated as follows: the firm issues N patents in a given year and within two years M patents had cited these N patents and of these M citations Y were by other companies. The ratio of Y/N is the measure imitability.
Marketing competency	Advertising/Sales
Regulatory competency	Number of new drugs per year per firm

Regression models were used to ascertain if there was any link between the dependent variable, firm performance, and the four other dependent variables. The models were built with ROA and Market-to-Book Value. The results of the hypotheses testing are summarised in Table 3.7.

Table 3.7 Outcomes of Hypotheses from DeCarolis (2003)

Firm Performance	*Return on Assets*	*Market-to-Book Value*
Technical competency	Positive	Negative
Imitability	Negative	Negative
Marketing competency	Not supported	Positive
Regulatory competency	Positive	Positive

The surprising feature of the results is the difference between the results for technical competence, depending on the choice of dependent variables, with the negative correlation for Market-to-Book Value being counterintuitive. DeCarolis (2003) provided an explanation for this by suggesting that building on the firm's existing knowledge may be seen as developing future rigidities. However, an alternative explanation lies in the limitations of the self-citation analysis that is the basis for measurement of technical competence; it is also noteworthy that the strength of the pipeline or its efficiency was not used to assess technical competence.

In the following chapter the lessons learnt from these pharmaceutical-related papers are used to design a PMF to support the analysis of R&D efficiency. Prior to this however, we review the DEA literature with particular reference to acquisitions and R&D.

3.6 Relevant DEA Literature

Taveres (2002) identified 3,203 DEA publications in the period 1978 to 2002. Only five were concerned with M&A and none were concerned with R&D or the Balanced Scorecard. In the past therefore, it seems that neither topic was of major interest, however, more recently there have been additions to the literature as discussed below.

We consider the DEA merger literature first and start with financial institutions. Avrikan (1999) found acquiring banks are more efficient than target banks but efficiency was not always maintained. Sufian (2004) examined scale efficiency in the Malaysian bank industry and found both positive and negative scale effects, with smaller banks benefiting from mergers. Worthington (2004) uses DEA to identify the determinants of merger activity in Australian cooperative deposit-taking institutions.

Another active area of DEA merger research has been hospitals. Ozgen and Ozcan (2000) used DEA to examine scale effects in hospitals and found it to be the dominant source of efficiency improvements following mergers but technical efficiency was not affected. Ferrier & Valmanis (2004) used DEA to compare merged and non-merged hospitals and found that mergers did not have a sustained advantage in productive performance. The focus of DEA M&A research on banks and hospitals reflects the availability of data in these institutions to undertake comparative efficiency analysis, especially as regards a large number of Decision Making Units (DMUs) with readily identifiable inputs and outputs.

R&D is less susceptible to this form of analysis, however, there has been some recent research. Linton et al. (2002) applied DEA to the portfolio optimisation of projects at Bell Laboratories. SubbaNarasimha et al. (2003) used DEA to examine the efficiency of deployment of technology knowledge; they used a composite income measure and patent-related output measure as the variables in the study.

Chen et al. (2004) in their DEA study found that R&D productivity in Taiwanese semiconductor firms could be improved by an increase in scale. Eilat et al. (2008) and Eilat et al. (2006) provided a multicriteria approach for

evaluating R&D projects within a portfolio at different stages in their lifecycle with some relevance to the computer technology industry (the papers were not explicit about the sector). Hashimoto & Haneda (2008) used DEA to measure changes in the productivity of the Japanese pharmaceutical industry over time and they found that it was monotonically decreasing. A single input was used, namely R&D expenditure, and the three outputs were patents, sales and operating profit, and they explained their choice as the best available.

DEA was also used to examine R&D productivity at a national level. Sharma & Thomas (2008) use DEA to examine R&D between nations. Lee and Park (2005) undertook a similar international comparison for Asian economies.

DEA has also been used in conjunction with the Balanced Scorecard. Banker et al. (2004) found some trade-off in a Balanced Scorecard between ROA and non-financial measures linked to future development in the US telecommunications industry. There is a further recent Balanced Scorecard application in the field of R&D: Garcia-Valderrama et al. (2009) used a Balanced Scorecard and DEA approach to analyse comparative performance of 90 companies in R&D in a variety of sectors in Spain.

Finally, the only truly comparable DEA study to this research is Hashimoto & Haneda (2008) in which the DEA outputs are actually financial parameters only loosely associated with one DEA input: R&D expenditure.

3.7 Synthesis

The focus of this thesis on the measurement principles and parameters that determine PAP is fully contemporary for the M&A field. The potential for diversity includes:

– Differing motives for the M&A deal that may include market power, financial performance or efficiency.

– A choice of different parameters for measuring progress towards the same objective, for example ROA or ROS, often made without a clear explanation.

– Potential bias of some metrics for measuring crucial aspects of performance, for example accounting conventions not to record internally generated intangible assets.

– Different approaches for the measurement of efficiency, including the processes included and the inputs and outputs considered, which can be especially challenging when their outputs are intangible and their production has an element of uncertainty, as is the case with R&D.

In the face of this diversity, the approach of this thesis has been to adopt a rigorous approach to the selection of measures used in the analysis. The rigour began with first establishing that multiple measures are beneficial and having done so establishing a theoretical basis for the selection of measures for the purposes of external evaluation. The verification by Crook et al. (2008) of a link between a firm's financial performance and its resources as identified by the RBV is confirmation of the suitability in principle of the RBV as a means for the identification of non-financial measures to populate a PMF. Furthermore, because the RBV has accumulated literature over two decades it also provides a source of practical guidance for the design of a set of principles for the selection of measures, as well as examples of measures that have been used in the pharmaceutical sector in the past. We now describe a practical set of RBV-based principles for the design of a PMF.

4 Design of PMF

4.1 Introduction

This chapter of the thesis develops a systematic approach to the design of a PMF:

– The first step is to develop a general set of Design Principles, derived from the RBV and the Balanced Scorecard literature reviewed in Chapter 3, which can be used to develop a PMF in any sector in a structured way.

– The second step is to apply the Design Principles to the pharmaceutical sector in order to produce a PMF; this is compared with prior literature to demonstrate that the Design Principles represent an advance on previous thinking.

– Finally, a reduced set of measures is selected that is suited to the application of DEA to the pharmaceutical R&D process, along with an explanation of why that process was selected.

We begin with describing the creation of the Design Principles from a theoretical basis.

4.2 PMF Design Principles

The lessons for the design of a PMF have been annotated (a) to (h) in Table 3.2 and (i) to (iv) in Table 3.3 with reference to academic authors. The sources in these 2 tables have provided 12 lessons and they are arranged in Table 4.1 by topic and they retain the original table references.

Table 4.1 Design Principles

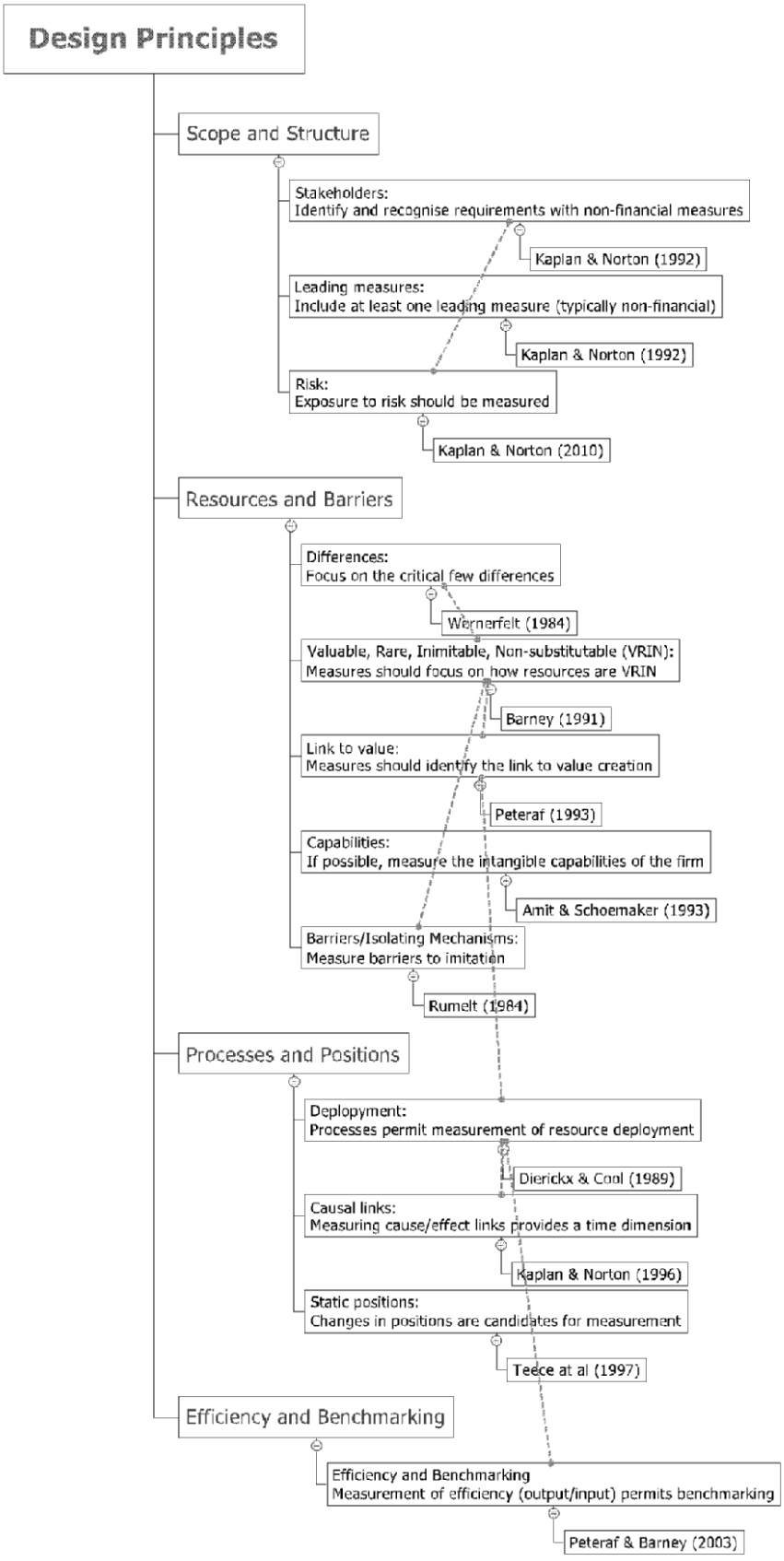
Category	*No.*	*Principle*	*Ref.*
Scope and Structure			
Stakeholders	1	Recognise requirements of major stakeholders of the firm (e.g. the firm's owner and customers) with non-financial measures.	(i)
Leading measures	2	Include at least one leading measure (typically non-financial).	(ii)
Risk	3	Risk exposure should be measured.	(iv)
Resources and Barriers			
Differences	4	The PMF should measure the critical few differences between firms.	(a)
VRIN	5	Measures should be on how resources are VRIN.	(c)
Link to value	6	Measures should consider how resources are linked to value creation or economic rent.	(d)
Intangibles	7	Capabilities, or intangible resources, should be measured where possible.	(f)
Barriers	8	Barriers to imitation that affect the value of a resource should be measured.	(b)
Processes and Positions			
Deployment	9	Deployment of resources, through processes, should be measured.	(e)
Dynamic links	10	Causal links between measures should be identified to provide a time dimension.	(iii)
Static positions	11	Static positions are candidates for measurement.	(g)
Efficiency and Benchmarking			
Benchmarking	12	Efficiency should be measured, recognising prior paths of development, for benchmarking.	(h)

The relatively few references to measurement within the core RBV texts allowed these references to be included without selectivity; the scarcity of references to measurement is perhaps unsurprising given the comments of Kraaijenbrink et al. 2010 that resources require closer definition. Given this ambiguity, the issue of measurement has been to the forefront.

In the case of the Balanced Scorecard, the issue was the opposite, namely there exists a superfluity of commentary on measure selection, albeit for an evaluator with access to the internal working of the firm. The approach here was therefore to identify the main principles of the Scorecard (the balanced provided by multiple perspectives and leading and lagging indicators) and the need to understand the inter-relationships between the measures; to this was added Kaplan's view on the main omission, namely risk.

The grouping of the twelve principles into four headings was not driven by the literature itself but by identifying major association. However there are also secondary associations and these are shown graphically in Figure 4.1. This figure summarises the relationship between the principles and the major references, while also showing the primary and secondary linkages (the secondary linkages are shown with a dotted line) and the key references from the literature review (whose attachment is marked by a small circular symbol).

Figure 4.1 Summary of Design Principles



Having derived the 12 Design Principles from the academic literature, without regard to the availability of information, it is now necessary to confirm this availability, if the principles are to be of practical use to an external evaluator.

4.3 Availability of Information

4.3.1 Practicality

The availability of information is discussed below, by considering each heading in turn.

4.3.2 Scope and Structure

Stakeholders

The identification of stakeholders should be straightforward but there may be complications, for example different classes of shareholders may have different interests (especially as regards exposure to risk, for example ordinary versus preference shareholders) and these might need to be recognised.

The customers of a company are usually evident to an external evaluator, although complications can arise; this is especially so in the pharmaceutical industry where the eventual consumer of a product, the patient, may well differ from the purchaser. However, the actual identities of the consumer and purchaser are typically known. Other common stakeholders include employees and society as a whole, whose interests may be represented by regulators.

A good understanding of stakeholders is essential because they are the medium through which competition is felt, for example competition for

customers, employees or scarce resources. Ultimately 'value' derives from satisfying stakeholder requirements (primarily those of the paying customer) and later principles require the link to value to be established.

Leading Measures

Leading measures of performance often include measures of stakeholder satisfaction, both customer and employee; the challenge is the collection of information, although polling is one option that has been used by investors where there is a matter for concern.

Other leading measures might include the results of a product development programme or the emergence of substitutes.

Risk

Assessment of risk exposure for an external evaluator is more straightforward for publicly quoted companies because there are disclosure requirements, for example in the USA, the Annual 10K form required by the Securities and Exchange Commission gives disclosure of major risks in 'Item 1A – Risk Factors'. Otherwise some form of due diligence is required, for example to detect overdependence on certain products or customers.

4.3.3 Resources and Barriers

Critical Differences

The next step is fundamental to the entire PMF design, and it requires the identification of Resources and this requires some sector knowledge even if specific company knowledge is only incompletely known to the external evaluator. Nonetheless, some company-specific knowledge is also essential because the RBV focuses on the differences between firms competing in the

same market. For public companies there are minimum disclosure requirements. For companies quoted in the USA, Form 10-K, discloses tangible assets in 'Item 2 – Properties' and 'Item 1 - Business' provides a comprehensive list of products, markets and customers. Similar disclosures are made in other jurisdictions.

Fortunately, in publicly quoted firms the management often see that it is in their interest to publicly disclose some of the unique strengths of their companies beyond the minimum required in annual reports thus enabling establishment of a fuller picture of resources.

VRIN (Valuable, Rare, Imperfectly imitable and Non-substitutable)

The VRIN tests are used to screen potential candidates for measurement. Although a potential parameter may seem valuable it might not be a useful addition to PMF, for example if it is easily imitated.

Link to Value

Even if a resource is VRIN, it may not merit measurement if its link to value creation is obscure, for example the possession of prestige premises. The most direct link to economic value derives from the satisfaction of customers' requirements and the fulfilment of a product or service.

Intangibles

Identification of intangible resources may be less straightforward, although details of patents and trademarks are in the public domain. The most elusive intangible is knowledge, especially tacit knowledge.

Barriers

In some cases, barriers to imitation of resources will be sufficiently important to be an object of measurement in their own right. For example, for a technology company the remaining life on a patent is a crucial measure. Similarly, where brand strength is crucial, then monitoring of major brands by independent valuation may be merited.

4.3.4 Processes and Positions

Deployment

Resources are deployed through processes and these offer an opportunity for measurement; they need to be identified and placed in the context of the wider supply chain outside the firm. Order fulfilment processes are externally visible through the delivery of products and services, although product and market development processes may be less visible (fortunately this is not the case in the pharmaceutical sector). In selecting process measures, the external evaluator, as Lebas & Euske (2002) noted, is less interested in 'action variables' used for process management but in the 'critical few' variables, to use the phrase of Murray & Richardson (2000): parameters of process performance that are crucial to the success of the organisation.

Dynamic Links

The presence of multiple measures in a PMF can be a source of confusion if their dependencies are not understood. Identifying associations between measures has an additional potential advantage of understanding positive or negative interdependencies that arise from underlying business processes.

Static Positions

In many cases performance will not depend on accumulation of past performance into the present position. Generally, the interest of an external evaluator will be in the firm's position relative to competitors and there is a rich source of academic and practitioner literature on competitor intelligence, for example Lackman et al. (2000) provide a comparison of 16 competitor intelligence functions. The widespread presence of such functions is evidence not only of the feasibility of collecting information on a company from an external perspective but also demonstrates the usefulness of the information obtained.

4.3.5 Efficiency

Benchmarking

Efficiency measurement and benchmarking requires information on both inputs and outputs of a process that are often expressed as a ratio. Financial ratios are a type of efficiency analysis where information is readily available, although ratios formed with at least one non-financial parameter can also be illuminating (e.g. sales per employee). Trends in efficiency ratios are often of equal interest.

Another approach to efficiency analysis, adopted in this thesis, is comparative efficiency in which the efficiency of a company relative to its peers is measured.

4.4 Application of Design Principles to the Pharmaceutical Sector

4.4.1 Demonstration of Use

Having established the practicality of using the Design Principles to populate a PMF in general, there remains the task to apply it to the pharmaceutical sector and demonstrate that the results are superior to less systematic methods.

The application of the Design Principles to the pharmaceutical sector is considered below and the resulting PMF presented in the following section.

4.4.2 Scope and Structure

Stakeholders

The following stakeholders were identified:

– The shareholders or owner of the company, who are concerned with financial performance. Earnings per Share is of prime interest and is linked to share price through the Price Earnings ratio for the sector.

– The customer stakeholders are unusually complex with different customers having different priorities, for example national health authorities and hospitals will be relatively more cost-conscious, whereas the patient and physicians will be concerned about the efficacy of the formulation. Notwithstanding the structural complexity of the stakeholders, satisfaction however can be measured by market share in particular therapeutic categories, reflecting the efficacy of the treatment and its affordability, although loss of share can occur through lapse of patents, allowing low-cost competition to erode market share, or the existence of product substitutes in therapeutic categories that themselves may not be patent-protected.

– The employees are natural stakeholders but are a diverse group with some groups such as research workers being crucial. The turnover of this group is of special interest, as is the value-added per employee in total (the difference in revenue and costs excluding payroll), to understand the average financial contribution of each employee.

– Society is a key stakeholder for the pharmaceutical industry with a need for a supply of new and better formulations and also expectations that dangerous formulations will not be released. This stakeholder is represented by the regulatory authorities (e.g. the Food and Drug Administration in the USA) who serve adverse reports and notices when society is judged to be at risk.

Four internal and external stakeholders have therefore been identified, to which is added Process. Although not a stakeholder in its own right, process efficiency is a necessary condition for satisfaction of the other stakeholders and all stakeholders will have an interest in it.

Leading Measures

The R&D process is an obvious source of leading measures and it might be thought that a patent with a 30-year life is also a potential candidate for a measure, given the legal protection against imitation. However, the number of patents was not used because of criticisms in the academic literature, including the pharmaceutical R&D literature, of the usefulness of this measure. To amplify, DeCarolis & Deeds (1999) established the lack of correlation between patents and a firm's performance and identified patent citations as an alternative. However, the counterintuitive results in DeCarolis (2003) regarding the negative correlation between technical competence and Market-to-Book Value raises questions over the use of citation analysis, so this variant of

patent analysis was not used, especially given the criticism of citation analysis by Meyer (2001).

Given the rejection of patents as a measure, the measurement of outputs therefore focuses on the number of compounds that have passed the hurdle of approval by the regulatory authorities.

Risk

The decisions of the regulatory authorities also represent major risks to the company and merit measurement; fortunately adverse reports on products and facilities are publicised.

There is also a further negative factor that requires recognition, namely litigation. Major pharmaceutical companies are usually engaged in large litigation suits and of these some are opportunistic.

4.4.3 Resources and Barriers

Differences

The primary differentiation for a research-based pharmaceutical company is current and future product portfolio, the latter being represented by its R&D pipeline.

The benefit of the current portfolio is visible through the ROS and market share and the latter can be seen as a measure of competence in marketing. Regarding production facilities, the role of this tangible resource is to ensure continuity of supply.

VRIN, Link to Value & Intangibles

The previous discussion on focusing on differences between the firms highlights the importance of seeking measures that focus on the current and future product portfolio, as evidenced by ROS and the R&D pipeline respectively. Measures in these areas already pass the tests on VRIN, establishing a link to value and give full recognition to intangibles, as do any measures related to research employees, for example retention measures.

However production facilities are usually not rare and production can be outsourced; manufacturing competence is expressed as the avoidance of regulatory censure while ensuring continuity of supply.

Barriers

The prime isolating mechanism for a research-based pharmaceutical company is the patent. However these have a fixed life (30 years) so the barrier to imitation erodes with time. Products can also be grouped into therapeutic categories that address particular medical conditions; the specificity of the action of a drug is an isolating mechanism because a drug does not compete against drugs as a whole, but only against those that treat the same condition.

4.4.4 Processes and Positions

Deployment and Dynamic Links

For the pharmaceutical sector, key processes include:

- Discovering new drugs (i.e. New Chemical Entities) that successfully pass through preclinical development.

- Rapidly and successfully progressing them through the clinical trials process to maximise the useful patent life. This depends on the avoidance of unnecessary delay in communication with regulatory authorities.

- Communicating with and satisfying regulatory agencies.

- Marketing the drugs in as many markets as possible and identifying as many indications of a drug for different medical conditions as possible.

These topics have largely been addressed in the preceding discussion except for the dynamic aspect: the avoidance of regulatory delay while a compound is in the R&D pipeline and the need to address not only the number of drugs produced but also the number of clinical trials for multiple indications. Both these additional factors need to be addressed by the PMF.

Static Positions

The static position of a company in a market is best observed by its revenue in general and by its market share in therapeutic categories specifically. However, the prime concern of the industry is the erosion of a static position by patent expiry.

4.4.5 Efficiency

Benchmarking

Regarding efficiency ratios, the prime concern in the industry is availability of funds to invest in R&D with R&D as a proportion of sales being seen as a prime metric of a firm's commitment to the future. Consequently ROS to fund the expenditure on R&D is seen as the key financial metric.

4.5 Proposed Pharmaceutical PMF

4.5.1 Outcome of Design Principles

The outcome of the application of the Design Principles is shown in Table 4.2. The measures have been grouped by stakeholder, rather than linked back to the category of the Design Principles by which they were created, so as to present a view on the coverage and balance of measures by the stakeholders identified in Subsection 4.4.2.

Table 4.2 Proposed Pharmaceutical PMF

Owners	*Customers*	*Employees*	*Processes*	*Regulatory*
►Return on Sales ►Earning per Share ►Litigation liability (-ve)	►Market share by therapeutic category ►Future loss of sales to therapeutic substitutes (-ve) ►Future loss of sales to expiring patents (-ve)	►Research employees as % total ►Value added per employee ►Employee turnover (-ve)	►# compounds in pipeline, by stage ►# clinical trials in pipeline, by stage ►R&D/Sales ►Marketing/Sales ►Attrition rates in pipeline (-ve)	► Patent life lost to submission process (-ve) ► # adverse drug reports (-ve) ► # adverse manufacturing reports (-ve)

Although Table 4.2 represents an illustration of the concept of the design principles, the question arises whether the scorecard is a useful set of measures for measurement of pharmaceutical performance or an advance on contemporary practice.

An opportunity for comparison was provided by Stankevicien & Svidersk (2010). The scorecard was designed by a German subsidiary of an Italian company described thus (Stankevicien & Svidersk, 2010: 242): *"The Italian Group enjoys an outstanding reputation worldwide as an efficient and reliable partner. This applies both to the development of new drugs and to the communication of scientific insights".* The company designed the scorecard shown in Table 4.3.

Table 4.3 Scorecard for Pharmaceutical Company

High Performance Organization	Systematic Execution & Implementation of System Requirements	Stakeholder Service Excellence	Excellence in Financial Performance
• Employee satisfaction rate • Training compliance rate • Successful job rotation	• Audit recommendation • Implementation score • Information sharing score	• Business improvement rate • Management satisfaction rate • External rating score	• Risk management score • Expense spending control • Performance score • Target achievement

			rate

Comparison of the two tables suggest that the Design Principles have led to a scorecard whose measures focus on the competitive position of the company rather than process compliance and improvement, which are the natural concerns of the management of a subsidiary.

4.5.2 Use of Negative Indicators

A feature of the PMF produced by the Design Principles is its inclusion of large numbers of negative indicators; this is uncommon in the Scorecard literature in which emphasis is placed upon a monitoring rate of strategic deployment. However, the RBV stresses the importance of barriers to competition and the lessening of barriers has an important influence on the value of resources and these represent a negative indicator for future performance. In recognition of this, one of the measures listed in Table 4.2 relates to future sales lost to patent expiry.

Litigation risks over consumer harm and patent infringements are also major topics of interest and represent a leading measure of performance.

The inclusion of negative indicators can be seen as fully contemporary in its recognition of risk to the business, as noted in an interview with Kaplan, held in 2010, as discussed previously.

4.5.3 Choice of Financial Measures

ROS has been selected rather than ROA. The first reason concerns the limitation of ROA in this sector: the denominator in ROA without an acquisition history will include only tangible assets, as internally generated intangible

assets are not shown according to accounting conventions. The measure is therefore of limited relevance in a sector where profitability depends on earning a return on intangible assets.

ROS by contrast allows the profitability of the company to be expressed as a percentage of revenue, allowing for inter-firm comparison, and shows the funds available for investment in R&D, with R&D as a percentage of revenue being an accepted approach for comparisons of research-based pharmaceutical companies, for example Grabowski et al. (2002).

Despite the advantages in ROS, this research does consider ROA in parallel to the ROS to further examine the relative merit of the two measures.

4.6 Focus on R&D and Adaptation to DEA

Comparative efficiency is measured at the level of the DMU however this still leaves some discretion whether to measure the comparative efficiency of an entire firm or a particular process within the firm. If one opts for the entire firm, then there is the possibility of blurring the analysis by aggregation of many factors, whereas the application of the analysis to one element of a firm, such as an individual process, risks overlooking important interdependencies between processes that can affect performance. In this thesis the decision has been to apply the analysis of comparative efficiency at the level of a major business process within the firm, at a high-enough level so that the impact on the firm's competitiveness can be understood, while isolating the intangible production processes from the other parts of the firm.

The selection of the R&D process for examination was made because a necessary but not sufficient condition for the success of an ethical pharmaceutical firm is its R&D core competence, as evidenced by an efficient

R&D pipeline. This pipeline is the process that provides deployment of capabilities that generate resources that can be most easily converted to income. These resources are the multiple outputs of the pipeline: compounds at progressive stages of the pipeline that meet the VRIN tests required by the RBV by virtue of patent protection. This protection ensures an economic rent is earned once a compound has progressed to the end of the pipeline and is granted marketing approval. Once marketing approval has been granted, additional competences become important, especially marketing to maximise revenue during the period of patent protection and manufacturing, to ensure continuity of supply. However before marketing-related resources can become valuable there must be compounds to produce and hence the primary focus for an evaluator is the efficiency of the R&D pipeline.

Once the R&D process has been selected for examination of comparative efficiency, there remains the task of choosing from Table 4.2 a mix of input and output parameters relevant to the R&D process. The candidates are:

- Inputs: Research employees, % R&D expenditure.
- Outputs: Compounds, Trials, Attrition rates (negative).

These are the measures used in the analysis, except the number of research employees is not available so the total number of employees has been used instead. This does have the advantage of recognising the indirect input of non-research employees to the operation of the R&D pipeline; the total number of staff may also be relevant in examining the link to acquisition history because acquisitions are generally followed by staff reductions.

The attrition rates were not included in the DEA model for two reasons, namely the difficulty in collecting information on failed trials over the historical

period and the difficulty of including outputs with a negative influence on productivity into a DEA model (one option is to include a reciprocal of the output but this itself poses a problem where there is zero attrition).

4.7 Conclusion

This chapter has outlined a set of measurement principles for an external evaluator to measure the performance of a pharmaceutical company with a comparative efficiency technique. The focus is on the R&D process and inputs and outputs have been selected on the basis of a RBV-derived process and comparison with prior literature.

Future chapters will develop these principles into a DEA model that will enable the modelling of comparative efficiency from an external perspective.

5 Research Methodology

5.1 Introduction

This chapter describes the research methodology that has been used to examine the association between a pharmaceutical firm's history of acquisitions and the efficiency of its R&D process.

The first step was to consider the range of possible efficiency and productivity analysis approaches, and the decision to opt for a DEA approach is explained. Several DEA models have been developed within the literature and the selected model types are explained, along with their mathematical formulation. Weight restrictions have been applied to the DEA model and their implications are considered.

Returns to scale for the pharmaceutical R&D process has been investigated and tested as a preliminary step. The primary focus of the research however is the association between efficiency and acquisition history. Statistics on acquisition history were collected and their distributions analysed prior to the development of a typology to support the subsequent analysis.

Various hypotheses have been proposed and their testing requires an approach that avoids the difficulty that arises from statistical testing of DEA scores directly; this is then defined, followed by the application to the testing of the scale hypothesis and the acquisition-related hypotheses. Finally, the treatment of outliers is also discussed.

5.2 Efficiency and Productivity Analysis Approaches

Efficiency and productivity measurement (the terms are not synonymous but have been used interchangeably in the literature) has a long history and one

of the earliest measures is unit cost. The seminal author in the field of measurement of productive efficiency is Farrell (1957) who introduced the distinction between technical and allocative efficiencies. Despite this early work, the analysis of R&D efficiency has been largely confined to examining the technical aspect through the consideration of unit costs: dividing an output measure (typically number of approved compounds) by an input measure (typically expenditure). However, unit costs cannot measure the efficiency of a productive unit with multiple inputs or outputs. Unit costs were not employed in this research because the R&D process has multiple outputs.

An approach which is able to consider multiple inputs and outputs is to use *'parametric'* methods, whose characteristic is an assumption of the form of the production function relating inputs to outputs. The simplest parametric method is Ordinary Least Squares regression and more sophisticated approaches include Stochastic Frontier Analysis (Kumbhakar, 1988) that separates the effect of noise (e.g. from measurement error) from variation in efficiency. If the form of the production function is known, then parametric analysis confers several advantages for econometric analysis (as noted by Cubbin & Tzanidakis, 1998). However in this case, the form of the production function linking R&D expenditures (inputs) to the outputs of the process is not known. Therefore a parametric approach was not adopted for the efficiency analysis in this research.

Given the presence of multiple inputs and outputs and the lack of knowledge of the production function, the natural choice for the efficiency measurement is DEA, which is not a statistical or econometric technique but has its origins in Operations Research.

The formulation of the DEA models is described below, once the mathematical notation used in the thesis has been defined. DEA has been selected for the evaluation of R&D productivity because it is able to analyse multiple inputs and outputs and does not require the production function to be specified. In this section we specify several DEA models that:

– Recognise the longitudinal nature of pharmaceutical R&D, namely that it may take many years of R&D to produce a measurable output. Therefore R&D over several years has been considered.

– Have the potential to consider both financial and non-financial outputs, while investigating the differing restrictions on the weights given to these two different types of outputs.

We now define the structure of the model in more detail and in particular how the longitudinal aspect of the pipeline is addressed.

Following this, the design of the acquisition typology, used to analyse acquisition history, is summarised.

5.3 Summary of DEA Model

5.3.1 Orientation of Model

There is a distinction between an input-orientated model (that examines efficiency from the viewpoint of minimising resources used for a given level of output) and an output-orientated model (that examines efficiency from the viewpoint of maximising output for a given level of resources consumed). The output-orientated model is more relevant to pharmaceutical R&D because the generic strategy within the industry is to ‘speculate to accumulate’: to spend

available surplus on R&D in the hope of discovering new compounds to secure the future of the company.

5.3.2 Inputs and Outputs

For all the models used, the inputs included were R&D (current), that is expenditure in 2006, and R&D (historic), that is expenditure in the previous five years (2001–2005), expressed in US dollars; the definition of this is likely to be relatively standard between firms and include all the operating costs of a firm's R&D facilities, including staff. Although R&D expenditure is the prime monetary input to the creation of preclinical compounds and the progression of compounds through the R&D pipeline, it is necessary to consider a sufficient number of years of expenditure to relate the input to outputs in all stages of the pipeline.

However, other factors are also required for pharmaceutical R&D, for example activity on dealing with regulatory agencies, staff recruitment and retention, and raising finance and so on. These may need to be reflected in the inputs in some way, therefore number of staff was also considered an additional input in one of the DEA models.

In the DEA model used for association with acquisitions, the outputs are:

– the number of compounds in Preclinical phase (i.e. yet to gain approval for clinical trials to commence);

– the number of compounds in Phase 1 clinical trials;

– the number of compounds in Phase 2 clinical trials, having passed Phase 1;

– the number of compounds in Phase 3 clinical trials, having passed Phase 2;

– the number of compounds awaiting approval for marketing, having passed Phase 3.

An alternative model considering the number of clinical trials was also considered for comparison, although after examination of the trends in the ratio of trials to compounds it was considered less representative of R&D process efficiency and more reflective of marketing strategy.

5.4 Longitudinal Dimension

Pharmaceutical compounds take time to develop, so R&D expenditure is unlikely to produce a preclinical compound in the same year because it takes many years for a drug to move from discovery to the market place. DiMasi & Grabowski (2007) provide a contemporary summary of the times and costs involved (see table below).

Table 5.1 Time and Costs of R&D Development

Testing Phase	*Duration (months)*	*Monthly cost ($m, 2005)*
Preclinical	52.0	1.15
Phase I	19.5	1.66
Phase II	29.3	1.08
Phase III	32.9	1.38

Six years, or 72 months, of R&D expenditure has been collected for this thesis. This period not only covers the majority of the duration of the pipeline (which is 133.7 months) but also is greater than any phase of the pipeline (a maximum of 52 months), so therefore the inputs can be related to each output.

Table 5.1 also shows that monthly costs per phase are comparable between phases and therefore the measured input (R&D expenditure) for 72 months should be representative of the cost required to support the pipeline production process as a whole. Further evidence to support this is given by the analysis of the descriptive statistic for R&D expenditure which shows that R&D expenditure as a proportion of sales varies little year-on-year.

Including R&D expenditure relating to years prior to 2001 could be misleading because this expenditure would relate to the discovery and preclinical stages of compounds now in the later stages of the pipeline. The advent of combinatorial chemistry for screening in the decade prior to the year 2000 had a major impact on the productivity of this stage in the pipeline as noted by Sweeny (2002: 10)

> *This was a major rate-limiting step in developing new drugs and has seen remarkable increases in productivity over the past ten years or so through the use of combinatorial chemistry linked to high throughput screening.*

5.5 Definition of Notation

5.5.1 MCT

There are two MCT that are relevant to this research: the arithmetic mean and the median; the first is pertinent to the parametric test for the difference between two means (used in the statistical testing) and the second is relevant to the non-parametric test. Both measures have been used for statistical testing of the mean for the parametric tests and the median for the non-parametric test. Where appropriate, the acronym ‘MCT’ (i.e. Measure of

Central Tendency) has been used in the terminology below; the choice of MCT was determined by the test used: parametric or non-parametric.

5.5.2 Normalisation Factor

In quantifying merger history for a particular firm, it is necessary to establish a normalisation factor for the firm because firms vary considerably in size. There are various options for the selection of a normalisation factor. A natural choice of the normalisation factor would be the assets of the company because an acquisition involves an expansion of the asset base; however this presents some technical difficulties because many assets were acquired in times of different asset prices and have been subject to varying depreciation policies. Furthermore the figure does not include many of the self-generated intangible assets on which pharmaceutical companies earn a return (these criticisms affect the usefulness of the ROA as a performance measure despite its popularity). Because pharmaceutical companies earn a return on intangible assets through the sale of medicines whose price reflects the value of those assets, the normalisation factor could be based on the profitability of the firm; however, profitability, being the difference between cost of sales and revenue, can vary considerably between years. Revenue itself is also a commonly used scaling factor in industry analysis and is often used to compare R&D intensity between firms, however it can be affected by competitive conditions not related to the underlying scale of assets or processes of the firm. Therefore cost of sales, which is usually of comparable magnitude to revenue and has an underlying proportionality to the maintenance of the tangible and intangible assets, has been selected. The sum of the deal value over the period in question has been divided by the annual cost of sales of the surviving company at the end of the period. This allows the significance of the merger history to be expressed independently of the size of the resulting company.

In the notation below the acronym ‘NDV’ (i.e. Normalised Deal Value) is used to denote the cumulative values of deals of a firm over the analysis period (chosen to include an entire merger wave and economic cycle) divided by the revenue scaling factor.

5.5.3 Algebraic Notation for Efficiency Analysis

Tables 5.2 sets out the algebraic notation used in the DEA modelling. (Subentry Tables 5.3 to 5.5 define further algebraic notation; the notation is first defined completely so that the equations can then be considered without interruption of further definition of terms).

Table 5.2 Algebraic Notation for DEA Models

Symbol	*General Meaning*	*Specific Meaning*	*# Elements in Variable*
S	# output measures	Number of compounds at different stages of pipeline (value = 5)	1
M	# input measures	Number of input measures; (these are R&D current, R&D historic, and staff numbers) i.e. value = 3)	1
N	# DMUs	Number of firms in sample after exclusion of two outliers (value = 48)	1
y_{ik}	Value of output measure i (i = 1, …, s) for DMU k (k = 1, …, n)	Compounds or clinical trials for each firm *(i=1, Preclinical; i=2, Phase 1; i=3, Phase 2; i=4, Phase 3; i=5, Awaiting Approval)*	5 × 48
x_{jk}	Value (≥ 0) of input measure j (j = 1, …, m) for DMU k (k = 1, …, n)	R&D spend for each firm *(j=1, Current; j=2, Historical)* and staff numbers where used *(j=3)*	3 × 48
u_i	Weight (> 0) of output measure i (i = 1, …, s)	Weight given to each compound or clinical trial for each firm	5
v_j	Weight (> 0) of	Weight given to R&D current,	2

	input measure j (j = 1, …, m)	R&D historic or staff numbers for each firm	
d'_k	Optimal objective function value for each DMU	Reciprocal of technical output efficiency for CRS model	48
d''_k	Optimal objective function value for each DMU	Reciprocal of technical output efficiency for VRS model	48
η_k	Relative technical output efficiency of each DMU (CRS)	Technical output efficiency score for each firm from CRS model	48
θ_k	Relative pure technical output efficiency of each DMU (VRS)	Pure technical output efficiency score for each firm from VRS model	48
r_k	Financial efficiency of each DMU	ROS or ROA or SOA for each firm	48

5.5.4 Form of DEA Equations

The equations defining DEA can be expressed in three forms. The first is the original Fractional Programming form in which the efficiency of each DMU is expressed in the form of a ratio. These equations can be restated in Linear Programming form of which there are two variants: one is called the Multiplier form, and there is also a dual form termed the Envelopment form. In this thesis the Multiplier form is used.

5.5.5 Algebraic Notation for Examination of Returns to Scale

Table 5.3 sets out the algebraic notation used in the examination of returns to scale based on the use of the average of the Current R&D expenditure and the Historic R&D expenditure as an R&D-specific scale factor.

Table 5.3 Algebraic Notation for Examining Returns to Scale

Symbol	*Specific Meaning*	*# Elements in Variable*
e_k	Scale efficiency of each DMU, $E_k = \eta_{k\,/}\,\theta_{k,}$ for k = 1 … n	48
w_k	Mean of Current and Historic R&D expenditure of each DMU	48
w_l	Mean of w_k with below-median scale efficiency, e_k	1
w_h	Mean of w_k with above-median scale efficiency, e_k	1
$Var(w)_l$	Variance of average of Current R&D and Historic R&D expenditure of DMUs with below-median scale efficiency, e_k	
$Var(w)_h$	Variance of average Current R&D and Historic R&D expenditure of DMUs with above-median scale efficiency, e_k	

5.5.6 Algebraic Notation for Classification of Acquisition History

Table 5.4 sets out the algebraic notation used in the examination of acquisition history.

Table 5.4 Algebraic Notation for Classification of Acquisition History

Symbol	*Specific Meaning*	*# elements in Variable*
A_k	Sum of all deal values for $DMU_{k,}$ for k = 1 … n	48
B_k	Sum of cross-border deal values for DMU_k for k = 1 … n	48
C_k	Sum of cross-sector deal values for DMU_k for k = 1 … n	48
F_k	Annual Cost of Sales for DMU_k for k = 1 … n	48
a_k	NDVs for DMU_k for k = 1 … n	48
b_k	NDVs of cross-border deals for DMU_k for k = 1 … n	48
c_k	NDVs of cross-sector deal for DMU_k for k = 1 … n	48
a_l	MCT of a_k for those DMUs with below-median θ_k	1
b_l	MCT of b_k for those DMUs with below-median θ_k	1
c_l	MCT of c_k for those DMUs with below-median θ_k	1
a_h	MCT of a_k for those DMUs with above-median θ_k	1
b_h	MCT of b_k for those DMUs with above-median θ_k	1
c_h	MCT of c_k for those DMUs with above-median θ_k	1
a'_l	MCT of a_k for those DMUs with below-median r_k	1
b'_l	MCT of b_k for those DMUs with below-median r_k	1
c'_l	MCT of c_k for those DMUs with below-median r_k	1
a'_h	MCT of a_k for those DMUs with above-median r_k	1
b'_h	MCT of b_k for those DMUs with above-median r_k	1
c'_h	MCT of c_k for those DMUs with above-median r_k	1
$Var(a)_l$	Variance of a_k for those DMUs with below-median θ_k	1
$Var(b)_l$	Variance of b_k for those DMUs with below-median θ_k	1
$Var(c)_l$	Variance of c_k for those DMUs with below-median θ_k	1
$Var(a)_h$	Variance of a_k for those DMUs with above-median θ_k	1

$Var(b)_h$	Variance of b_k for those DMUs with above-median θ_k	1
$Var(c)_h$	Variance of c_k for those DMUs with above-median θ_k	1
$Var(a)'_l$	Variance of a_k for those DMUs with below-median r_k	1
$Var(b)'_l$	Variance of b_k for those DMUs with below-median r_k	1
$Var(c)'_l$	Variance of c_k for those DMUs with below-median r_k	1
$Var(a)'_h$	Variance of a_k for those DMUs with above-median r_k	1
$Var(b)'_h$	Variance of b_k for those DMUs with above-median r_k	1
$Var(c)'_h$	Variance of c_k for those DMUs with above-median r_k	1

5.5.7 Algebraic Notation for Statistical Testing

It is necessary to avoid the statistical testing of DEA scores directly because they are not independent observations. To avoid the testing of scores the approach adopted has been to use the DEA parameter to divide the population into two groups on the basis of the DEA scores: one a group with a below-median DEA efficiency and the other group with an above-median DEA efficiency. Table 5.5 defines the notation used to describe the variables used in the statistical tests employed for hypothesis testing using this approach.

Table 5.5 Algebraic Notation for Hypothesis Testing

Symbol	*General Meaning*
μ_l	Mean of below-median group
μ_h	Mean of above-median group
σ_l^2	Variance of below-median group
σ_h^2	Variance of above-median group
π_l	Number in below-median group
π_h	Number in above-median group
T	*t* test statistic
R_l	Sum of ranks for lower-median group
R_h	Sum of ranks for upper-median group
U_l	U-test statistic for lower-median group
U_h	U-test statistic for upper-median group
U	$U = \min (U_l, U_h)$
Z	z-test statistic

5.6 DEA

DEA was proposed by Charnes et al. (1978) in a paper that began "*This paper is concerned with developing measures of 'decision making efficiency'*" and coined the term DMU; in this research DMU refers to 1 of 48 pharmaceutical firms. The paper then defined what has since been termed the Charnes, Cooper & Rhodes (CCR) model in the Fractional Programming form and the two Linear Programming forms.

There is a choice to be made between the input- and output-orientated form of the DEA model. The output-orientated model maximises the outputs for a

given level of input whereas the input-orientated model minimises the input for a given level of output. Because a pharmaceutical firm 'speculates to accumulate' and commits surplus resource to R&D to maximise R&D output, the output-orientated form is the more appropriate and has been selected.

An output-orientated form of the CCR model is described below. Also described is a later model that was developed to accommodate VRS.

5.7 CCR Model

The original CCR model calculates an efficiency score for each DMU, based on its ratio of multiple outputs to its multiple inputs, weighted so as to maximise its efficiency, subject to constraints that all the DMUs have an efficiency less than or equal to unity. DEA can therefore be seen as an extended formulation of unit cost analysis.

The output-oriented form of the CCR model is summarised below in the multiplier form that establishes the relative efficiency for the DMU under consideration: DMU_0 (as opposed to an absolute efficiency based on technical standards).

$$\text{Min} \quad d'_0 = \sum_{i=1}^{s} v_j x_{io} \qquad \text{Eq. (1)}$$

$$\text{Subject to:} \quad \sum_{i=1}^{s} u_j y_{io} = 1$$

$$\sum_{j=1}^{s} u_j y_{ik} \leq \sum_{j=1}^{m} v_j x_{ik} \qquad k = 1 \ldots n$$

$$u_i > 0 \qquad i = 1 \ldots s$$

$$v_j > 0 \qquad j = 1 \ldots m$$

where the subscript '0' refers to the element of any variable relating to the DMU under analysis.

A Linear Programming equation has three aspects: an objective function to be optimised, a set of variables and some constraints. In the equation above, the optimisation relates to the efficiency of the DMU under analysis and the value of $d_{0'}$ is the reciprocal of the technical output efficiency score, η_0. The variables are the weights and the operation of the DEA optimisation algorithm assigns weights to each DMU that maximises its efficiency (although later in this section we discuss the inclusion of weight restrictions). The constraints ensure that the efficiencies of all the DMUs are less than or equal to unity with the chosen weights. The optimised choice of weights will allow the efficiency of each DMU to be the highest possible and at least one DMU will lie on the 'efficiency frontier' (i.e. be technically efficient whereas typically some others are relatively inefficient) and have a score of $d'_k = 1$.

A basic property of the CCR model is that it assumes there are no economies or diseconomies of scale: it assumes CRS. Subsequently alternative DEA models have been developed, one of which allows VRS and is described below. In this research the CCR model is used only to establish economies of scale by comparing the CRS efficiency scores with the VRS efficiency scores.

5.8 BCC Model

The model used for the acquisition hypothesis testing is the Banker, Charnes and Cooper (BCC) model, defined by Banker et al. (1984). This is an extension to the CCR model (Eq. 1) that accommodates VRS through the addition of an additional free scalar variable. The output-orientated BCC model is defined below:

$$\text{Min} \quad d''_{j'} = \sum^{m} v_j x_{io} - v_0 \qquad \text{Eq. (2)}$$

$$\max_{u,v} \; d''_0 = \sum_{j=1}^{s} u_j y_{jo} + v_0$$

Subject to:

$$\sum_{j=1}^{s} u_j y_{jo} = 1$$

$$\sum_{j=1}^{s} u_j y_{ik} \leq \sum_{j=1}^{m} v_j x_{ik} + v_0 \qquad k = 1 \ldots n$$

$$u_i > 0 \qquad i = 1 \ldots s$$

$$v_j > 0 \qquad j = 1 \ldots m$$

where the subscript '0' refers to the element of any variable relating to the DMU under analysis.

It can be seen that the BCC model has an additional term, v_0. The value of d''_0 is the reciprocal of the technical output efficiency score, θ_k. The firms on the efficiency frontier will have a value of $d''_k = 1$.

5.9 Output Weight Restrictions

Weight restrictions are a means of incorporating subjective judgements into a DEA model and may be of two types: absolute or relative. Without restrictions it is possible for DEA to generate weights that conflict with the judgements of the DMUs' decision makers; an example from this research would be for a lower weight to be given to a compound in a late stage in the R&D pipeline, compared with a weight in an earlier stage in the pipeline, when the latter must still face cost and uncertainty to moving forward to subsequent stages (i.e. $u_{j-1} < u_j$, for $j = 2 \ldots 5$).

Weight restrictions improve the credibility of the model in the eyes of decision makers but the subjective judgements involved must be defended. In this case, simple relative output weight restrictions have been applied along the lines indicated by Wong & Beasley (1990). Specifically four restrictions have been applied:

$u_j \geq u_{j-1}$ for j = 2 ... 5, Eq. (3)

where j = 5 represents the output relating to the compound at the final stage of development

These output weight restrictions are applied to both the VRS and CRS models.

5.10 Input Weight Restrictions

It has been found that the current CRS and VRS models tend to often assign zero weights to one or the other of the two inputs in the current models: Historical R&D (i.e. the annual historical average) and Current R&D expenditure, whose magnitudes are similar. Input weight restrictions have been added that limit the extent to which either input can be reduced to zero to recognise that both inputs are required to produce the outputs. The restrictions are:

$u_1 \geq 0.5\, u_2$ *and* $u_2 \geq 0.5\, u_1$ Eqs (4 & 5)

These input weight restrictions are applied to both the VRS and CRS models and have the effect of ensuring both R&D inputs have a material effect on the model, while allowing each input to be up to two times as significant as the other. However, the introduction of the input weights given in Eqs (4 and 5) had only a minor observed effect on the efficiency scores and given this minor effect further variations on the arbitrary 0.5 factor in Eqs 4 & 5 were not made.

5.11 Returns to Scale

The research afforded an opportunity for a fresh examination of returns to scale in pharmaceutical R&D using DEA. Banker et al. (1984) suggested the possibility of the use of the CCR model to relate returns to scale to the size of

the firm and introduced the concept of scale efficiency as defined in Eq. 6, which is calculated by reference to the technical output efficiency produced by the CRS model (Eq. 1) and pure technical output efficiency produced by a VRS model (Eq. 2), or in mathematical form:

$$e_k = \eta_k \div \theta_k \qquad k = 1 \ldots n \qquad \text{Eq. (6)}$$

where the subscript k represents the DMU under analysis

The scale efficiencies do not in themselves provide a test for whether there are returns to scale. A statistical test for investigating this is described below, following a description of the analysis of acquisition history.

5.12 Design and Population of Acquisition Typology

5.12.1 Identification of Acquisitions

The Thomson One Banker database has been used to identify all acquisitions over a ten-year period with a deal value exceeding $100 million, where the acquiring company was in the North American Industry Code (NAIC) for *"Medicinal and Botanical Manufacturing, Pharmaceutical Preparation Manufacturing, In-Vitro Diagnostic Substance Manufacturing, Biological Product (except Diagnostic) Manufacturing".*

Corporate acquisitions are one of many means by which a firm may purchase technological or marketing resources. Licences are preferred for minor acquisitions of resources which represent a stream of activity that would be undetected by the research methodology. From 1998 to 2002 the average value of a licensing deal was $84.5m (Pharmaventures, 2003). To exclude alternative means of resource acquisition from the study, for this thesis a $100 million threshold was set on the M&A analysis to ensure that the effects of

alternative lower-value means of acquiring resources, such as licensing, would not affect the analysis of the scale of historical resource acquisition for each firm.

For the M&A analysis, a period from 1993 to 2005 was selected; this spans at least an entire merger wave (commencing in 1993) and also approximates to the length of a typical economic cycle. The year in which R&D outputs are measured is the following year, namely 2006, to avoid the M&A activity affecting the collection of data on R&D outputs. The selection criteria used to identify deals in the Thomson One database are given in Table 5.6.

Table 5.6 Selection Criteria

Search Term	*Scope*
Acquirer NAIC *or* Acquirer Ultimate Parent Primary NAIC (Code)	Medicinal and Botanical Manufacturing Pharmaceutical Preparation Manufacturing In-Vitro Diagnostic Substance Manufacturing Biological Product (except Diagnostic) Manufacturing
Date Unconditional	01/01/1993 to 31/12/2005
Ranking Value inc. Net Debt of Target ($Mil)	100 upwards
Per cent of Shares Owned after Transaction	51 upwards

The searching process led to 591 acquisitions which met the criteria.

5.12.2 Classification of Acquisitions

The initial classification of acquisitions is as follows:

– The name of the acquirer.

– The size of the acquisition is measured by the 'Ranking Deal Value': a parameter used by the Thomson database to identify the value of the acquisition (in essence the amount paid by the acquirer after adjustment for debt).

– A binary value indicating whether the acquirer and the target are in the same country (i.e. a cross-border acquisition).

– A binary value indicating if the target is in the same NAIC code as the acquirer, or not (i.e. a cross-sector acquisition).

This classification makes it possible to calculate the sum of the deal values in total for each named acquirer, and in addition the sum of the cross-border deal values and cross-sector deals for each acquirer, as required by the research methodology.

The identification of cross-border and cross-sector acquisitions is amplified further below.

5.12.3 Identification of Cross-border and Cross-sector Acquisitions

The simple binary classification of cross-border and cross-sector deals has the advantage of data being readily available and reflects the additional complexity involved in acquiring a company in a different nation, for example dealing with different jurisdictions, the additional complexity of accounting and

control procedures and more costly logistics. It might be argued that the classification neglects:

– Geographic distance, however in practice information flows are now instantaneous.

– Language differences, however English is now the lingua franca for the pharmaceutical industry.

– Cultural differences. This is a significant issue, for example a US/UK or a Swiss/German acquisition is likely to encounter fewer cultural obstacles than say, a US/Japanese acquisition. Although techniques exist to measure cultural distances between nations their application is complicated by firm-specific differences and a resolution of these differences is impractical.

The simple binary classification is then used to select out the cross-border acquisitions from the total and these are then linked to the major pharmaceutical companies.

Regarding cross-sector acquisitions, pharmaceutical companies have a number of acquisition options available to them:

– To remain within their current field but to acquire emerging technologies, for example a traditional chemically based company choosing to acquire more contemporary biotechnology expertise.

– To acquire closely associated non-pharmacological technology, for example acquiring delivery devices for the administration of medicines being produced by the company.

– To diversify into related businesses within the same value-chain, for example by acquiring the means of distribution of its products.

– To undertake unrelated diversifications.

This research has adopted a relatively simple classification of diversification: a binary classification that would classify the first of these four options as undiversified and the remaining options as a full diversification.

The primary reason for opting for a simple classification relates to sample size. Although the various types of diversification listed above could be subjectively assessed and categorised reliably, the size of the sample in each category would be very small, especially because pharmaceutical companies have generally had an aversion to making acquisitions outside their core business. It would have therefore been difficult to obtain statistically significant results with a more granular classification of cross-border and cross-sector deals.

5.12.4 Linkage to Major Pharmaceutical Companies

The top 50 pharmaceutical companies were identified based on their health-care revenue generated during 2006, as recorded in Pharmalive (2007). Of these, details of the R&D pipeline were available for 48 that were the focus of the research and termed the ‘major’ companies below. Access to the database on which the report was based was also purchased and specific queries were resolved with the company. It is possible to check specific items of data on the database against public records.

Not all of the major companies had undertaken acquisitions and not all acquisitions were undertaken by these companies. However, out of the 591 acquisitions identified by the Thomson database in the sector during the 10

years' history, 140 related to the major pharmaceutical companies, of which 64 were cross-border and 29 were cross-sector acquisitions.

The resulting analysis measures M&A history where an acquiring company has since been acquired by a 'surviving' major company, (e.g. the acquisitions allocated to AstraZeneca include those for both Astra and Zeneca).

5.13 Analysis of M&A History

The collection of data of acquisitions and the boundaries set on the size of deal and the periods considered are described in Chapter 6 along with the acquisition typology. The key terms in the merger typology are defined in Table 5.7.

Once populated, the deal values for all deals, cross-border deals and cross-sector deals, are summed to arrive at the SDV values, A_k, B_k, C_k respectively, for k = 1 … 48, for the three cases. These are then divided by the annual cost of sales for the firms, D_k, to arrive at the NDV, a_k, b_k, c_k, for k = 1 … 48, for each of three cases. Both the SDV and the NDV that are applied in the statistical test approach are described in the following section.

Table 5.7 Key Terms for Acquisition Typology

Term	*Meaning*
Cross-border	A deal where the acquirer and the acquired have headquarters in different nations
Deals	An acquisition which results in majority control of the acquired firm by the acquiring firm
Deal Value	The 'ranking deal value' of the deal as specified on the Thomson One database. Broadly, this is the amount paid for the acquisition used in 'ranking' the deal in league tables
Firm	One of the Top 50 pharmaceutical companies existing in 2006 that has not been eliminated as an outlier
SDV	The sum of the deal values for an acquirer
NDV	SDV divided by the annual cost of sales of that firm
Cross-sector	A deal where the acquired company does not have a pharmaceutical Standard Industry Code

5.14 Statistical Test Approach

Traditional statistical testing, for example differences in mean DEA scores, (by parametric methods) is problematic because the scores are not independent. Grosskopf (1996) discussed approaches to the resolution of this problem; however, the approach in this thesis has been to circumvent the problem entirely by applying statistical tests to independent variables that were not themselves derived from DEA.

The hypothesis testing was initially undertaken using a test of significance based on a variation of the Student *t* test, a test proposed by Welch (1947),

suitable for testing two samples with unequal variances (the variances were calculated and shown to be unequal). This test is used to establish the confidence with which the difference between the two group means could be considered significant (a one-tailed or two-tailed test was used as appropriate, reflecting the phrasing of the null and the alternative hypotheses).

The *t* test depends on the calculation of a test statistic, T, given by:

$$T_o = (\mu_h - \mu_l)\,(\sigma_l^2/\pi_l + \sigma_h^2/\pi_h)^{-0.5} \qquad \text{Eq. (7)}$$

where the terms are as defined in Table 5.5 and the subscript '0' refers to the element of any variable relating to the DMU under analysis.

In this thesis, n = 48 and is even, so $\pi_l = \pi_h = n/2$. The T statistic is used to calculate the p-value by reference to the integral of the probability density function of the Student's *t* distribution. That p-value is then used in the hypothesis testing and compared with thresholds, as defined by Bowerman et al. (2011: 360).

In order to undertake the test for returns to scale for the R&D process the total set firms were divided into two subgroups: one with below-median scale efficiency and the other with above-median scale efficiency. For each group the mean of R&D current (x_{1k}, for k = 1 … n) for firms in the pair of groups was calculated, w_l and w_h, for the below-median and above-median groups respectively. In Eq. (7), μ_l to μ_h were set equal to w_l and w_h respectively and the variances σ_l^2 and σ_h^2 were set equal to $Var(w)_l$ and $Var(w)_h$ respectively.

In order to test the association between acquisition history and pure technical output efficiency a similar process was followed, namely θ_k, for k = 1 … n was used to divide the firms into two subgroups with lower-median and upper-

median values of θ_k. For each group, the statistics a_k, b_k, c_k, namely the NDVs for all deals, cross-border and cross-sector respectively, were used to calculate the mean values for the lower-median and upper-median groups. In Eq. (7):

- the value of μ_l was set equal to a_l, b_l, c_l;
- the value of μ_h was set equal to a_h, b_h, c_h;
- the variance σ_l^2 and were set equal to $Var(a)_l$, $Var(b)_l$, and $Var(c)_l$;
- the variance σ_h^2 was set equal to $Var(a)_h$, $Var(b)_h$, and $Var(c)_h$.

The testing of the ROS-related hypotheses followed an identical form to the testing of pure technical efficiency.

There was a second stage in the significance testing. A visual inspection of the distribution of the variables x_k a_k, b_k and c_k indicated a non-normal distribution. This was confirmed by the use of an Anderson–Darling test (1952). An additional significance test was therefore undertaken using a non-parametric test, namely the Mann–Whitney U test (Mann & Whitney, 1947), shown in Eq. (8).

$$U_l = \pi_l \pi_h + 0.5 \pi_l (\pi_l + 1) - R_l \qquad \text{Eq. (8)}$$

$$U_h = \pi_l \pi_h + 0.5 \pi_h (\pi_h + 1) - R_h$$

$$U = \min (U_l, U_h)$$

To apply the test, the ranks of the parameters of the two groups were calculated and the sums of the ranks in the two subgroups (R_l and R_h in Eq. 8) were calculated for each; U_l and U_h are then calculated and the lower value is used for the statistical test (in this case $\pi_l = \pi_h = n/2$ because n is even).

For samples where there are over 20 items in each group (i.e. n/2 > 20), as is the case in this research, the U statistic can be considered to be normally distributed and the z statistic can be calculated as shown in Eq. (9):

$$z = (U - 0.5\,\pi_l\,\pi_h)\,(\pi_l\,\pi_h\,(\pi_l + \pi_h + 1)/12)^{-0.5} \qquad \text{Eq. (9)}$$

where the terms are as defined in Table 5.5 and the subscript '0' refers to the element of any variable relating to the DMU under analysis.

The z statistic is then used to generate a p-value by reference to the normal distribution and the p-value is used for hypothesis testing as described earlier for the parametric tests.

Both the parametric Welch test and the non-parametric Mann–Whitney test were used for testing because some assumptions were violated in both (normality in the first and equal variances in the second); Zimmerman (1998) compares the approaches under the violation of assumptions. The paper found that non-parametric methods may not be acceptable substitutes for parametric methods when parametric assumptions are violated, and the approach in this thesis has therefore been to use both methods.

5.15 Incomplete Data

There were two cases of companies that appeared in the 'Top 50' list of global pharmaceutical companies, where it was not possible to establish their pharmaceutical R&D expenditure. Therefore these companies were excluded from the analysis, leaving a sample of 48 companies.

6 Data and Descriptive Statistics

6.1 Introduction

This chapter describes:

- the data used as inputs and outputs of the DEA models;
- the results from the DEA models that are used to examine the association with acquisition history;
- the financial data ROS, ROA and SOA are also described;
- the calculation of the acquisition history statistics, SDV and NDV.

The DEA model data are presented in tables given in Appendix D and the full acquisition data are presented in Appendix E, where the acquisition typology is populated for deals in aggregate, cross-border deals and cross-sector deals.

Having described the data, descriptive statistics are provided for:

- the R&D process, including the relation between scale efficiency and the R&D scale variable and the distribution of the R&D scale variable;
- the parameters used as DEA outputs: an assessment of the differences between the numbers of clinical trials and numbers of compounds;
- acquisitions in the sector, to establish the relation between size and frequency, and the NDV of major firms.

In some cases this analysis produces empirical findings in its own right and in the remaining cases it is preparatory work for the statistical testing of hypotheses. This chapter concludes with a summary of the main findings.

6.2 Available Input Data for the DEA Models

The available input data (not all the data are used in all the DEA models) are presented in Table D.1. The third column presents R&D expenditure for 2006 in $million. The fourth column shows a calculated figure for the historical expenditure that is expressed in 2006 currency values; the calculation principles are described in Appendix A and in summary comprise adjusting historical data for R&D expenditure back to 2001 for inflation and the ratio of R&D expenditure to sales. The fifth column is a figure for staff levels, based on a five year average of staffing levels, and the data for the calculations are shown in Appendix B.

Table D.1 also defines an abbreviated code for each company and the codes are used in later tables.

6.3 Available Output Data for the DEA Models

There are two possible output sets for the DEA models: the number of compounds produced for approval and the number of applications of those compounds either within the clinical trial process or awaiting approval. The numbers of compounds are shown in Table D.2.

Table D.3 shows the number of clinical trials at each stage of the pipeline and the ratio of trials to compounds at each stage. The ratios of trials to compounds at different stages of the pipeline can be used to draw inferences on which parameter is the most appropriate to use as an output for a DEA

model to examine R&D efficiency, although both models are built for both cases and their results compared.

6.4 Comparing CRS and VRS Efficiency Scores

The input data in Table D.1 relating to R&D only and the output data in Table D.2 were applied to both a VRS and a CRS output-orientated model. The resultant VRS and CRS efficiency scores, by firm, are shown in the second and third columns of Table D.4. The fourth column gives the calculated scale efficiency and the fifth column the natural logarithm of that parameter. The sixth column shows the natural logarithm of the mean of the two R&D inputs.

Table D.5 shows similar information to Table D.4 except that the outputs of the DEA model are the number of clinical trials as opposed to the number of compounds.

6.5 DEA Model Results: Comparing Input Assumptions

The previous results of the VRS DEA models did not include staff as an input. Table D.6 shows a comparison of R&D expenditure (current and historical) as inputs and then additionally with staff numbers as an additional input. In both cases, the outputs were the number of compounds (as opposed to the number of clinical trials).

6.6 Financial Efficiency Data

The ROS, ROA and SOA (formed by dividing ROS by ROA) are shown in Table D.7 for each firm.

6.7 Acquisition and NDV Data

The full acquisition data, extracted from the Thomson One Banker database, are provided in Appendix E. It comprises details on the deals and permits analysis by size, nation of acquirer and acquired, and the sector of the acquirer and acquired. Table D.8 gives the total value number of acquisitions for each company: SDV, the normalising factor (cost of sales and NDV), and the resulting NDV for each company.

Descriptive statistics on acquisitions and NDVs are provided later.

6.8 Association of M&A and Technical Efficiency

The bisection of the acquisition history statistics into two subgroups, below-median and above-median pure technical efficiency is shown in Tables D.9, D.10 and D.11.

Tables D.9 and D.10 list NDV and they show the bisection based on two different DEA models, and Table D.11 shows the bisection of SDV using the base model. In the table headings '<M' is the abbreviation for below median and '>M' is the abbreviation for above median.

Table D.9 shows the bisection based on the VRS technical efficiencies that are calculated using the number of compounds as an output and R&D expenditure alone as an input. This is the base model used for comparisons with alternatives.

Table D.10 shows the bisection based on the VRS technical efficiencies using the number of compounds as an output and both R&D expenditure as well as staff numbers as inputs.

The outcome of the hypothesis testing is when the two different DEA models are later compared.

6.9 Association of M&A and Financial Efficiency

The bisection of the acquisition history statistics into two subgroups on the basis of financial efficiency is shown in Tables D.12, D.13 and D.14.

Table D.12 shows the bisection based on ROS, Table D.13 shows the bisection for ROA and Table D.14 shows the bisection based on SOA.

6.10 Descriptive Statistics of the DEA Model Outputs

The initial choice of outputs for the measurement framework was made with reference to the RBV and the consideration of what constitutes a resource of the firm. On this basis the number of compounds and the number of clinical trials within the R&D pipeline were both identified as resources because they represented potential future revenue. However, it was not possible to use the RBV further to make a choice between these options as to which would be the better parameter to use to measure R&D productivity. It may be the case that a higher ratio of trials to compounds indicates that a firm is producing more productive compounds, or it may simply be the case that the firm is choosing to incur higher development costs for higher eventual return from the compounds they have available.

It is, however, possible to examine the data of the proportions of compounds to trials and draw inferences. Table 6.1 shows the mean and standard deviation of the ratio of clinical trials to compounds through the pipeline.

Table 6.1 Descriptive Statistics of Ratio of Trials to Compounds

Phase	PreClinical	Phase I	Phase II	Phase III	Awaiting Approval
Mean	1.16	1.26	1.56	1.65	1.35
Std Dev	0.25	0.36	0.54	0.60	0.58

Table 6.1 shows a small ratio in the Preclinical and Phase 1 stages, where the interaction between the compound and a human is first examined. After this, the ratio increases as does the variance, as the compound enters subsequent more expensive phases. The results for the 'Awaiting Approval' may indicate that where large numbers of trials have been commissioned then some of the more speculative trials did not produce the intended results.

This qualitative reasoning was supported by a series of paired two-tailed *t* tests undertaken between the ratios of compounds at each stage of the pipeline on whether they were taken from the same sample (see Table 6.2).

Table 6.2 *t* test on Ratios of Trials to Compounds in Successive Phases

Phase	Preclinical/Phase 1	Phase I/II	Phase II/III	Phase III/AA
p-value	34%	0.003%	38%	0.7%

These statistics are consistent with the hypothesis that the safety of a compound on humans is first confirmed in Preclinical and Phase 1, with no statistical significant difference between the ratios of compounds per trial. A commercial decision is then made as to whether to incur considerable

expense funding multiple trials in Phase II and Phase III, or to adopt a more cautious approach by restricting the more expensive clinical trials to the most promising indications. Finally there seems to be confirmation that some degree of caution in commissioning trials is justified because the ratio of trials to compounds going forward for eventual approval drops back, and there is a statically significant difference between the ratio for Phase 3 and Awaiting Approval (by contrast to the absence of a difference between Phase II and phase III).

Given this analysis, the primary examination of R&D efficiency has been undertaken by considering the number of compounds as the output of the R&D process, as opposed to the number of clinical trials.

6.11 Descriptive Statistics of the R&D Process

Figure 6.1 shows a plot of the logarithm of the scale efficiency and the logarithm of the average of the current and historic annual R&D expenditure for the 48 firms. The graph shows that there is an apparent linear relationship between the two variables when the output of the DEA model is considered to be the number of compounds. A regression line is also given as a visual aid, although no formal regression was undertaken.

Figure 6.1. Graph of Scale Efficiency Versus Mean R&D (Compounds as Output)

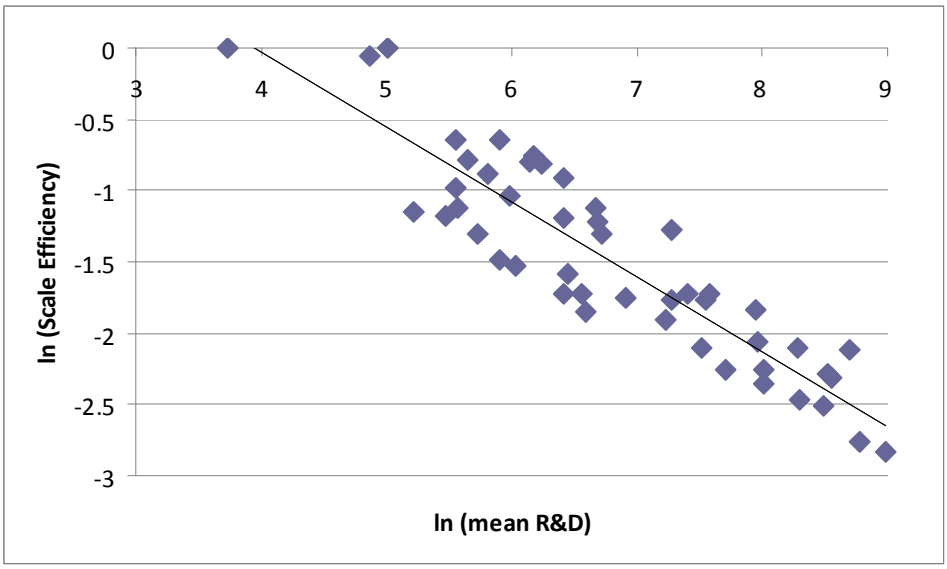
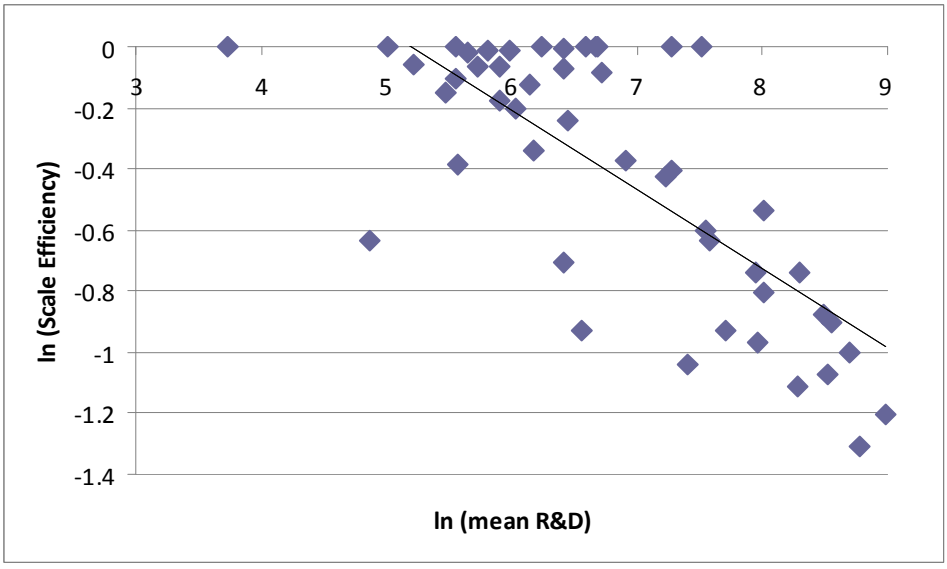


Figure 6.2 shows an equivalent graph but with the number of trials as an output. The linear relationship is still apparent but the degree of scatter is higher. This could imply that there are fewer exogenous influences on production when the output of the R&D processes is taken to be the number of compounds as opposed to the number of trials.

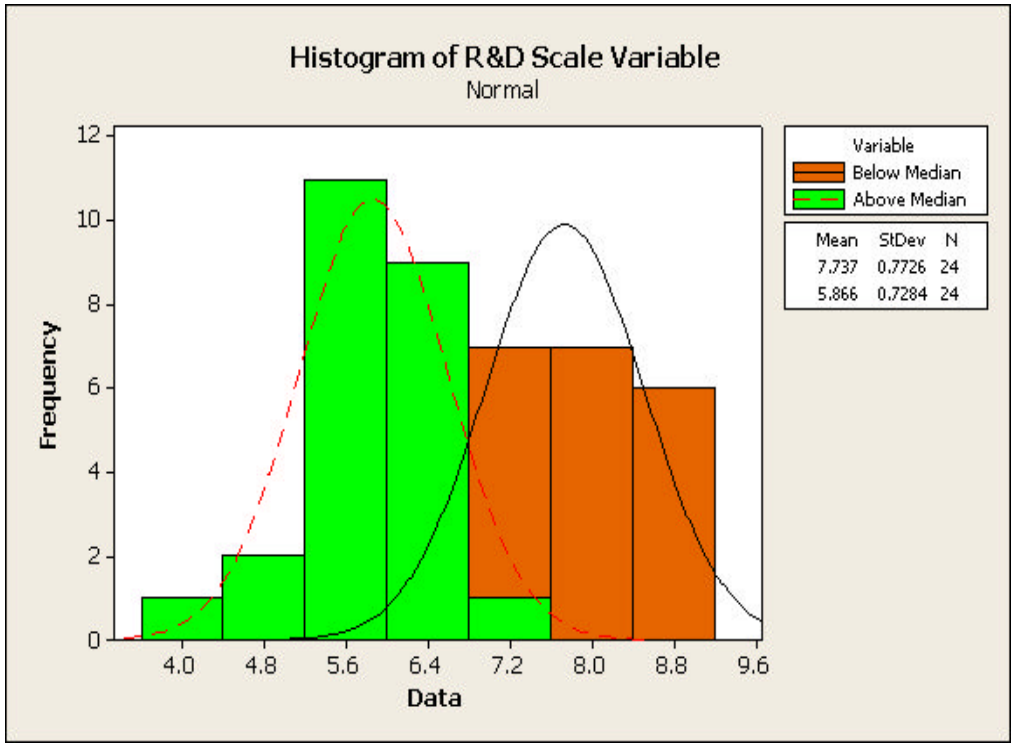
Figure 6.2 Graph of Scale Efficiency Versus Mean R&D (Trials as Output)



The graphs above do not in themselves test for scale, although they are strongly suggestive that scale effects exist. To test for scale, the model with the number of compounds as an output was used. The scale efficiencies of the firms was used to bisect the sample into two subgroups of above-median and below-median efficiency. The mean of the R&D expenditure of the firms in the two subgroups was then tested for a statistically significant difference.

The distribution of R&D expenditure for the two groups is shown in Figure 6.3

Figure 6.3 Distribution of R&D Expenditure of Above- and Below-Median Efficiency



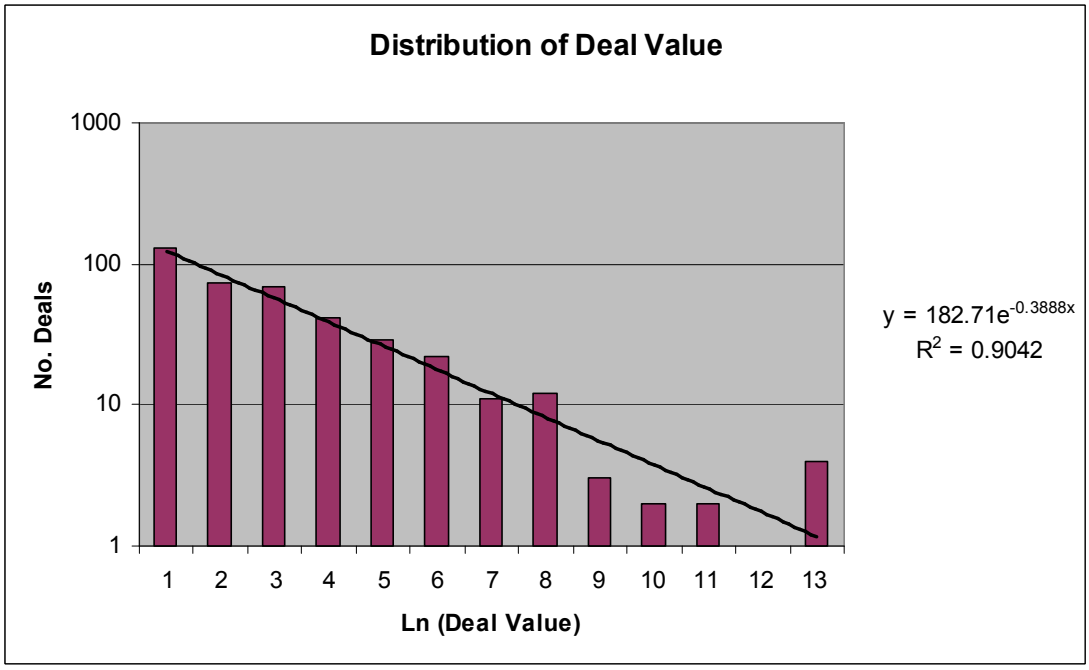
Visually it is apparent that the subgroups have markedly different distributions however formal hypothesis testing is problematic. The subgroup with below-median scale efficiency does not have a normal distribution and therefore the assumptions of the Welch test, which requires normally distributed data, have

been violated. The non-parametric Mann–Whitney test can be used, however this requires equal variances in the subgroups and in the sample above the variances differ by 40%. Therefore a triangulation approach has been employed, using both a parametric approach and a non-parametric approach, with the results being compared (as explained further in Section 7.2).

6.12 Descriptive Statistics of M&A

Park et al. (2010) have asserted that the distribution of size of M&A versus frequency follows a power law: the logarithm of the size of an occurrence is proportional to the increase of the frequency. This research offered the opportunity to examine this claim in the context of the pharmaceutical sector. The distribution of M&A deal size in the acquisitions for the 510 pharmaceutical acquisitions in the full sample was examined by plotting logarithm of value by frequency, as shown in Figure 6.4.

Figure 6.4 Frequency of M&A Deals by Value



The results generally are consistent with a power law (as indicated by the linear trendline on log/log scales), however it must be stressed the evidence is not conclusive because other distributions can show a similar relationship (see Appendix C). It can be seen that for very large acquisitions the linear relationship breaks down, with a disproportionate number of 'mega-mergers' (four) in the top category in Figure 6.4 and a dearth of numbers of mergers in the categories immediately below (although this effect might depend on the threshold of adjacent categories used in that figure). Of the four mega-mergers two were undertaken by Pfizer, one by Sanofi-Aventis and one by GlaxoSmithKline. Pfizers' ROS was close to mean, GlaxoSmithKline's near the top of the range and Sanofi-Aventis's relatively poor. This is consistent with a diversity of motive for the mega-mergers, with Pfizer acting as a profitable predator and the Sanofi-Aventis deal being a defensive merger (which was actually encouraged by the French government to preserve a French major pharmaceutical company[2]).

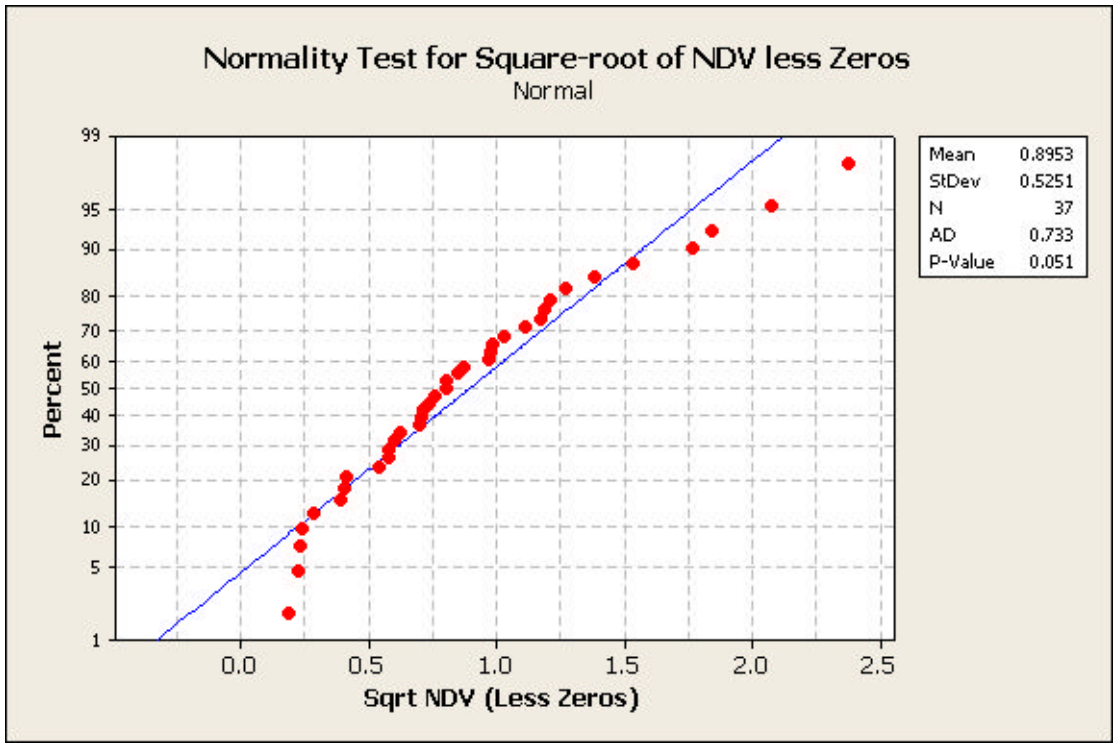
NDV has been used as a measure of acquisition history for the individual firm and the distribution of this parameter was also examined. Park et al. (2010) note that when examining acquisition frequency a Poisson distribution is commonly assumed, and given acquisitions are discrete events this is not implausible.

A goodness-of-fit test for a Poisson distribution was performed and the expected versus observed values showed a higher than expected number of zeros (shown in column 1, Figure 6.4). If the 11 zeros are removed and the square root of the remaining NDV's is subject to a normality test (McCullagh & Nelder, 1989: 196, explain that a feature of the Poisson distribution is that the

[2] http://news.bbc.co.uk/1/hi/business/3658639.stm

square root of the distribution may approximate normal), then the resulting p-value is close to 5%, as Figure 6.5 confirms.

Figure 6.5 Normality Test for Square Root of NDV less Zeros



The establishment that the square root of NDV is normally distributed once zeros are removed is an interesting finding that suggests that the use of Zero-Inflated Poisson models may have some future application in analysing merger behaviour or undertaking statistical tests, however this was not taken further in this thesis.

6.13 Summary

The differences in measures of mean NDV, which will be tested in the next chapter, are summarised in Table 6.3 for technical efficiency and Table 6.4 for financial efficiency.

Table 6.3 Summary of Association of Acquisition History with Technical Efficiency

	Table Ref.	a_k θ_k <M	a_k θ_k >M	b_k θ_k <M	b_k θ_k >M	c_k θ_k <M	c_k θ_k >M
NDV, DEA Base Model	6.9	0.74	0.91	0.33	0.21	0.06	0.03
NDV, DEA Staff Model	6.10	0.72	0.92	0.36	0.18	0.06	0.03
SDV, DEA Base Model	6.11	4345	19174	1056	4442	472	744

Table 6.4 Summary of Association of Acquisition History with Financial Efficiency

	Table Ref.	a'_k θ_k <M	a'_k θ_k >M	b'_k θ_k <M	b'_k θ_k >M	c'_k θ_k <M	c'_k θ_k >M
NDV, ROS	6.12	0.50	1.15	0.13	0.41	0.06	0.02
ROA	6.13	0.70	0.95	0.28	0.26	0.044	0.041
SOA	6.14	1.03	0.62	0.31	0.23	0.02	0.07

The MCTs of the subgroups with above and below efficiencies are now subject to statistical testing (see Chapter 7).

7 Hypothesis Testing

7.1 Scope of Hypothesis Testing

7.1.1 Classical Hypothesis Testing Model

The hypotheses have been divided into five sets, as explained in Section 1.4. The hypotheses are tested using p-values derived from parametric and non-parametric tests, using what Sheshkin (2011: 57) terms the *'classical hypothesis testing model'*, which is a fusion of the work of Fisher (1925) who proposed the concept of the null hypothesis and Neyman & Pearson (1933) who developed the concept of the alternative hypothesis. There were substantial differences between Fisher (1925) and Neyman and Pearson (1933) and the hybrid development (that is now termed the 'classical hypothesis testing model') was developed in subsequent text books; Lehmann (1993) examines the consistency of the hybrid and considers there is statistical consistency.

A comprehensive contemporary textbook, Sheskin (2011: 58) outlines the key terms of the classical model, beginning with the null hypothesis which is defined as "*a statement of no effect or no difference'*. In this thesis, the null hypothesis is therefore taken to correspond to the status of the literature prior to the research. Having defined the null hypothesis, Sheskin (2011: 58) then defines the second key concept: *"The alternative hypothesis, on the other hand, represents a statistics statement indicating the presence of an effect or a difference"*. The null and alternative hypotheses are exclusive; it is the alternative hypothesis that is tested and any conclusion regarding the null hypothesis is drawn by inference.

The classical model also requires a significance level to be chosen, although it should be noted Neyman & Pearson (1933) opposed the use of an arbitrary significance level, believing the researcher should choose the level in order to balance the risk of Type I and Type II errors. Fisher (1925) proposed 1% and 5%, although Fisher (1955) stated that it was not necessary to stipulate a significance level before an experiment (a modification of his earlier stance) and if the result was considered significant by the researcher, then the result should be reported along with its probability value (or p-value). Fisher's concluding comment in that paper was: *"We have the duty of formulating, of summarising, and of communicating our conclusions, in intelligible form, in recognition of the right of other free minds to utilize them in making their own decisions"* seems to be a call for transparency as opposed to an arbitrary selection of a significance levels.

To avoid arbitrariness in this thesis, a probability level for the statistical test ('p-level') is calculated using both parametric and non-parametric tests and then interpreted. For guidance in interpretation, Bowerman et al. (2011: 360) provide the following interpretations of p-values: *"0.1, some evidence; 0.05, strong evidence; 0.01, very strong evidence; 0.001, extremely strong evidence"*, however the authors go onto note: *"there are no really sharp borders between different weights of evidence. Rather, there is only increasingly strong evidence...as the p-value decreases"*.

In the unusual cases here there is divergence in interpretation between the parametric and non-parametric tests, then each case is considered on its merits and a retrospective check has been made for consistency of interpretation across cases.

In summary the method proposed by Fisher (1955) and the terminology of Bowerman et al. (2011) has been drawn upon to develop an approach to the interpretation of both the parametric and non-parametric results.

7.1.2 Set 1, Hypothesis 1: Returns to Scale

Hypothesis 1 is to establish whether pharmaceutical R&D demonstrates CRS or VRS. This allows for the selection of the most appropriate form of DEA model to be used in the subsequent hypothesis tests and is a necessary step in this research because previous literature has provided disparate results, with a sector-specific reference: Graves & Langowitz (1993) indicating Decreasing Returns to Scale (DRS) in contrast to the generic Schumpeterian hypothesis of Increasing Returns to Scale (IRS) for R&D, as originally proposed in Schumpeter (1950).

Given the conflicting prior references on DRS and IRS, the null hypothesis does not presume either and is:

H1n: There are CRS for pharmaceutical R&D.

The alternative hypothesis, which will be tested, is:

H1a: There are VRS for pharmaceutical R&D.

A testing approach has been developed that avoids the statistical testing of DEA scores by using the DEA scores to form two subgroups of the more efficient and less efficient, and testing the difference of the means of the R&D expenditure of the two subgroups.

The testing approach does presume that IRS and DRS do not exist simultaneously for different sizes of firms in the sample. However, examination

of the descriptive statistics in Figure 6.1 shows a decreasing monotonic relationship between scale efficiency and size of R&D expenditure (average).

7.1.3 Set 2, Hypotheses 2, 3 & 4: Firm Acquisition History and Technical Efficiency

The main focus of the research is the association between acquisition history and the technical efficiency of the R&D process. The null hypothesis is that firms with above-median efficiency and below-median efficiency have similar merger history, as measured by the parameter NDV: the sum of M&A value over time divided by a normalisation factor that represents the size of the firm. The set of firms is divided into two equal-sized subgroups of above- and below-average efficiency and the MCT, that is the mean or median[3], of NDV for each subgroup is calculated. The null hypothesis is:

> H2n: Firms with an above-median technical efficiency have the same MCT of NDV as those with below-median technical efficiency.

The alternative hypothesis, which will be tested, is one-sided to reflect the Merger Paradox and is:

> H2a: Firms with an above-median technical efficiency have a lower MCT of NDV than those with below-median technical efficiency.

Less formally, this states that companies that are more merger-prone are less efficient, as is consistent with the Merger Paradox.

[3] The term MCT is used in preference to either mean or median because both parametric and non-parametric tests have been used to test the differences in MCT between samples, with the former testing mean and the latter testing median.

Two further hypotheses examined diversifications to gain resources in new markets (i.e. cross-border acquisitions) and new sectors (i.e. cross-sector acquisitions). The two hypotheses consider each of these types of diversification and follow a similar format to that considering acquisitions in general. The two null hypotheses are:

> H3n: Firms with an above-median technical efficiency have the same MCT of NDV for cross-border deals as those with below-median technical efficiency.
>
> H4n: Firms with an above-median technical efficiency have the same MCT of NDV for cross-sector deals as those with below-median technical efficiency.

The corresponding alternative hypotheses are:

> H3a: Firms with an above-median technical efficiency have a lower MCT of NDV for cross-border deals than those with below-median technical efficiency.
>
> H4a: Firms with an above-median technical efficiency have a lower MCT of NDV for cross-sector deals than those with below-median technical efficiency.

The outcomes of the testing of these alternative hypotheses are then compared with the outcomes of the tests examining financial efficiency, as described below.

7.1.4 Set 3, Hypotheses 5, 6 & 7: Deal History and Financial Efficiency

The null hypotheses H5n, H6n and H7n are restatements of H2n, H3n and H4n but with ‘technical efficiency’ replaced with ‘financial efficiency’. However

the alternative hypotheses are phrased in the opposite direction, namely that above-median financial efficiency is associated with a higher MCT of NDV, as might be expected if the M&A deal is allowed to proceed and indeed Higgins & Rodriguez (2006) confirm improved financial performance following acquisitions in the pharmaceutical industry.

The alternative hypotheses are:

> H5a: Firms with an above-median financial efficiency have a higher MCT of NDV than those with below-median financial efficiency.
>
> H6a: Firms with an above-median financial efficiency have a higher MCT of NDV for cross-border deals than those with below-median technical efficiency.
>
> H7a: Firms with an above-median financial efficiency have a higher MCT of NDV for cross-sector deals than those with below-median technical efficiency.

Financial efficiency is measured by ROS and ROA so six tests are undertaken on the three alternative hypotheses.

7.1.5 Set 4, Hypotheses 8, 9 & 10: Acquisition History and Sectoral Efficiency

Hypotheses H8n, H9n and H10n are restatements of H2n, H3n and H4n but with NDV replaced by Sum of Deal Value (SDV). SDV omits the normalisation used to express the sum of previous acquisitions in a form relative to the size of the firm. Efficiency is still measured at firm level at the firm but all the acquisitions in the sector are associated with firms grouped into the more efficient and the less efficient. In practice the larger acquisitions made by the

larger firms overshadow the smaller acquisitions made by the smaller firms. The effect is to examine if the sector's acquisitions as a whole are associated with higher or lower efficiency at firm level and hence consider the effect of acquisitions on the sector in aggregate.

The direction of the alternative hypotheses reflects findings in the financial M&A literature that M&A could benefit the sector as a whole, if not the acquiring firm; that is, the hypotheses are one-sided in the direction indicated by Seth et al. (2000) who found M&A provides benefits if the gains of the acquirer and acquired are considered together

The null hypotheses are that there is no difference in distribution of acquisition value between the more efficient and the less efficient companies. The alternative hypotheses, which will be tested, are:

> H8a: Firms with an above-median technical efficiency have a higher MCT of SDV than those with below-median technical efficiency.
>
> H9a: Firms with an above-median technical efficiency have a higher MCT of SDV for cross-border deals than those with below-median technical efficiency.
>
> H10a: Firms with an above-median technical efficiency have a higher MCT of SDV for cross-sector deals than those with below-median technical efficiency.

The outcomes of the testing of these alternative hypotheses are then used to examine the Merger Paradox at sector-level.

7.1.6 Set 5, Hypotheses 11, 12, 13 & 14: Acquisition History and Sales over Assets

The purpose of H11 is to examine the effect of M&A on financial metrics. The null hypothesis for M&A is that there is no difference in the acquisition history of firms between those with above-median SOA and those with below-median SOA (there is no reason to expect a difference to occur) and the hypothesis for M&A in aggregate is:

> H11n: Firms with an above-median SOA have the same MCT of NDV as those with below-median SOA.

The null hypotheses for cross-border and cross-sector deals, H12 and H13 respectively, are similar.

The alternative hypotheses, which will be tested, are one-sided in the direction indicated by Boekestein (2009), and are:

> H11a: Firms with an above-median SOA have a lower MCT of NDV than those with below-median SOA.
>
> H12a: Firms with an above-median SOA have a lower MCT of NDV for cross-border deals than those with below-median SOA.
>
> H13a: Firms with an above-median SOA have a lower MCT of NDV for cross-sector deals than those with below-median SOA.

This presumes that M&A leads to a greater recognition of intangible assets and hence a lowering of SOA, as Boekestein (2009) noted.

It transpires that in the last case the alternative hypothesis is ‘accepted’ but in the reverse direction, which undermines the basis for a unidirectional test.

Therefore a fourteenth non-directional alternative hypothesis has been formulated:

> H14a: Firms with an above-median SOA do not have the same MCT of NDV for cross-sector deals as those with below-median SOA.

H14n is identical to H13n, which is similar to H11n, as shown above.

7.2 Returns to Scale (H1)

The relationship between scale efficiency and an R&D scale variable has already been examined graphically and a monotonic relationship observed between the log of the R&D scale variable and the log of the scale efficiency, indicating VRS (more specifically, DRS). The hypothesis of CRS is now formally tested.

A two-sided parametric Welch test and a two-sided non-parametric Mann–Whitney test for H1a was undertaken and in both cases H1a was accepted for $p < 0.1\%$. Because the alternative hypothesis was accepted, the null hypothesis of CRS was rejected with strong statistical evidence.

The testing results are summarised in Table 7.1

Table 7.1 Results of Tests on Hypothesis H1a

Test	P-value	Interpretation
Non-parametric	< 0.1%	Extremely Strong Evidence to Accept
Parametric	< 0.1%	Extremely Strong Evidence to Accept

In summary there is extremely strong evidence for accepting VRS and the descriptive statistics confirm show this to be monotonic DRS and the null hypothesis H1n is rejected.

7.3 M&A and Technical Efficiency (H2, H3, H4)

7.3.1 Hypothesis 2

For the base model, the mean of the NDV for the companies with above-median efficiency is 0.91 and the mean NDV for the companies with below-median efficiency is 0.74, the reverse of that indicated in the alternative hypothesis. Testing for the significance of the reverse of H2a using a one-sided Mann–Whitney test gives a p-value of 28%. A one-sided Welch test gives a p-value of 30%. We conclude that there is no statistical evidence to accept the reverse of H2a on the basis of the DEA scores of the base model.

For the model with staff as an input, the mean of the NDV for the companies with above-median efficiency is 0.92 and the mean NDV for the companies with below-median efficiency is 0.72, a slightly larger difference than the base model, and the reverse of that indicated in the alternative hypothesis. Testing for the significance for the reverse of H2a using a one-sided Mann–Whitney test gives a p-value of 24%. A one-sided Welch test gives a p-value of 28%. We conclude that there is no statistical evidence to accept the reverse of H2a on the basis of the DEA scores of the DEA model with staff inputs.

The testing results for H2a are summarised in Table 7.2:

Table 7.2 Results of Tests on Hypothesis H2a

Test	Model	Direction	P-value	Interpretation
Non-parametric, H2a	Base	Reverse	28%	No Evidence
Parametric, H2a	Base	Reverse	30%	No Evidence
Non-parametric, H2a	Staff Input	Reverse	24%	No Evidence
Parametric, H2a	Staff Input	Reverse	28%	No Evidence

In summary, in each case there is no statistical evidence to accept the reverse of the alternative hypothesis with either DEA model and the null hypothesis H2n therefore stands.

7.3.2 Hypothesis 3

For the base model, the mean of the NDV for the companies with above-median efficiency is 0.21 and the mean NDV for the companies with below-median efficiency is 0.33, in the direction of that indicated in the alternative hypothesis. Testing for significance using a Mann–Whitney test gives a p-value of 40%. A one-sided Welch test gives a p-value of 28%. We conclude that there is no statistical evidence to accept H3a on the basis of the DEA scores of the base model.

For the model with staff as an input, the mean of the NDV for the companies with above-median efficiency is 0.18 and the mean NDV for the companies with below-median efficiency is 0.36, in the direction of that indicated in the alternative hypothesis. Testing for significance using a Mann–Whitney test gives a p-value of 47%. A one-sided Welch test gives a p-value of 20%. We conclude there is no statistical evidence to accept H3a on the basis of either test and therefore the null hypothesis stands.

The testing results for H3a are summarised in Table 7.3:

Table 7.3 Results of Tests on Hypothesis H3a

Test	Model	Direction	P-value	Interpretation
Non-parametric, H3a	Base	Standard	40%	No Evidence
Parametric, H3a	Base	Standard	28%	No Evidence
Non-parametric, H3a	Staff Input	Standard	47%	No Evidence
Parametric, H3a	Staff Input	Standard	20%	No Evidence

In summary, in each case there is no statistical evidence to accept the alternative hypothesis with either DEA model and the null hypothesis H3n therefore stands.

7.3.3 Hypothesis 4

For the base model, the mean of the NDV for the companies with above-median efficiency is 0.03 and the mean NDV for the companies with below-median efficiency is 0.06, in the direction of that indicated in the alternative hypothesis. Testing for significance using a Mann–Whitney test gives a p-value of 30%. A one-sided Welch test gives a p-value of 11%. We conclude, although there is formally no evidence on the basis of the parametric test (although the p-value is close to the 10% threshold), and no evidence from the non-parametric test, taking the tests together, there is not sufficient statistical evidence to accept the alternative hypothesis. The null hypothesis therefore stands.

For the model with staff as an input, the mean of the NDV for the companies with above-median efficiency is 0.03 and the mean NDV for the companies with lower-median efficiency is 0.06, in the direction of that indicated in the alternative hypothesis. Testing for significance using a Mann–Whitney test gives a p-value of 31%. A one-sided Welch gives a p-value of 12%. We

conclude that there is not sufficient statistical evidence to accept the alternative hypothesis. The null hypothesis therefore stands.

The testing results for H4a are summarised in Table 7.4:

Table 7.4 Results of Tests on Hypothesis H4a

Test	Model	Direction	P-value	Interpretation
Non-parametric, H4a	Base	Standard	30%	No Evidence
Parametric, H4a	Base	Standard	11%	No Evidence
Non-parametric, H4a	Staff Input	Standard	31%	No Evidence
Parametric, H4a	Staff Input	Standard	12%	No Evidence

In summary, in each case there is no statistical evidence to accept the alternative hypothesis with either DEA model and the null hypothesis H4n therefore stands.

7.3.4 Summary of the Set

The main finding is that the DEA efficiency scores, for either DEA model, do not provide statistically significant evidence to accept the alternative hypothesis (or, where appropriate its reverse). Therefore the null hypothesis stands for all the three cases, namely M&A deals in aggregate, or cross-border and cross-sector deals, specifically are not associated with changes in technical efficiency.

Furthermore, the p-values for testing with the R&D-only model and the model with staff inputs are similar, and this suggests that any staff reduction effect is small. Therefore the base model alone is used in later hypothesis testing.

7.4 M&A and Financial Efficiency (H5, H6, H7)

7.4.1 Hypothesis 5

When financial efficiency is measured with ROS, the mean of the NDV for the companies with above-median efficiency is 1.15 and the mean NDV for the companies with below-median efficiency is 0.5, in the direction indicated by the alternative hypothesis. Testing for significance using a Mann–Whitney test gives a p-value of 20%. However a one-sided Welch test gives a p-value of 3%, which indicates strong evidence. Given the disparity between strong and no evidence, the interpretation of the results is that there is some evidence (we note the average of the scores in the region of 10%, the threshold for 'some evidence').

When financial efficiency is measured with ROA, the mean of the NDV for the companies with above-median efficiency is 0.95 and the mean NDV for the companies with below-median efficiency is 0.7, again in the direction indicated in the alternative hypothesis. Testing for significance using a Mann–Whitney test gives a p-value of 33%. A one-sided Welch test on the NDV gives a p-value of 23%. We conclude that there is no statistical evidence to accept H5a for ROA and the null hypothesis stands.

The testing results for H5a are summarised in Table 7.5:

Table 7.5 Results of Tests on Hypothesis H5a

Test	Model	Direction	P-value	Interpretation
Non-parametric, H5a	ROS	Standard	20%	No Evidence
Parametric, H5a	ROS	Standard	3%	Strong Evidence
Non-parametric, H5a	ROA	Standard	33%	No Evidence
Parametric, H5a	ROA	Standard	23%	No Evidence

In summary, following the discussion above, there is some statistical evidence to accept the alternative hypothesis when ROS is used but not when ROA is used to measure financial efficiency. The null hypothesis H5n is therefore rejected for ROS but stands for ROA.

7.4.2 Hypothesis 6

When financial efficiency is measured with ROS, the mean of the cross-border NDV for the companies with above-median efficiency is 0.41 and the mean NDV for the companies with below-median efficiency is 0.13, in the direction of that indicated in the alternative hypothesis. Testing for significance using a Mann–Whitney test gives a p-value of 12% for acceptance of the alternative hypothesis. A one-sided Welch test gives a p-value of 8%. Taking both results together, the parametric result indicates some evidence although the non-parametric does not; however the non-parametric result is only slightly over the threshold and the mean of the results is on the threshold. On this basis, there is some statistical evidence to accept H6a and on the basis of the ROS scores and reject the null hypothesis.

When financial efficiency is measured with ROA, the mean of the cross-border NDV for the companies with above-median efficiency is 0.26 and the mean NDV for the companies with below-median efficiency is 0.28, the reverse of

that indicated in H6a. Testing the reverse of H6A for significance using a Mann–Whitney test gives a p-value of 22%. A one-sided Welch test gives a p-value of 47%. We conclude that for ROA there is no statistical evidence to accept the reverse of H6a on the basis of either a parametric or a non-parametric test.

The testing results for H2a are summarised in Table 7.6.

Table 7.6 Results of Tests on Hypothesis H6a

Test	Model	Direction	P-value	Interpretation
Non-parametric, H6a	ROS	Standard	12%	No Evidence
Parametric, H6a	ROS	Standard	8%	Some Evidence
Non-parametric, H6a	ROA	Reverse	22%	No Evidence
Parametric, H6a	ROA	Reverse	47%	No Evidence

In summary, there is some statistical evidence to accept the alternative hypothesis H6a when ROS is used but not to accept the reverse of H6a when ROA is used to measure financial efficiency. Therefore where ROS is used the null hypothesis H6n is rejected but it stands when ROA is used.

7.4.3 Hypothesis 7

When financial efficiency is measured with ROS, the mean of the cross-sector NDV for the companies with above-median efficiency is 0.02 and the mean NDV for the companies with below-median efficiency is 0.06, the reverse of the direction indicated in the alternative hypothesis. Testing the reverse of H7a using a Mann–Whitney test gives a p-value of 33% and a one-sided Welch test gives a p-value of 8%. The results do diverge, however the non-parametric test is close to the 10% threshold and the mean of the results

exceeds the threshold by a factor of two. Given this there is no reliable statistical evidence to accept the reverse of hypothesis H7a.

When financial efficiency is measured with ROA, the mean of the cross-sector NDV for the companies with above-median efficiency is 0.044 and the mean NDV for the companies with below-median efficiency is 0.041: close to equal but the reverse of that indicated in H7a. A one-sided Welch test of the reverse of H7a gives a p-value of 45% and a Mann–Whitney test (which compares medians) gives a p-value of 18%. We note there is no statistical evidence to accept the reverse hypothesis H7a with either test.

The testing results for H2a are summarised in Table 7.7:

Table 7.7 Results of Tests on Hypothesis H7a

Test	Model	Direction	P-value	Interpretation
Non-parametric, H7a	ROS	Reverse	33%	No Evidence
Parametric, H7a	ROS	Reverse	8%	No Evidence
Non-parametric, H7a	ROA	Reverse	18%	No Evidence
Parametric, H7a	ROA	Reverse	45%	No Evidence

In summary, there is no reliable evidence to accept the reverse of alternative hypothesis H7a for either ROA or ROS when the parametric and non-paramagnetic tests are considered in unison. The null hypothesis H7n therefore stands.

7.4.4 Summary of the Set

For M&A in aggregate and for cross-border deals there is some statistical evidence to accept the alternative hypotheses H5a and H6a, and hence reject the hypotheses H5n and H6n for M&A in aggregate and cross-border deals

respectively, when ROS is used as a metric for financial efficiency; however this is not observed when ROA is used. For cross-sector deals, there is no evidence to accept H7a with either ROS or ROA.

7.5 Sector Effects and Technical Efficiency (H8, H9, H10)

7.5.1 Hypothesis 8

For the base model, the mean of the SDV for the companies with above-median efficiency is 19174 and the mean SDV for the companies with below-median efficiency is 4345, in the direction of that indicated in the alternative hypothesis. Testing for significance using a Mann–Whitney test gives a p-value of 18%. A one-sided Welch test gives a p-value of 4%. Following similar logic to that proposed for the testing of H5a for the use of ROS, namely the parametric test shows strong evidence although the mean of the parametric and non-parametric tests is in the region of 10%, we conclude that there is some statistical evidence to accept H8a on the basis of the DEA scores of the base model. The testing results for H8a are summarised in Table 7.8:

Table 7.8 Results of Tests on Hypothesis H8a

Test	Direction	P-value	Interpretation
Non-parametric, H8a	Standard	18%	No Evidence
Parametric, H8a	Standard	4%	Strong Evidence

On this basis H8n was rejected.

7.5.2 Hypothesis 9

For the base model, the mean of the SDV for the companies with above-median efficiency is 4442 and the mean NDV for the companies with below-

median efficiency is 1056, in the direction of that indicated in the alternative hypothesis. Testing for significance using a Mann–Whitney test gives a p-value of 26%. A one-sided Welch test gives a p-value of 4%. As the mean of these scores is 15%, we conclude that there is no statistical evidence to accept H9a or reject the null hypothesis.

Table 7.9 Results of Tests on Hypothesis H9a

Test	Direction	P-value	Interpretation
Non-parametric, H9a	Standard	26%	No Evidence
Parametric, H9a	Standard	4%	Strong Evidence

There is no statistical evidence to accept the hypothesis H9a and the null hypothesis H9n stands.

7.5.3 Hypothesis 10

For the base model, the mean of the SDV for the companies with above-median efficiency is 744 and the mean SDV for the companies with below-median efficiency is 472, in the direction of that indicated in the alternative hypothesis. Testing for significance using a Mann–Whitney test gives a p-value of 45%. A one-sided Welch test gives a p-value of 30%. We conclude that there is no statistical evidence to accept H10a. The testing results for H10a are summarised in Table 7.10:

Table 7.10 Results of Tests on Hypothesis H10a

Test	Direction	P-value	Interpretation
Non-parametric, H10a	Reverse	28%	No Evidence
Parametric, H10a	Reverse	30%	No Evidence

There is no statistical evidence to accept the hypothesis H10a and the null hypothesis H10n stands.

7.5.4 Summary of the set

The main finding is that in aggregate the DEA efficiency scores do provide some statistically significant evidence to accept the alternative hypothesis that mergers are associated with higher technical efficiency in aggregate, when SDV was considered to examine sector effects.

For cross-border deals the parametric test gave strong evidence to accept but this was not supported by the non-parametric test and therefore a conclusion of no evidence was drawn; for cross-sector deals neither test gave evidence to accept the alternative hypotheses.

7.6 M&A and Financial Metrics (H11, H12, H13, H14)

7.6.1 Hypothesis 11

For M&A in aggregate, the mean SOA of the cross-sector NDV for the companies with above-median efficiency is 0.62 and the mean NDV for the companies with below-median efficiency is 1.03, in the direction of the alternative hypothesis. Testing for significance using a Mann–Whitney test gives a p-value of 40%. A one-sided Welch test gives a p-value of 12%.

The testing results for H11a are summarised in Table 7.11:

Table 7.11 Results of Tests on Hypothesis H11a

Test	Direction	P-value	Interpretation
Non-parametric, H4a	Standard	40%	No Evidence
Parametric, H4a	Standard	12%	No Evidence

There is no statistical evidence to accept the hypothesis H11a and the null hypothesis H11n stands.

7.6.2 Hypothesis 12

For cross-border deals, the mean SOA of the cross-border NDV for the companies with above-median efficiency is 0.23 and the mean NDV for the companies with below-median efficiency is 0.31, in the direction of the alternative hypothesis. Testing for significance using a Mann–Whitney test gives a p-value of 45%. A one-sided Welch test gives a p-value of 35%. The testing results for H12a are summarised in Table 7.12:

Table 7.12 Results of Tests on Hypothesis H12a

Test	Direction	P-value	Interpretation
Non-parametric, H12a	Standard	45%	No Evidence
Parametric, H12a	Standard	35%	No Evidence

There is no statistical evidence to accept H12a and the null hypothesis H12n stands.

7.6.3 Hypotheses 13 & 14

For cross-sector deals, the mean SOA of the cross-sector NDV for the companies with above-median efficiency is 0.07 and the mean NDV for the companies with below-median efficiency is 0.02, in the reverse direction of the alternative hypothesis. If the reverse of H13a is tested, namely “For cross-sector deals, firms with an above-median SOA have a higher MCT of NDV than those with below-median SOA”, the significance using a Mann–Whitney test gives a p-value of 7%. A one-sided Welch test gives a p-value of 3%. Taken together, there is strong evidence to accept the reverse of hypothesis

H13a because the parametric test indicates strong evidence and the mean of the p-values is below the 5% threshold. The testing results for H13a are summarised in Table 7.13:

Table 7.13 Results of Tests on Hypothesis H13a

Test	Direction	P-value	Interpretation
Non-parametric, H4a	Reverse	7%	Some Evidence
Parametric, H4a	Reverse	3%	Strong Evidence

To summarise the reverse of the alternative hypothesis H13a has been accepted; however Sheshkin (2011: 451) notes this cannot be a basis for rejecting a null hypothesis. A non-directional alternative hypothesis, which will be tested instead, is therefore tested.

Testing for significance using a Mann–Whitney test gives a p-value of 14%. A one-sided Welch test gives a p-value of 6%. As the mean of these scores is 10%, we conclude that there is some (but not strong) statistical evidence to accept H14a. The results are shown in Table 7.14:

Table 7.14 Results of Tests on Hypothesis H14a

Test	P-value	Interpretation
Non-parametric, H14a	14%	No Evidence
Parametric, H14a	6%	Strong Evidence

The alternative hypothesis H14a is accepted and the hull hypothesis H14n is therefore rejected. Because H13n is the same as H14n this is also rejected.

7.6.4 Summary of the Set

For H11 and H12, although the ratio of the means is in the direction that would accept the alternative hypothesis and hence reject the null hypotheses, there is insufficient statistical evidence to do so.

However, the cross-sector finding for H13 does show a statically significant finding, associating increased SOA with increased cross-sector activity, in the reverse direction of H13a. The null hypothesis cannot be rejected on this basis and so the non-directional equivalent, H14a, was tested instead and some evidence was found to accept this hypothesis and reject the null hypothesis.

The implications for financial measure selection are discussed in the next chapter.

7.7 Summary of Findings

7.7.1 Collation of Findings

Table 7.15 summarises those tests where there was evidence to reject the null hypothesis.

Table 7.15 Rejected Null Hypotheses

H1n	There are CRS for pharmaceutical R&D
H5n	Firms with an above-median financial efficiency have the same MCT of NDV as those with below-median financial efficiency.
H6n	Firms with an above-median financial efficiency have the same MCT of NDV for cross-border deals as those with below-median financial efficiency.

H8n	Firms with an above-median technical efficiency have the same MCT of SDV as those with below-median technical efficiency.
H13n, H14n	For cross-sector deals, firms with an above-median SOA have the same MCT of NDV as those with below-median SOA.

All were rejected with some evidence, except for H1n which was rejected with extremely strong evidence.

7.7.2 Check for Consistency

Both parametric and non-parametric tests have been considered and in most cases they are in agreement on the presence or absence of statistical evidence. However there are cases where the p-value of the parametric test is below the threshold and the p-value of the non-parametric test is above the threshold and each case has been assessed on its merits. The treatment is however consistent and in all cases follows the rule:

> *If the p-value of the parametric test is below the threshold for evidence and the mean of the parametric and non-parametric p-values is above the threshold by no more than a fifth of the threshold value, then the test for evidence is accepted.*

The treatment of borderline cases is summarised below in Table 7.16.

Table 7.16 Borderline Alternative Hypotheses

No.	Hypothesis	Parametric p-value	Mean p-value
Some evidence			
H5a	Firms with an above-median financial efficiency [ROS] have a higher MCT of NDV than those with below-median financial efficiency.	3	11.5
H6a	Firms with an above-median financial efficiency [ROS] have a higher MCT of NDV for cross-border deals than those with below-median technical efficiency. (When using ROS)	8	10
H8a	Firms with an above-median technical efficiency have a higher MCT of SDV than those with below-median technical efficiency.	4	11
H14a	For cross-sector deals, firms with an above-median SOA does not have the same MCT of NDV as those with below-median SOA.^	4	10
No evidence			

H7a	Firms with an above-median financial efficiency [ROS] have the same MCT of NDV for cross-sector deals as those with below-median financial efficiency.	8	20.5
H9a	Firms with an above-median technical efficiency have a higher MCT of SDV for cross-border deals than those with below-median technical efficiency.	4	15

^ *H14a was assessed as 'some evidence' not 'strong evidence' because the mean p-value was more than one fifth above the 5% threshold for 'strong evidence'.*

Table 7.16 shows a consistent treatment of cases that seeks to balance the risk of Type I errors (concluding a false alternative hypothesis is true by a adopting a lax threshold) and a Type II error (concluding a true alternative hypothesis is false by adopting a strict threshold). It can be seen that the borderline has been drawn between the results for H8a and H9a: in both cases the parametric p-value was 4% but in the former the mean of the parametric and non-parametric tests was 11% judged to support a view of some evidence but in the latter the mean was 15%, judged to represent no evidence.

8 Discussion of Results

8.1 Range of Findings

The five groups of hypotheses have addressed five different aspects of the measurement of PAP:

– *The returns to scale of the pharmaceutical R&D process*. It is necessary to establish this in order to select the most appropriate model for the measurement of R&D comparative efficiency. This has yielded a very strong conclusion on returns to scale for the process and shows DRS.

– *The association of technical efficiency with M&A history.* This has not yielded statistically significant results, although this is itself a finding (discussed later) and an indirect contribution to the understanding of the Merger Paradox when contrasted with the findings on financial efficiency.

– *The association of financial efficiency with M&A history.* These findings differ according to the financial measure chosen. However, a rationally selected measure, ROS, does show a relation that is in opposition to the merger paradox.

– *The sector-level consequences of M&A.* It has been found that substantially more acquisitions by value are associated with technically efficient firms than with less efficient firms.

– *The examination of the interrelationship between two measures of financial efficiency for the different types of deal*. The results of the test shows the choice of financial metric for PAP can lead to differing conclusions and the ratio of ROS to ROA, SOA, was affected by the level of historical cross-sector acquisitions.

These findings on measures themselves depend on a robust process for measure selection and are therefore supported by the systematic approach to the selection of measures encapsulated in the 12 Design Principles.

Each of the five areas of results is now discussed in turn, focusing on the findings, followed by a section on the qualitative findings for the selection of measures for PAP (the Design Principles themselves were designed for a general application, not specifically PAP).

The contributions arising from the findings are discussed in the following section.

8.2 Returns to Scale of R&D

The strength of the linear relationship, when R&D output is measured by the number of compounds, between the logarithm of the scale efficiency of R&D and the logarithm of R&D expenditure (i.e. a power law) was a striking feature, when perhaps more variability might have been expected given the role of serendipity in R&D. VRS were established with $p < 0.01\%$ and the clarity of the power-law relationship between returns to scale and scale efficiency may have future econometric application.

The relationship was less clear when the numbers of compounds were considered. A multiplicity of clinical trials, especially in the later stages when expense can be an issue, may not be an indicator of higher efficiency. The analysis of the ratio of clinical trials and compounds between companies in the later stages of the pipeline does suggest a divergence of management practice, whereas in the early stages when the safety of a compound has to be established, divergence is less and there are lower ratios of compounds to trials. The findings suggest (although in the absence of statistical tests) that

the number clinical trials should not be considered an output measure in preference to the number of compounds.

The DRS for pharmaceutical R&D has significant implications for the Merger Paradox and these are discussed in the next sections.

8.3 The Association of Technical Efficiency with M&A History

The absence of a statistically significant relationship between technical efficiency and merger history might at first sight seem disappointing, although it is a finding in itself. There are many possible reasons for the absence of a relationship at the firm level, given the multiplicity of motives for M&A. Some acquirers choose to use the strength of their R&D pipeline, which is reflected in market ratings and hence share price, to acquire potential competitors; in these cases, there would be a strong association between acquisition history and R&D efficiency. Conversely, there are other cases, where historical M&A deals have been undertaken with the objective of achieving economies of scale by the reduction of overheads costs in the face of weak pipelines; in these cases an inverse relationship might be expected with M&A history and technical efficiency. Examples of both were given in Section 6.12: Pfizer is an example of an aggressive acquirer and the Sanofi-Aventis merger is an example of two low productivity firms merging, with the lowering of fixed costs being a plausible motive.

The methodology of this study has not included an event study so cannot comment directly on whether M&A is damaging to the acquiring company. Nonetheless the findings on economies of scale are unequivocal and because an M&A deal inevitably leads to a larger company it can be expected that R&D productivity will fall. Because the future prosperity of a pharmaceutical company depends on its R&D productivity compared with competitors, it can

be stated indirectly that the Merger Paradox has been confirmed in the pharmaceutical sector: pharmaceutical M&A deals are popular but do not improve the performance of the acquirer.

Similar comments also apply to cross-border mergers, tested by H3, and cross-sector deals, tested by H4.

8.4 The Association of Financial Efficiency with M&A History

ROS was selected over ROA as a better measure of financial efficiency; this was done because of the distortions, noted in the literature, inherent in ROA when it is used to measure financial efficiency in a sector with substantial intangible assets.

A statistically significant relationship has been established between financial efficiency of the firm as measured by ROS, and that an improved ROS is associated with higher historic merger activity; this is in contrast to the findings for technical efficiency where no statistically significant relationship was found. The contrast is further support of the Merger Paradox because although the acquirer may have many motives for the deal (including an increase in ROS), the change in financial efficiency is also likely to act as a qualifying factor, for instance a deal that lowers financial efficiency is unlikely to proceed even if there are other benefits. We therefore observe a divergence in incentives for M&A, with an association with an increase in an accounting measure (ROS) but no equivalent prospect of an increase in long-term operational performance (technical R&D efficiency).

This argument is an elaboration of Angwin (2007) in which the multiplicity of motives was recognised; although such a multiplicity undoubtedly exists and even if the motives are not metric-related (e.g. the motive of elimination of a

competitor to enhance market power), metrics can also act as a qualifying factor for a deal to proceed. It is therefore necessary to consider a two-phase model of M&A comprising initial motives and subsequent metric-related constraints or qualifying factors, rather than motive alone.

There were very similar findings for cross-border deals; this is perhaps not surprising because international firms now dominate the pharmaceutical industry and the importance of the 'cross-border' effect may be attenuated and many major cross-border deals did follow language-orientations, for example USA/UK deals.

However, the ROS for cross-sector deals had no relation to acquisition history and we later suggest that this arises because of the difference in ROS between the pharmaceutical sector and the sectors in which pharmaceutical companies make acquisitions.

Regarding the lack of statistically significant findings for ROA, this can be explained by reference to the unreliability of the denominator, where investments in intangible assets are not recognised as assets when the assets are internally created. Even if the numerator of the measure were improved for acquiring firms, then the effect of increased acquisitions leading to greater recognition of assets would depress the effect of an improved ratio as reported in the literature. The effect of acquisitions on the two measures is tested directly later, where this effect has been observed but not to a level of statistical significance.

8.5 The Sectoral Consequences of M&A

This thesis does not examine sector effects directly but it is possible to associate the total value of deals with the surviving firms and their relative

efficiency. H8a was confirmed, namely 'Firms with an above-median technical efficiency have a higher MCT of SDV than those with below-median technical efficiency.' This does have implications for the sector because it is has been established that more acquisitions by monetary value are associated with efficient firms than with the less efficient firms. The implication is that those large firms who choose to acquire tend to be more efficient than small acquiring firms and non-acquirers.

At the sectoral level, the implication is that M&A activity, where it does occur, leads to a concentration of market power in the more efficient firms, which is the underlying argument for a liberal M&A regime. There is a parallel with findings from the financial M&A literature, where M&A is found to increase the total wealth of shareholders in the acquiring and acquired firm, even if the subsequent performance of the acquirer is indifferent.

For the individual pharmaceutical firm, however, it can be expected to become less technically efficient following the acquisition because R&D efficiency decreases with size, and if this occurs it may itself be acquired in the future.

8.6 Relationship between SOA and M&A

The testing of SOA for M&A in aggregate and for cross-border deals did not lead to a higher NDV for firms with below-median SOA being found to be statistically significant, even though this might have been expected from consideration of accounting principles and previous academic literature.

For cross-sector M&A, however, there was strong statistical evidence that firms with above-median SOA had a higher cross-sector NDV.

This is explicable by reference to industrial practice. Some sector acquisitions tend to be into sectors that have operations elsewhere in the health value

chain, especially companies that trade in medical goods, in order to obtain a route to market. These companies tend to have elevated SOA ratios because they are distributors and retailers, and exhibit a high turnover of goods through the supply chain with a relatively small asset base (the retail and distribution network).

8.7 Synthesis of Findings

The previous discussion has considered the implications of each quantitative finding individually and some are valuable in their own right, for example the establishment of a linear relationship between the logarithm of scale efficiency and the logarithm of R&D expenditure. We now synthesise the findings in order to establish their relevance to the main topic of this thesis: the measurement of PAP in the pharmaceutical sector, as it relates to R&D.

The scale efficiency finding is important on several fronts. Firstly, it shows that M&A, which leads to larger companies, can be expected to lower efficiency unless off-setting gains in technical efficiency are to be found; no statistically significant evidence has been found that this is the case. This finding is therefore supportive of the Merger Paradox, namely an activity is continuing which can be expected to lead to a lowering of performance in a crucial business process.

However, the finding also provides a motive for the continuation of the practice. If a large firm recognises that its own R&D is unproductive it is in the position to temporarily redress this in the short term by the purchase of smaller productive companies, even though both the acquiring and the acquired company might have concerns regarding the effect on longer-term performance. This is especially problematical in R&D where the resources being purchased are largely intangible and therefore can be readily dissipated

following the merger, for example by the resignation of key staff. We therefore see an additional pharmaceutical specific Merger Paradox, namely the response of a pharmaceutical firm to declining R&D is likely to exacerbate the problem. This also has implications for public policy, especially because the productivity of R&D is declining at the sectoral level.

We now turn to the finding that if M&A in the sector as a whole is considered, then it is associated with the most efficient companies; this may seem to suggest that at the sectoral level M&A is functioning as it is intended, namely it leads to a concentration of power with the more successful firms and the elimination of the poorer performers. That may well be the case, because it is possible that the share prices of the efficient firms permit them to make hostile takeovers to increase their market power and eliminate competition, while M&A permits the less productive to undertake non-hostile deals with a shared objective of reducing fixed costs to improve efficiency. Therefore at a given moment in time, the observation that the sector's acquisitions are associated with more technically efficient companies is not inconsistent with the finding that historically M&A tends to lower performance. A similar effect is observed at the disaggregated product-level within a pharmaceutical firm, where the most successful products or technologies today are unlikely to remain so as patents expire and new competition emerges; nonetheless despite the certainty of this occurring it may still be rational to focus R&D investments on the areas that are currently most successful in order to maximise the return on R&D in the short term.

Although the motives for an M&A deal are diverse, the deals are unlikely to proceed if they damage the financial performance of the firm. The findings that acquisitions are associated with firms that are more financially efficient is therefore fully consistent with the Merger Paradox because improved financial

performance will act as a qualifying factor for a deal proceeding, whatever its subsequent effect on the underlying fundamentals of the firm.

In summary, the findings point not so much to a Merger Paradox as to the Paradoxes of Mergers. Not only do M&A deals continue when their effects on long-term performance are likely to disappoint (if only because of scale effects) but the behaviour seems fully rational to the acquirer; furthermore the need for good accounting-based performance will ensure that when analysed by conventional accounting measures, M&A will seem to be successful, at least in the short term. Meanwhile, at the sector-level, it would seem that the most efficient companies undertake acquisitions at any moment in time, even though over time they may become less efficient as a result.

Moving on from the role of measurement in the Paradoxes of Mergers and their motives to the narrower topic of measurement of PAP itself, the findings highlight the difficulties of PAP measurement, especially where intangibles are involved. The effect on M&A of the recognition of intangibles in ROA was noted in earlier literature and was not refuted in this thesis. However, a separate effect on the preferred alternative measure, namely ROS, has been identified when cross-sector deals are considered, this effect arises from diversification into retail and distribution from research-based manufacturing.

This reinforces the need for a PMF when studying M&A rather than relying upon a single measure. Regarding financial measures, neither ROA nor ROS should be relied upon on their own and non-financial measures are required to consider the preservation of intangibles in the aftermath of a deal. Furthermore, if a PMF for the external evaluation of M&A is to be used, then there should be a theoretical basis for the selection of the measures, and the RBV-based 12 Design Principles have shown themselves to be a practical

approach through their application in designing a PMF for a pharmaceutical firm.

9 Contributions

9.1 Overview

This thesis examines the association of efficiency of the R&D process in the major pharmaceutical firms with their history of M&A. Studies of PAP are numerous, and their results diverse, however this thesis starts from the premise that PAP is itself an intellectual construct based upon assumptions on motives for the deal and the perspectives of relevant stakeholders. Therefore prior to measuring PAP there has to be a thorough consideration of the measures to be used.

From this initial stance on the assessment of PAP, this thesis contributes to the field by first applying the RBV to the selection of multiple performance measures for a PMF; this approach is encapsulated as a set of 12 Design Principles that can be applied in any sector. The thesis then sheds new light on the Merger Paradox, namely why M&A continue to be transacted when historically their results seem to be disappointing overall. The thesis contrasts PAP as measured by a PMF with PAP as measured by a conventional financial measure: ROS. In essence, an association between above-median ROS and increased acquisition activity was established, but the same relationship was not established when a non-financial PMF was used. This finding provides an incentive-related explanation for the Merger Paradox linked to differing indications from financial and non-financial measures.

The thesis also examines PAP of subsets of acquisitions, namely cross-border and cross-sector deals, to consider diversification effects and establishes a contrast between the findings as they affect the individual firms and the effects

at the sectoral level, which has parallels with earlier research using financial event studies.

By adopting a novel means for the assessment of PAP, namely combining a longitudinal view of acquisition history and a cross-sectional view of comparative efficiency (that itself considers the longitudinal nature of the R&D pipeline and the multiple outputs of the R&D process), this thesis has provided a new application for DEA in the M&A literature that has not previously been used to examine R&D. In doing so, the use of DEA has also established scale efficiency factors for pharmaceutical R&D, clarifying earlier ambiguity in findings in this field and recognising the multiple inputs and outputs of the process.

A further empirical contribution is the examination of the relation between size and frequency of M&A in the pharmaceutical sector and its consistency with a power-law distribution.

Finally, the thesis examines the relative merits of ROS and ROA as a financial measure and whether there is a statistically significant difference in the conclusions on PAP arising from the use of the two different measures.

9.2 Contributions to the Acquisition Literature

The timing of the findings of the research are fortuitous because after four decades of contradictory findings on PAP, there is now a focus on the assumptions underlying this construct and especially the examination of the original objectives for an acquisition (Angwin, 2007) and how one can measure attainment of those objectives. This is related to the Merger Paradox, which is concerned with the motives and their attainment, and currently the most common explanations involve an element of agency theory, namely the

divergence of motives between managers and shareholders. This research suggests that agency theory is not required to explain the Merger Paradox, at least in the pharmaceutical sector and the actions of managers are consistent with improving a common financial measure under their control.

9.2.1 Reduction of Uncertainty

In undertaking an additional study in a well-researched area where there is already a disparity of findings, there is a danger of adding another observation that does not provide further insight. This is especially the case where meta-analyses have concluded that previous studies, for example King et al. (2004), have not identified the full range of moderating factors on PAP, and others have concluded that there is little relation to the findings of studies where different measurement principles have been employed, for example Schoenberg (2006) and Papadakis & Thanos (2010).

The line of enquiry in this research has therefore been to reduce uncertainty by consciously removing potential moderating factors from the research. By focusing on one industry and analysing performance on the same set of companies in two different ways, it was possible to establish that a multiparameter, non-financial method of measurement and a common financial measurement gave rise to differing conclusions. Although many other factors may affect performance, the conclusions on differences in performance as measured by financial and non-financial parameters have been established.

9.2.2 Differences in Measured Performance

The lack of a statistically significant association between technical efficiency and M&A history is a useful finding, especially when coupled with the

presence of statistically significant findings showing diseconomies of scale in R&D and in associations between M&A and ROS.

Because M&A leads to larger entities with larger R&D processes, this might be expected to lead to a lower efficiency in the longer run, which might offset shorter-term cost reductions from the deal (e.g. removal of duplicated posts or premises). This is a natural explanation for the lack of association, coupled with the possibility that some companies with lower technical efficiency may choose to merge in order to seek short-term economies and buttress financial performance.

Regarding PAP as measured financially, companies with above-median ROS had a significantly higher historical incidence of acquisitions. A direct comparison with an event-study approach using financial measures cannot be made and indeed the findings of these event studies are not consistent amongst themselves, possibly because of unidentified moderating factors, as suggested by King et al. (2004).

A lack of association between ROA performance and M&A history may arise from the shortcomings of that measure where intangible assets are significant, despite it being the most popular accounting measure in PAP research. This is a worrying finding but nonetheless a contribution to the M&A literature.

The thesis sheds much light on the Merger Paradox, whereby acquisitions continue despite their disappointing non-financial outcomes (Schenk, 2008). The transactions may improve ROS or be facilitated by higher ROS originally (e.g. access to merger finance). This explanation is also consistent with Schoenberg's (2006) study in which it was suggested that approach to measurement was an explanation for the variation in the findings of research on PAP.

9.2.3 Diversification

The research also examined the impact of diversification and the findings here for cross-border deals were different from cross-border deals when ROS was considered.

For cross-border deals, there was an association of such deals with improvements in financial efficiency, similar to that for acquisitions as a whole, however the cross-sector analysis did yield a strongly significant result for ROS. This is in line with Shelton (1988) who reported: *"Multivariate regression analysis shows that acquisitions which permit the bidder access to new but related markets create the most value with the least variance*" with cross-sector deals into retailing and wholesaling of health goods being associated with poorer performance, unlike cross-border deals which offer access to new markets for R&D-based products.

9.3 Contributions to the Performance Literature

There is a growing body of literature on performance measurement using multiple measures in PMFs for an individual firm, but the choice of measures has presumed a detailed knowledge of the internal operations of the company to select the parameters. The development of a theoretical basis for the solution of measures could assist in multiparameter measurement processes in general. It is especially useful in the field of comparative efficiency analysis that is frequently undertaken from outside the firm.

Any proposed theoretical approach should be capable of considering both tangible and intangible inputs and outputs and be related to a theoretical base that is widely accepted. The RBV meets both these requirements and has evolved into the dominant theory, however relatively little attention has been

paid to the measurement of resources within the RBV literature. By reviewing the literature within the RBV, where measures were considered, a set of criteria for selection of measures relevant to competitive advantage was identified and used as a set of Design Principles. As well as being used to select measures for this research, the Design Principles and Construction Process could have further application in other sectors.

9.4 Contributions to the DEA Literature

The application of DEA to measure the effects of M&A has been confined to date to short-term event studies that are not suitable for measuring R&D efficiency in a sector that has a lengthy R&D pipeline. The analysis of the efficiency of the R&D pipeline using data on its inputs for the majority of its average duration and then using DEA in a cross-sectional analysis is a novel form of the use of DEA for the analysis of M&A. In other respects the use of DEA is conventional although the application is unusual in the effort taken to measure intangible outputs directly rather than through the use of financial surrogates for intangibles, for example revenue or share price, although the pharmaceutical sector was consciously selected to enable this to be possible.

In summary, this research has extended the application of DEA, as well as considering its field of application and the approach taken to the selection of inputs and outputs to the DEA models.

9.5 Empirical Contributions

9.5.1 Returns to Scale

There have been earlier attempts in the literature to measure R&D productivity, for example Graves and Langowitz (1993) used a simple unit cost, examining approved compounds produced per unit of R&D expenditure,

but they did not account for the multiple outputs of the R&D process. Therefore application of a multiple input/output approach to the R&D pipeline is itself a useful contribution.

DEA was selected even though it has not been extensively used to measure the efficiency of the R&D process of a firm. The use of DEA to measure the efficiency of the R&D process for pharmaceutical firms of a variety of sizes provided the opportunity to determine if pharmaceutical R&D had CRS. It was found not to and furthermore a clear relationship was found between scale efficiency and a R&D scale parameter, which showed DRS, in contrast to the Schumpeterian hypothesis (over IRS in R&D) and Jensen (1987) who found that marginal productivity was not adversely affected by firm size.

From the view of industry practice, the industry has also been concerned with a fall in the number of new drugs approved despite rising R&D costs, although Cockburn (2006) suggests this is due to rising R&D input costs rather than declining efficiency in conversion of inputs to outputs. The response of some companies to declining internal efficiency has been to acquire R&D resources externally, through acquisition, although this response is not universal. Although acquisition will circumvent the effects of the R&D efficiency problem in the short term, this research suggests that it may only add to the problem of declining R&D efficiency in the long term, if the association with acquisitions and lower productivity reflects a causal link.

9.5.2 Power Laws in M&A

Further empirical findings included the distribution of mergers by size and establishing the limits of the power-law hypothesis, including the divergence of the mega-mergers from the linear log–log relationship for this particular sector (an elaboration on Park et al., 2010). However the research has not

established a power law conclusively because it has not eliminated alternative explanations for the linear log–log relationship. The limits of the linear relationship in pharmaceutical M&A in the chosen sample involved a surfeit of mega-mergers and a lower than expected number of mergers in the size range immediately below the mega-merger range. Beneath these large sizes, a power law prevails indicating a self-organised critical system. This finding is consistent with industry analysis, where there has been a conscious attempt to consolidate the industry from the top, consisting of mergers of mid-tier pharmaceutical companies in the second M&A wave and then the merger of giants in the third M&A wave.

It was also found that following the removal of zeros from the statistics for NDV, the statistical distribution follows a Poisson distribution, suggesting that the normalisation of total deal value by cost of sales reveals the underlying Poisson process (and thus confirms the validity of the normalisation factor).

9.5.3 Financial Metrics in M&A

The divergence of findings between the financial and non-financial metrics and between different financial metrics was a major finding of the research and adds further support for the use of a PMF over a single measure (Schoenberg, 2006). However there is also a case for the use of using multiple financial metrics, with the potential shortcomings of ROA being noted previously and the limitations of ROS for analysing cross-sector deals being established within this thesis. The finding relating to SOA, the ratio of ROS to ROA, showed that particular types of deal (e.g. cross-sector deals) can have a differential effect on common financial metrics.

9.6 Directions of Future Research

Greater recognition of the role of chance in R&D productivity and the sensitivity of the findings to this random element would be a fruitful area for future research. The role of uncertainty in the analysis of DEA has been considered by Dyson & Shale (2010), and the use of Monte Carlo simulation to perturb the outputs from the R&D processes (the inputs are well defined) to observe the effects on relative efficiency, and also the assessment of the difference in the MCT of NDV between the subgroups of above- and below-median efficiency would be useful.

Given the difference in results between ROS and ROA it would be possible to consider measuring financial efficiency by some alternative parameter, such as the residual income measure Economic Profit. Regarding normalisation factors, the use of Cost of Sales to normalise the sum of the deals was the most defensible choice, however examining other factors such as revenue, or average R&D expenditure (on the grounds that an acquisition is an alternative means of acquiring a stocked pipeline) in order to undertake a sensitivity analysis could be worthwhile. A further refinement could be to adjust the proportion of Cost of Sales figure for the costs that are related to generic manufacture of pharmaceuticals, however this would prove difficult because this information is not publicly disclosed.

The research has merely touched on the issue of causality by considering the stated intentions of the four mega-mergers that seem to set off ‘aftershocks’ according to some hypotheses of merger dynamics. The next steps are to extend the case-by-case analysis of major acquisitions to establish causality with smaller deals and to analyse further the distribution relating size of deals to their frequency.

10. References

Abernethy, M.A., Horne, M., Lillis, A.M., Malina, M.A. and Selto, F.H. (2005) A multi-method approach to building casual performance maps from expert knowledge. *Manage. Acc. Res.,* 16: 135–155.

Accenture (2009) *Performance Measurement Frameworks In Board Reports: Insights Into Leading Practice From The Private And International Public Sectors*, Accenture.

Agrawal, A., Jaffe, J. and Mandelker, G. (1992) The post-merger performance of acquiring firms – a re-examination of an anomaly. *Journal of Finance,* 47: 1605–1621.

Ahuja, G. and Katila, R. (2001) Technological acquisitions and the innovation performance of acquiring firms – a longitudinal study. *Strategic Management Journal,* 22 (3): 197–227.

Ambrosini, V., Bowman, C. and Schoenberg, R. (2010) Should acquiring firms pursue more than one value creation strategy? An empirical test of acquisition performance. *British Journal of Management*, doi: 10.1111/j.1467-8551.2010.00693.x

Amit, R. and Livnat, J. (1988) Diversification strategies, business cycles and economic performance. *Strategic Management Journal,* 9 (2): 99–110.

Amit, R. and Schoemaker, P.J.H. (1993) Strategic assets and organizational rent. *Strategic Management Journal*, Jan 1993, 14 (1).

Anand, J. and Singh, H. (1997) Asset redeployment, acquisitions and

corporate strategy in declining industries. *Strategic Management Journal,* Summer Special Issue, 18: 99–118.

Anderson, T.W. and Darling, D.A. (1952) Asymptotic theory of certain "goodness-of-fit" criteria based on stochastic processes. *Annals of Mathematical Statistics,* 23: 193–212.

Angwin, D. (2007) Motive archetypes in mergers and acquisitions (M&A): The implications of a configurational approach to performance. *Advances in Mergers and Acquisitions*, 6: 77–105.

Angwin, D. and Vaara, E. (2005) Connectivity in merging organisations: beyond traditional cultural perspectives. *Organisation Studies*, 26 (10): 1445–1453.

Association of the British Pharmaceutical Industry (2010) *Key Facts*. Available from http://www.abpi.org.uk/statistics/section.asp?sect=3

Avrikan, N.K. (1999) The evidence on efficiency gains: The role of mergers and the benefits to the public. *Journal of Banking & Finance*, 23 (7), July: 991–1013.

Banker, R.D., Chang, H., Janakiraman, S.N. and Konstans, C. (2004) A balanced scorecard analysis of performance metrics. *European Journal of Operational Research*, 154, 423–436.

Banker, R.D., Charnes, A. and Cooper, W.W. (1984) Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science*, 30 (9), Sept: 1078–1092.

Banker, R.D., Potter, G. and Srinicasan, D. (2000) An empirical investigation of an incentive plan that includes non-financial performance measures. *The Accounting Review,* 75 (1): 65–92.

Barber, B.M. and Lyon, J.D. (1997) Detecting long-run abnormal stock returns – the empirical power and specification of test statistics. *Journal of Financial*

Economics, 43: 341–372.

Barney, J.B. (1991) Firm resources and sustained competitive advantage, *Journal of Management,* 17: 99–120.

Barney, J.B. (2001) Is the resource-based "view" a useful perspective for strategic management research? Yes. *Strategic Management Journal,* 26 (1): 41–56.

Barney, J.B, Ketchen D.J. and Wright M. (2011) The future of resource-based theory: revitalization or decline?, *Journal of Management*, September, doi: 10.1177/0149206310391805

Beckman, C.M. and Haunschild, P.R. (2002) Network learning – the effects of partners' heterogeneity of experience on corporate acquisitions. *Administrative Science Quarterly,* 47(1): 92–124.

Berger, P.G. and Ofek, E. (1995) Diversification's effect on firm value. *Journal of Financial Economics,* 37: 39–65.

Bergh, D.D. (2001) Executive retention and acquisition outcomes – a test of opposing views on the influence of organizational tenure. *Journal of Management,* 27: 603–622.

Blackwell, D. (1951) Comparison of experiments. In: Neyman, J. (Ed.) *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability*, Berkeley, University of California Press, pp. 93–102.

Boekestein, B. (2009) Acquisitions reveal the hidden intellectual capital of pharmaceutical companies. *Journal of Intellectual Capital,* 10 (3), 389–400.

Bontis, N., Dragonetty, N.C., Jacobsen, K. and Roos, G. (1999) The knowledge toolbox: a review of the tools available to measure and manage intangible resources. *European Management Journal*, 17 (4): 391–402.

Bourguignon, A., Malleret, V. and Nørreklit, H. (2004) The American balanced scorecard versus the French tableau de bord: the ideological dimension.

Management Accounting Research, 15: 107–134.

Bowerman, B.L., O'Connell, R.T. and Murphree, E.S. (2011) *Business Statistics in Practice*, 6th edition, McGraw-Hill.

Braam, G.J.M. and Nijssen, E.J. (2004) Performance effects of using the balanced scorecard: A note on the Dutch experience. *Long Range Planning,* 37(4), 335–349.

Bradley, M., Desai, A. and Kim, E.H. (1988) Synergistic gains from corporate acquisitions and their division between the stockholders of target and acquiring firms. *Journal of Financial Economics,* 21: 3–40.

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

Brooking, A. (1996) *Intellectual Capital: Core Assets for the Third Millennium Enterprise*, London, Thompson Business Press.

Brouthers, K.D., van Hastenburg, P. and van den Ven, J. (1998) Long Range Planning. *International Journal of Strategic Management*, 31 (3): 347–354.

Brush, T.H. (1996) Predicted change in operational synergy and post-acquisition performance of acquired businesses. *Strategic Management Journal,* 17(1): 1–24.

Bruton, G.D., Oviatt, B.M. and White, M.A. (1994) Performance of acquisitions of distressed firms. *Academy of Management Journal*, 37: 972–989.

Buono, A.F., Bowditch, J.L. and Lewis, J.W. (1985) When cultures collide - the anatomy of a merger. *Human Relations,* 38: 477–500.

Cañibano, L., García-Ayuso, M. and Sánchez, P. (2000) Accounting for intangibles: a literature review. *Journal of Accounting Literature*, 19: 102–130.

Cannella, A.A. Jr. and Hambrick, D.C. (1993) Effects of executive departures on the performance of acquired firms. *Strategic Management Journal,* 14

(Special Issue): 137–153.

Capon, N., Hulbert, J. M., Farley, J. U. and Martin, I. E. (1988) Corporate diversity and economic performance - the impact of market specialization. *Strategic Management Journal,* 9 (1): 61–74.

Capron, L. (1999) The long-term performance of horizontal acquisitions. *Strategic Management Journal,* 20: 987–1018.

Capron, L. and Pistre, N. (2002) When do acquirers earn abnormal returns? *Strategic Management Journal,* 23: 781–794.

Carow, K., Heron, R. and Saxton, T. (2004) Do early birds get the returns - an empirical investigation or early-mover advantages in acquisitions. *Strategic Management Journal,* 25: 563–585.

Chang, S.J. (1996) An evolutionary perspective on diversification and corporate restructuring - entry, exit, and economic performance during 1981-89. *Strategic Management Journal,* 17 (8): 587–611.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978) Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2: 429–444.

Chatterjee, S. (1986) Types of synergy and economic value - the impact of acquisitions on merging and rival firms. *Strategic Management Journal,* 7 (2): 119–139.

Chatterjee, S. (1991) Gains in vertical acquisitions and market power - theory and evidence. *Academy of Management Journal,* 34 (2): 436–448.

Chatterjee, S. (1992) Sources of value in takeovers: Synergy or restructuring – Implications for target and bidder firms. *Strategic Management Journal,* 13: 267–287.

Chatterjee, S., Lubatkin, M.H., Schweiger, D.M. and Weber, Y. (1992) Cultural differences and shareholder value in related mergers - linking equity and

human capital. *Strategic Management Journal,* 13 (5): 319–334.

Chen, T., Chien, C.F., Wang, J.T. and Lin, M.H. (2004) Using DEA to evaluate R&D performance of the computers and peripherals firms in Taiwan. *International Journal of Business*, 9 (4): 347–360.

Clark, K. and Ofek, E. 1994. Mergers as a means of restructuring distressed firms: An empirical investigation. *J. Finance. Quant. Anal*., 29: 541–565.

Clauset, A., Shalizi C. and Newman M. (2009), Power-law distributions in empirical data, http://arxiv.org/abs/0706.1062v1

Cockburn, I. (2006) Is the Pharmaceutical Industry in a Productivity Crisis? *NBER Innovation Policy and the Economy Conference*, Washington DC.

Covin, T.J., Kolenko, T.A., Sightler, K.W. and Tudor, R.K. (1997) Leadership style and post-merger satisfaction. *Journal of Management Development,* 16 (1): 22–33.

Crook, T.R., Ketchen, D.J. Jr, Combs, J.G. and Todd, S.Y. (2008) Strategic resources and performance: a meta-analysis. *Strategic Management Journal*, 29 (11): 1141–1154.

Cubbin, J. and Tzanidakis, G. (1998) Techniques for analysing company performance. *Business Strategy Review*, 9 (4): 37–46.

Datta, D.K. (1991) Organizational fit and acquisition performance: Effects of post-acquisition integration. *Strategic Management Journal,* 12: 281–298.

Datta, D.K. and Grant, J.H. (1990) Relationships between type of acquisition, the autonomy given to the acquired firm, and acquisition success - an empirical analysis. *Journal of Management,* 16 (1): 29–44.

Datta, D.K., Pinches, G.E. and Narayanan, V.K. (1992) Factors influencing wealth creation from mergers and acquisitions: A meta-analysis. *Strategic Management Journal,* 13: 67–84.

Davis, S. and Albright, T. (2004) An investigation of the effect of Balanced

Scorecard implementation on financial performance. *Manage. Acc. Res.,* 15: 135–153.

DeCarolis, D. (2003) Competencies and imitability in the pharmaceutical industry: an analysis of their relationship with firm performance. *Journal of Management*, 29 (1): 27–50.

DeCarolis, D. and Deeds, D. (1999) the impact of stocks and flows of organizational knowledge on firm performance: an empirical evaluation of the biotechnology industry. *Strategic Management Journal*, 20: 953–968.

DeLong, G. and DeYoung, R. (2004) *Learning by Observing - Information Spillovers in the Execution and Valuation of Commercial Bank M&As*. Working paper.

Dierickx, I. and Cool, K. (1989) Asset stock accumulation and sustainability of competitive advantage. *Management Science*, 35 (12): 1504–1511.

DiMasi, J.A. and Grabowski H.G. (2007) Managerial and decision economics. *Manage. Decis. Econ*., 28: 469–479.

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: 151–185.

Dyson, R.G. and Shale, E.A. (2010) Data envelopment analysis, operational research and uncertainty. *Journal of the Operational Research Society*, 61: 25–34.

Eckbo, B.E. (1983) Horizontal mergers, collusion, and stockholder wealth, *Journal of Financial Economics (JFE)*, 11: 241–273.

Edvinsson, L. and Malone, M.S. (1997) *Intellectual Capital: The Proven Way to Establish Your Company's Real Value By Measuring Its Hidden Values*. London, Piatkus.

Edvinsson, L. and Sullivan, P. (1996) Developing a model of managing

intellectual capital. *European Management Journal*, 4 (4): 356–364.

Eilat, H., Golany, B. and Shtub, A. (2006) Constructing and evaluating balanced portfolios of R&D projects with interactions: A DEA based methodology. *European Journal of Operational Research*, 172: 1018–1039.

Eilat, H., Golany, B. and Shtub, A. (2008) R&D project evaluation: An integrated DEA and balanced scorecard approach. *Omega International Journal of Management Science*, 36: 895–912.

Elgers, P.T. and Clark, J.J. (1980) Merger types and stockholder returns: Additional evidence. *Financial Management,* 9: 66–72.

Enhanced Business Reporting Consortium (2006) *The Enhanced Business Reporting Framework for Private Companies*, July, Washington, DC 20036.

Eun, C.S., Kolodny, R. and Scheraga, C. (1996) Cross-border acquisitions and shareholder wealth: Tests of synergy and internalization hypotheses. *Journal of Banking and Finance*, 20: 1559–1582.

Fama, E.F. (1970) Efficient capital markets: a review of theory and empirical work. *The Journal of Finance*, (25) 2. Papers and Proceedings of the Twenty-Eighth Annual Meeting of the American Finance Association New York, N.Y. December, 28–30, 1969 (May, 1970), pp. 383–417.

Fama, E.F., Fisher, L., Jensen, M. and Roll, R. (1969) The adjustment of stock prices to new information. *International Economic Review,* 10: 1–21.

Farmer J.D. and Geanakoplos J., (2008), Power laws in economics and elsewhere. Unpublished book chapter, http://www.elautomataeconomico.com.ar/download/papers/Farmer-powerlaw3.pdf

Farrell, M.J. (1957) The measurement of productive efficiency*. Journal of the Royal Statistical Society. Series A (General)*, 120 (3): 253–290.

Feea, C E. and Thomas, S. (2004) Sources of gains in horizontal mergers -

evidence from customers, supplier, and rival firms. *Journal of Financial Economics,* 74 (3): 423–460.

Ferrier, G. and Valmanis, V. (2004) Do mergers improve hospital productivity? *Journal of the Operational Research Society*, 55: 1071–1080.

Fisher R.A. (1925) *Statistical Methods for Research Workers*, Edinburgh, Oliver & Boyd.

Fisher R.A. (1956) Statistical methods and scientific induction. *Journal of the Royal Statistical Society, Series B*, 17, 69–78.

Foss, N.J. (1997) *The Resource-Based Perspective: An Assessment and Diagnosis of Problems: 1-33*. Copenhagen Business School, Department of Industrial Economics and Strategy: DRUID Working Papers series 97-1.

Foss, N.J. and Knudsen, T. (2003) The resource-based tangle: towards a sustainable explanation of competitive advantage. *Managerial and Decision Economics*, 24: 291–307.

Fowler, K.L. and Schmidt D.R. (1989) Determinants of tender offer post-acquisition financial performance. *Strategic Management Journal,* 10 (4): 339–350.

Franks, J., Harris, R. and Titman, S. (1991) The postmerger share-price performance of acquiring firms. *Journal of Financial Economics*, 29, 81–96.

Garcia-Valderrama, T., Mulero-Mendigorri E. and Revuelta-Bordoy, D. (2009) Relating the perspectives of the balanced scorecard for R&D by means of DEA. *European Journal of Operational Research*, 196 (3), 1 August: 1177–1189.

Grabowski H., Vernon J. and DiMasi J., (2002), Returns on research and development for 1990s new drug introductions, *Pharmacoeconomics*, 20 (Suppl. 3): 11–29.

Graves, S.B. and Langowitz, N.S. (1993) Innovative productivity and returns to scale in the pharmaceutical industry. *Strategic Management Journal*, 14 (8): 593–605.

Grosskopf S. (1996), Statistical inference and nonparametric efficiency: A selective survey. *Journal of Productivity Analysis*, 7, (2–3): 161–176.

Haleblian, J. and Finkelstein, S. (1999) The influence of organizational acquisition experience on acquisition performance: A behavioral perspective. *Administrative Science Quarterly,* 44: 29–56.

Hall, R. (1992) The Strategic analysis of intangible resources. *Strategic Management Journal*, 13 (2), 135–144.

Hambrick, D.C. and Cannella, A.A. Jr. (1993) Relative standing: a framework for understanding departures of acquired executives. *Academy of Management Journal*, 36, 733-762.

Hamilton, G. (2005) *The Pharmaceutical Market Outlook to 2015*, Business Insights.

Harris, R.S. and Ravenscraft, D. (1991) The role of acquisitions in foreign direct investment - evidence from the U.S. stock market. *Journal of Finance,* 46 (3): 825–844.

Harrison, J.S., Hitt, M.A., Hoskisson, R.E. and Ireland, R D. (1991) Synergies and post-acquisition performance - differences versus similarities in resource allocations. *Journal of Management,* 17 (1): 173–190.

Harrison, J.S., Oler, D. and Allen, M.R. (2005) *Event Studies and the Importance of Longer Term Measures in Assessing the Performance Outcomes*, Working paper.

Hashimoto, A. and Haneda, S. (2008) Measuring the change in R&D efficiency of the Japanese pharmaceutical industry. *Res. Policy,* 37 (10): 1829–1836.

Haspeslagh, P.C. and Jemison, D.B. (1991) *Managing Acquisitions: Creating Value Through Corporate Renewal,* New York: The Free Press.

Hayward, M.L.A. (2002) When do firms learn from their acquisition experience? Evidence from 1990-1995. *Strategic Management Journal,* 23 (1): 21–39.

Hayward, M.L.A. and Hambrick, D.C. (1997) Explaining the premium paid for large acquisitions: Evidence of CEO hubris. *Administrative Science Quarterly,* 42: 103–127.

Healy P., Palepu, K. and Ruback, R. (1997) Which takeovers are profitable: strategic or financial? *Sloan Management Review*, 38:45–57.

Heron, R. and Lie, E. (2002) Operating performance and the method of payments in takeovers. *Journal of Financial and Quantitative Analysis*, 37 (1): 137–156.

Higgins M.J. and Rodriguez D. (2006) The outsourcing of R&D through acquisitions in the pharmaceutical industry, *Journal of Financial Economics*, 80 (2), May: 351–383.

Hitt, M., Harrison, J., Ireland, R.D. and Best, A. (1998) Attributes of successful and unsuccessful acquisitions of US firms. *British Journal of Management*, 9 (2): 91–114.

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. and Moesel, D. (1996) The market for corporate control and firm innovation. *Academy of Management Journal,* 39: 1084–1109.

H.M. Treasury, Cabinet Office, National Audit Office, Audit Commission &

Office for National Statistics (2001) *Choosing the Right FABRIC: A Framework for Performance Information*.

Holl, P. and Kyriazis, D. (1997) Wealth creation and bid resistance in UK takeover bids. *Strategic Management Journal*, 18: 483–498.

Holmström, B. (1979) Moral hazard and observability. *The Bell Journal of Economics*, 10 (1), Spring: 74–91.

Homburg, C. and Bucerius, M. (2006) Is speed of integration really a success factor of mergers and acquisitions? An analysis of the role of internal and external relatedness. *Strategic Management Journal,* 27: 347–67.

Hoskisson, R.E., Hitt, M.A., Johson, R.A. and Moesel, D.D. (1993) Construct validity of an objective (entropy) categorical measure of diversification strategy. *Strategic Management Journal,* 14 (3): 215–235.

Hunt, J.W. (1990) Changing pattern of acquisition behaviour in takeovers and the consequences for acquisition processes. *Strategic Management Journal*, 11 (1): 69–77.

Ittner, C. and Larcker, D.F. (1998) Are nonfinancial measures leading indicators of financial performance? An analysis of customer satisfaction. *Journal of Accounting Research,* 36 (Supplement): 1–36.

Ittner, C.D. and Larcker, D.F. (2003) Coming up short on nonfinancial performance measurement. *Harvard Business Review* (November): 88–95.

Ittner, C.D., Larcker, D.F. and Randall, T. (2003) Performance implications of strategic performance measurement in financial services firms. *Accounting, Organizations and Society,* 28: 715–741.

Jensen, E.J. (1987) Research expenditures and the discovery of new drugs. *Journal of Industrial Economics,* 36: 83–95.

Jensen, M.C. and Ruback, R.S. (1983) The market for corporate control: The

scientific evidence. *Journal of Financial Economics,* 11: 5–50.

Kaplan, R.S. (2010) Interview. See *http://www.bnet.com/blog/harvard/risk-management-the-balanced-scorecards-missing-piece/6050,* on 12 March 2010.

Kaplan, R.S. and Norton, D.P. (1992) The balanced scorecard - Measures that drive performance. *Harvard Business Review,* (January-February): 71–79.

Kaplan, R.S. and Norton, D.P. (1996) Using the balanced scorecard as a strategic management system. *Harvard Business Review*, (January/February): 75–85.

Kapoor R. and Lim K. (2007) The impact of acquisitions on the innovation performance of inventors at semiconductor companies. *Academy of Management Journal*, 50 (5): 1133–1155.

King, D.R., Dalton, D.R., Daily, C.M. and Covin, J.G. (2004) Meta-analyses of PAP: indications of unidentified moderators. *Strategic Management Journal*, 25 (2), Feb: 187–200.

Kitching, J. (1967) Why do mergers miscarry? *Harvard Business Review*, 45 (6): 84–102.

Kraaijenbrink J., Spender, J-C. and Groen A.J. 2010 The resource-based view: A review and assessment of its critiques, *Journal of Management,* 36 (1): 349–372.

Kramer, J.K. and Pushner, G. (1997) An empirical analysis of economic value added as a proxy for market value added. *Financial Practice and Education*, Spring/ Summer: 41–49.

Krishnan, H.A., Miller, A. and Judge, W.Q. (1997) Diversification and top management team complementarity. *Strategic Management Journal,* 18 (5): 361–374.

Kroll, M., Wright, P., Toombs, L. and Leavell, H. (1997) Form of control: A critical determinant of acquisition performance and CEO rewards. *Strategic Management Journal,* 18: 85–96.

Krug, J.A. and Hegarty, W.H. (2001) Predicting who stays and leaves after an acquisition – a study of top managers in multinationals. *Strategic Management Journal,* 22 (2): 185–196.

Kumbhakar S.C. (1988) Estimation of input-specific technical and allocative inefficiency in stochastic frontier models. *Oxford Economic Papers, New Series*, 40 (3), Sept: 535–549.

Kusewitt, J.B. (1985) An exploratory study of strategic acquisitions factors relating to performance. *Strategic Management Journal*, 6: 151–169.

Lackman C., Saban K. and Lanasa J. (2000), The contribution of market intelligence to tactical and strategic business decisions, Marketing Intelligence & Planning,18/1

Lahey, K.E. and Conn, R.L. (1990) Sensitivity of acquiring firms' returns to alternative model specification and disaggregation. *Journal of Business and Accounting,* 17: 421–439.

Larsson, R. and Finkelstein, S. (1999) Integrating strategic, organizational, and human resource perspectives on mergers and acquisitions - a case survey of synergy relatization. *Organization Science,* 10 (1): 1–26.

Lawrie, G. and Cobbold, I. (2004) Third-generation balanced scorecard: evolution of an effective strategic control tool. *International Journal of Productivity and Performance Management*, 53 (7): 611–623.

Lebas, M. and Euske, K. (2002) A conceptual and operational delineation of performance. In Neely, A. (Eds) *Business Performance Measurement: Theory and Practice,* Cambridge University Press, Cambridge

Lee, H. and Park, Y. (2005) An international comparison of R&D efficiency:

DEA approach. *Asian Journal of Technology Innovation,* 13 (2): 207–221.

Lehman, E.L. (1993) The Fisher, Neyman-Pearson theories of testing hypotheses: One theory or two? *Journal of the American Statistical Association*, 88: 1242–1249.

Leitner, K. and Warden, C. (2004) Managing and reporting knowledge-based resources and processes in research organisations: specifics, lessons learned and perspectives. *Management Accounting Research*, 15: 33–51.

Leitner, K.H., Linzatti, M.S., Stowasser, R. and Wagner, K. (2005) Data envelopment analysis as method for evaluating intellectual capital. *Journal of Intellectual Capital*, 6 (4): 528–543.

Lev, B. (2001) *Intangibles: Management, Measurement, and Reporting,* Washington, DC: The Brookings Institution.

Linton, J.D., Walsh, S.T. and Morabito, J. (2002) Analysis, ranking, selection of R&D projects in a portfolio. *R&D Management*, 32: 139–148.

Lorie, J.H. and Halpern, P.J. (1970) Conglomerates: The rhetoric and the evidence. *Journal of Law and Economics*, 13: 149–166.

Loughran, T. and Vijh, A. M. (1997) Do long-term shareholders benefit from corporate acquisitions. *Journal of Finance,* 52 (5): 1765–1790.

Lubatkin, M. (1987) Merger strategies and stockholder value. *Strategic Management Journal,* 8: 39–53.

Lubatkin, M., Srinivasan, N. and Merchant, H. (1997) Merger strategies and shareholder value during times of relaxed antitrust enforcement - the case of large mergers during the 1980s. *Journal of Management,* 23: 59–81.

Malina, M.A. and Selto, F.H. (2004) Choice and change of measures in performance measurement models. *Manage. Acc. Res.,* 15: 441–469.

Malo, J.L. (1995) Les tableaux de bord comme signes d'une gestion et d'une compatabilité à la Française. In: *Mélanges en L'honneur du Professeur*

Claude Perochon, Paris: Foucher, pp. 357–376.

Mann, H.B. and Whitney, D.R. (1947) On a test of whether one of two random variables is stochastically larger than the other. *Ann. Math. Statist.,* 18: 5060.

Markides, C.C. and Ittner, C.D. (1994) Shareholder benefits from corporate international diversification - evidence from U.S. international acquisitions. *Journal of International Business Studies,* 25(2): 343–366.

Marks, M.L. and Mirvis, P.H. (1998) *Joining Forces: Making One Plus One Equal Three in Mergers, Acquisitions, And Alliances,* San Francisco: Jossey-Bass Publishers.

Marr, B. and Schiuma, G. (2001) Measuring and managing intellectual capital and knowledge assets in new economy organisations. In Bourne, M. (Ed.), *Handbook of Performance Measurement*, London: Gee.

Marr, B., Gray, D. and Schiuma, G. (2004) Measuring intellectual capital – what, why, and how? In Bourne, M. (Ed.), *Handbook of Performance Measurement*, London: Gee.

Martin, J.D. and Sayrak, A. (2003) Corporate diversification and shareholder value: a survey of recent literature. *Journal of Corporate Finance,* 9: 37–57.

McCullagh P. and Nelder J.A. (1989) *Generalized Linear Models*, London: Chapman and Hall.

Meyer, M.S. (2001) Patent citation analysis in a novel field of technology: An exploration of nano-science and nano-technology. *Computer Science*, 51 (1): 163–.183.

Mitzenmacher, M. (2001) A brief history of generative models for power law and lognormal distributions. *Internet Mathematics,* 1 (2): 226–251.

Moeller, S.B., Schlingemann, F.P. and Stulz, R. (2004) Firm size and the gains from acquisitions. *Journal of Financial Economics,* 73 (2): 201–228.

Molloy J.C., Chadwick C., Ployhart R.E. and Golden S.J. (2011) Making

intangibles "tangible" in tests of resource-based theory: a multidisciplinary construct validation approach. Journal of Management, September, doi:10.1177/0149206310394185

Montgomery, C.A. and Wilson, V.A. (1986) Mergers that last - a predictable pattern. *Strategic Management Journal,* 7 (1): 91–96.

Morck, R., Shleifer, A. and Vishny, R. (1988) Management ownership and market valuation: an empirical analysis. *Journal of Financial Economics,* 20 (1/2): 293–315.

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.

Murray, E.J. and Richardson, P.R. (2000) Shared understanding of the critical few: a parameter of strategic planning effectiveness. *International Journal of Business Performance Management*, 2 (1/2/3): 5–16.

Neely, A. (2000) Performance measurement: theory and practice. *International Journal of Business Performance Management*, 2 (1/2/3): 1–4.

Neely, A., Adams, C. and Kennerley, M. (2002) *The Performance* Prism - *The Scorecard for Measuring and Managing Business Success,* Financial Times Prentice Hall.

Neely, A., Gregory, M. and Platts, K. (1995) Performance measurement systems. *International Journal* of *Operations and Production Management*, 15 (4): 80–116.

Neyman, J. and Pearson, E. (1933) On the problem of the most efficient tests of statistical hypotheses. *Philosophical Transactions of the Royal Society of London, Series A,* 231: 289–337.

OFWAT (2005) A Consultation Paper on Monitoring Companies' Performance, *Birmingham, AMP 4*, June return 2005–10.

Oral, M., Kettani, O. and Lang, P. (1991) A methodology for collective evaluation and selection of industrial R&D projects. *Management Science*, 37: 7.

ORR (2004) Consultation for a Balanced Scorecard for Network Rail, *Network Rail Monitor*, November, 137.

Ozgen, H. and Ozcan, Y. A. (2000) Do mergers enhance the performance of hospital efficiency? *Journal of the Operational Research Society*, 51: 801–811.

Palich, L.E., Cardinal, L.B. and Miller, C.C. (2000) Curvilinearity in the diversification performance linkage - an examination of over three decades of research. *Strategic Management Journal*, 21 (2): 155–174.

Pangarkar, N. (2004) The impact of market cycle on the performance of Singapore acquirers. *Strategic Management Journal,* 25 (12): 1209–1216.

Papadakis, V.N. and Thanos, T. (2010) Ioannis, measuring the performance of acquisitions: an empirical investigation using multiple criteria. *British Journal of Management*, 21 (4): 859–873.

Papalexandris, A., Ioannou, G., Prastacos, G. and Soderquist, K.E. (2005) An integrated methodology for putting the balanced scorecard into action. *Eur Mngt J*, 23 (2): 214–227.

Park, J., Morel, B. and Madhaven, R. 2010 *Big Surf: Self-Organised Criticality in M&A Waves*, SSRN working paper.

Pennings, J.M., Barkema, H. and Douma, S. (1994) Organizational learning and diversification. *Academy of Management Journal,* 37 (3): 608–640.

Penrose, E. (1959) *The Theory of the Growth of the Firm,* Oxford: Oxford University Press.

Peteraf, M.A. (1993) The cornerstones of competitive advantage: a resource-

based view. *Strategic Management Journal*, 14: 179–191.

Peteraf, M.A. and Barney, J.B. (2003) Unravelling the resource-based tangle. *Managerial and Decision Economics*, 24 (4): 309–323.

Pharmaceutical Research and Manufacturers of America (2010) *Pharmaceutical Industry Profile 2010,* Washington, DC: PhRMA.

Pharmalive (2007) *Top 50 Pharmaceutical Company Pipelines,* Los Angeles: Canon Communications LLC.

Pharmaventures (2003) *Valuing and Structuring Pharmaceutical Licensing* Agreements, page 8, *Pharmaventures*, Oxford, UK.

Pozen, David E. (2005) The mosaic theory, national security, and the Freedom of Information Act. Y*ale Law Journal*, 115: 628–679.

Prahalad, C.K. and Hamel, G. (1990) the core competence of the organization. *Harvard Business Review,* May-June: 79–90.

Priem, R.L. and Butler J.E. (2001a) Is the resource-based "view" a useful perspective for strategic management research. *Academy of Management Review,* 26 (1): 22–40.

Priem, R.L. and Butler J.E. (2001b) Tautology in the resource-based view and the implications of externally determined value: further comments. *Academy of Management Review,* 26 (1): 57–66.

Puranam, P., Singh, H. and Zollo, M. (2006) Organizing for innovation: Managing the coordination-autonomy dilemma in technology acquisitions. *Academy of Management Journal*, 49 (2): 263 - 280.

Ramaswamy, K. (1997) The performance impact of strategic similarity in horizontal mergers - evidence from the U.S. banking industry. *Academy of Management Journal,* 40 (3): 697–715.

Ravenscraft, D.J. and Scherer, F.M. (1987) Life after takeover. *Journal of Industrial Economics,* 36 (2): 147–156.

Reid, S.R. (1968) *Mergers, Managers and the Economy,* New York: McGraw-Hill.

Rockart, J.F. (1979) Chief executives define their own data needs. *Harvard Business Review,* (2): 81–93.

Roos, J., Roos, G., Dragonetti, N.C. and Edvinsson, L. (1997) *Intellectual Capital: Navigating the New Business Landscape*, London: Macmillan.

Rucci, A.J., Kirn, S.P. and Quinn, R.T. (1998) The employee-customer-profit chain at Sears. *Harvard Business Review*, 76 (1): 82–97.

Rumelt, R.P. (1984) Toward a strategic theory of the firm. In R. Lamb (ed.), *Competitive Strategic Management*, Englewood Cliffs, NJ: Prentice Hall, pp. 556– 570.

Schoenberg, R. (2006) Measuring the performance of corporate acquisitions: an empirical comparison of alternative metrics. *British Journal of Management*, 17 (4): 361–370.

Schoenberg, R. and Reeves, R. (1999) What determines acquisition activity within an industry? *European Management Journal,* 17 (1): 93–98(6).

Schumpeter, J. A. (1950) *Capitalism, Socialism, and Democracy*, 3rd edn, New York: Harper & Row.

Schweiger, D.M. and Denisi, A.S. (1991) Communication with employees following a merger - a longitudinal field experiment. *Academy of Management Journal,* 34 (1): 110–135.

Seth, A. (1990a) Value creation in acquisitions: A re-examination of performance. *Strategic Management Journal*, 11: 99–116.

Seth, A. 1990b. Sources of value creation in acquisitions: An empirical investigation. *Strategic Management Journal,* 11: 431–447.

Seth, A., Song, K.P. and Pettit, R. (2000) Synergy, managerialism or hubris? An empirical examination of motives for foreign acquisitions of U.S. firms. *Journal of International Business Studies*, 31 (3): 387–405.

Seth, A., Song, K.P. and Pettit, A.R. (2002) Value creation and destruction in cross-border acquisitions. *Strategic Management Journal,* 23: 921–940.

Shahrur, H. (2005) Industry structure and horizontal takeovers - analysis of wealth effects on rivals, suppliers, and corporate customers. *Journal of Financial Economics,* 76 (1): 61–98.

Shanley, M.T. and Correa, M.E. (1992) Agreement between top management teams and expectations for post-acquisition performance. *Strategic Management Journal,* 13(4): 245–266.

Sharma, S. and Thomas, V.J. (2008) Inter-country R&D efficiency analysis: An application of data envelopment analysis. *Scientometrics*, 76 (3): 483–501.

Shelton, L.M. (1988) Strategic business fits and corporate acquisition - empirical evidence. *Strategic Management Journal,* 9 (3): 279–287.

Sheskin D. (2011), *Handbook of Parametric and Nonparametric Statistical Procedures*, Fifth edition, Chapman & Hall/CRC.

Singh, H. and Montgomery, C.A. (1987) Corporate acquisition strategies and economic performance. *Strategic Management Journal,* 8: 377–387.

Sirower, M.L. (1997) *The Synergy Trap: How Companies Lose the Acquisition Game*, New York: The Free Press.

Slusky, A.R. and Caves, R.E. (1991) Synergy, agency, and the determinants of premia paid in mergers. *Journal of Industrial Economics,* 39 (3): 277–296.

Smith, K.V. and Schreiner, J.C. (1969) A portfolio analysis of conglomerate. diversification. *Journal of Finance*, 13: 413–428.

Speckbacher, G., Bischofb, J. and Pfeiffer, T. (2003) A descriptive analysis on the implementation of Balanced Scorecards in German-speaking countries.

Management Accounting Research, 14 (4): 361–388.

Stankevicien J. and Svidersk T. (2010) Developing a performance measurement system integrating economic value added and the balanced scorecard in pharmaceutical company, *6th International Scientific Conference*, May 13–14, Vilnius, Lithuania, Business and Management, doi:10.3846/bm.2010.033

Stewart, T.A. (1997) *Intellectual Capital: The New Wealth of Organizations,* New York, NY: Doubleday/Currency.

SubbaNarasimha, P.N., Ahmad, S. and Mallya, S.N. (2003) Technological knowledge and firm performance of pharmaceutical firms. *Journal of Intellectual Capital*, 4 (1): 20–33.

Sveiby, K.E. (1997) *The New Organizational Wealth: Managing and Measuring Knowledge-based Assets*, San Francisco, CA: Barrett-Kohler.

Sweeny, K. (2002) *Technology Trends in Drug Discovery and Development: Implications for the Development of the Pharmaceutical Industry in Australia*, Working paper No. 3.

Sykes, D. (1999) *Pharmaceutical Mergers and Acquisitions*, Business Insights.

Tavares, G. (2002) *A Bibliography of Data Envelopment Analysis (1978-2001)*, Rutcor Research Report Piscataway, New Jersey: Rutgers University.

Teece, D., Pisano, G. and Shuen, A. 1997. Dynamic capabilities and strategic management. *Strategic Management Journal,* 18 (7): 509–533.

Thakor, A.V. (1999) Information technologies and financial services consolidation. *Journal of Banking and Finance,* 23: 697–700.

Travlos, N.G. (1987) Corporate takeover bids, methods of payment, and bidding firms' stock returns. *Journal of Finance*, 42: 943–963.

Travlos, N.G. and Waegelein, J.F. (1992) Executive compensation, method of payment and abnormal returns to bidding firms at takeover announcements. *Managerial & Decision Economics* 13(6), Nov./Dec: 493–501.

Venkatraman, N. and Grant, J.H. (1986) Construct measurement in organizational strategy research: A critique and proposal. *Academy of Management Review*, 11 (1): 71–87.

Vermeulen, F. and Barkema, H. (1996) Learning through acquisition. *Academy of Management Journal,* 44 (3): 457–476.

Walker, M. (2000) Corporate takeovers, strategic objectives, and acquiring-firm shareholder wealth. *Financial Management,* 29: 53–66.

Walsh, J.P. (1988) Top management turnover following mergers and acquisitions. *Strategic Management Journal,* 9: 173–184.

Walsh, J.P. (1989) Doing a deal - merger and acquisition negotiations and their impact upon target company top management turnover. *Strategic Management Journal,* 10 (4): 307–322.

Wansley, J., Lane, W. and Yang, H. (1983) Abnormal returns to acquired firms by type of acquisition and method of payment. *Financial Management,* 12: 16–22.

Weber, Y. (1996) Corporate cultural fit and performance in mergers and acquisitions. *Human Relations,* 49 (9): 1181–1203.

Welch, B.L. (1947) The generalization of "Student's" problem when several different population variances are involved. *Biometrika*, 34 (1–2): 28–35.

Wernerfelt, B. (1984) A resource-based view of the organisation. *Strategic Management Journal*, 5: 171–180.

Weston, J.F. and Mansinghka, S.K. (1971) Tests of the efficiency performance in conglomerate firms. *Journal of Finance,* 26: 919–936.

Williamson, O.E. (1999) Strategy research: governance and competence perspectives. *Strategic Management Journal,* 20: 1087–1108.

Wong, Y.H.B. and Beasley, J.E. (1990) Restricting weight flexibility in data envelopment analysis. *J Opl Res Soc,* 41: 829–835.

Worthington, A.C. (2004) Determinants of merger and acquisition activity in Australian cooperative deposit-taking institutions. *Journal of Business Research*, 57 (1): 47–57.

Yeoh, P. and Roth, K. (1999) An empirical analysis of sustained advantage in the US pharmaceutical: impact of firm resources and capabilities. *Strategic Management Journal*, 20 (7): 637–653.

Zimmerman, D.W. (1998) Invalidation of parametric and nonparametric statistical tests by concurrent violation of two assumptions. *The Journal of Experimental Education*, 67: 55–68.

Zollo, M. and Meier, D. (2008) What is M&A performance? *Academy of Management Perspectives*, 22: 55–77.

Zollo, M. and Reuer, J.J. (2005) *Experience Spillovers Across Corporate Development Activities*, Working paper.

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.

A. R&D Data

A.1 Introduction

The R&D data used in the models are a combination of primary data and calculated data. The origins of the primary data and the adjustments are detailed in this Appendix.

A.2 Historical R&D Data

The historical R&D expenditure in $million unadjusted for inflation is shown in Table A.1 for the years from 2005 to 2001. These data are drawn from the same source to enhance compatibility. If this source did not have data for a particular firm or for a particular year, then the cells were left blank in Table A.1.

Table A.1 Historical R&D Data in US$million Actual

Firm	R&D 2005	R&D 2004	R&D 2003	R&D 2002	R&D 2001
Abbt	1821	1697	1624	1475	1492
Akzo	681	640	705	747	666
Alco	422	390	350	324	290
Alle	391	346	764	233	228
Amg	2314	2028	1655	1167	865
Astel	1214	1091	1221	562	547

Astr	3379	3467	3012	3069	2687
Baus	178	163	150	128	122
Baxt	533	517	553	501	426
Baye	1188	1300	1555	1727	1973
Biog	748	686	534		
BMS	2746	2500	2279	2206	2157
Boeh	1693	1534	1464	1623	1269
Ceph	125	134	102	82	64
Chug	424	408	369	411	405
CSL					
Daic	1357	1241			
Dain	253	149	136	130	112
Eisa	797	669	590	510	470
EliL	3026	2691	2350	2149	2235
Fore	410	294	234	205	158
Gene	1262	948	722	623	526
Genz	503	392	335	308	264
Gile					

GSK	5709	5286	5215	5279	4826
John	6312	5203	4684	3957	3591
King					
Kyow	239	207	2111	232	213
Lund	300	296	322	262	257
Merc	3848	4010	3280	2667	2456
Merk	721	612	630	621	596
Mits	410	431	432	413	293
Nova	4846	4171	3729	2843	2528
Novo	848	726	676	659	662
Nyco					
Pfiz	7442	7684	7487	5208	4776
Roch	4579	4137	3825	3417	3125
Sano	5034	4935	1638	1516	1283
Schr	1865	1697	1469	1425	1312
Shio	276	251	255	267	262
Shir					
Solv	437	366	354	335	276

Tais	197	198	207	252	275
Take	1417	1156	1046	972	792
Teva	369	338	214	165	107
UCB	642	454	264	268	211
Wats					
Wyet	2749	2461	2094	2080	1870

A.3 Historical Sales Data

The estimation of a single parameter for historical R&D also requires the revenue statistics for the years 2001 to 2005. These data are given below, unadjusted for inflation. Blank cells indicate unavailable data.

Table A.2 Historical Revenue Data in $million Actual

Firm	Rev. 2005	Rev. 2004	Rev. 2003	Rev. 2002	Rev. 2001
Abbt	22338	19680	17280	15280	13919
Akzo	4381	4197	4419	4990	5034
Alco	4369	3914	3407	3009	2748
Alle	2319	2946	1755	1385	1142
Amg	12430	10550	8356	5523	4016

Astel	7434	7195	3851	3778	3544
Astr	23950	21426	18849	17841	16222
Baus	2335	2232	2020	1817	1666
Baxt	9849	9509	8904	8099	7342
Baye	11738	10031	11044	11667	13309
Biog	2423	2212	1852		
BMS	19207	19380	18653	16208	16612
Boeh	11870	10155	9190	9436	8333
Ceph	1646	1641	1458	1223	1160
Chug	2773	2497	1972	2012	1794
CSL					
Daic	6707	6552			
Dain	1646	1276	1258	1272	1200
Eisa	4957	4369	4077	3777	3466
EliL	14645	13858	12583	11078	11543
Fore	2962	3160	2680	2246	1602
Gene	6633	4621	3300	2584	2044
Genz	2735	2201	1714	1329	1224

Gile					
GSK	39430	36383	38356	38614	37928
John	50514	47348	41862	36298	32317
King					
Kyow	1769	1831	1813	1702	1691
Lund	1513	1623	1658	1583	1277
Merc	22012	22939	22486	21446	21199
Merk	4848	4943	6849	6994	7259
Mits	2019	2002	2012	2390	1957
Nova	32212	28247	24864	20877	18762
Novo	5631	4842	4363	4148	3901
Nyco					
Pfiz	51298	52516	44736	32294	29024
Roch	28502	23695	25058	23640	23407
Sano	33999	31370	29019	9272	8077
Schr	9508	8272	8334	10180	9762
Shio	1653	1677	1681	2397	3504
Shir					

Solv	2826	2172	2281	2319	2202
Tais	2320	2388	2448	2343	2320
Take	9184	8295	8088	7605	
Teva	5250	4790	3276	2519	2077
UCB	2941	2368	1838	1854	1793
Wats					
Wyet	18776	17358	15851	14854	13984

A.4 Current R&D & Composite R&D Data

Column 2 of Table A.3 shows the R&D expenditure for 2006 and Column 3 shows the R&D expenditure for 2005, drawn from a source which allows direct comparison between those two years. In most cases the 2005 data are the same as shown in Column 2 of Table A.1 (for example 'Abbt' has an expenditure of $1821 million in both cases) however there can be small differences (for example 'Akzo' has an expenditure of $687m in the data shown in Table A.3 but an expenditure of $681m in Table A.1).

It is necessary to adjust the 2005 R&D expenditure shown in Column 3 of Table A.3 for 2005 for two effects:

- the rate of inflation of the US dollar from 2005 to 2006;
- the historic trend in R&D from 2001 to 2005 as shown in Table A.1.

The first adjustment requires the inflation of the 2005 data by 3%[4] to reflect 2006 prices. The second adjustment is more complex and is described below.

The data in Tables A.1 and A.2 (which are comparable between years) are used to express R&D expenditure as a percentage of Revenue for each year. The ratio of the percentage in 2005 to the average ratio for the years from 2001 to 2004[5] is then used to apply an adjustment factor (reflecting the historic trend in R&D as a percentage of Revenue) to the 2005 R&D expenditure in Column 3 of Table A.3. This calculation of the historic adjustment factor is shown for each firm in Columns 4, 5 and 6 respectively of Table A.3.

The final column, Column 7 in Table A.3, shows the data used as in input to the DEA model for historic DEA, which is the product of the Historic Adjustment to reflect historic R&D expenditure as a percentage of Revenue and the changing price levels from 2005 to 2006.

The adjustment can be expressed algebraically as:

Historic R&D DEA Input *equals*

Comparable 2005 R&D Expenditure

times Inflation adjustment to 2006 price levels

times $\frac{\text{average R\&D as \% sales 2001 to 2004}}{\text{average R\&D as \% sales in 2005}}$

The results of the calculation are shown in Table A.3.

[4] http://data.bls.gov/cgi-bin/cpicalc.pl?cost1=1000&year1=2005&year2=2006

[5] The R&D expenditure for the year 2005 is excluded from the calculation of the average, so as to avoid the circularity of adjusting a figure for a historic trend that includes the figure itself.

Table A.3 Current & Composite R&D Data in $million Actual

	R&D 2006	R&D 2005 (comp. to '06)	R&D/Rev 2005 %	Mean R&D/Rev '04 – '01 %	Historic Adjustment	DEA Input for Historic R&D
Abbt	2255	1821	8.15%	9.60%	117.74%	2208
Akzo	741	687	15.54%	14.85%	95.54%	676
Alco	512	422	9.66%	9.25%	95.81%	416
Alle	1056	388	16.86%	23.02%	136.51%	546
Amg	3366	2314	18.62%	20.42%	109.71%	2615
Astel	1435	1214	16.33%	19.29%	118.15%	1477
Astr	3902	3379	14.11%	16.48%	116.82%	4066
Baus	197	178	7.62%	7.27%	95.42%	175
Baxt	614	533	5.41%	5.91%	109.19%	599
Baye	1791	1048	10.12%	14.17%	139.97%	1511
Biog	718	748	30.87%	29.92%	96.93%	747
BMS	3067	2746	14.30%	12.93%	90.43%	2558
Boeh	1977	1709	14.26%	15.87%	111.24%	1958

Ceph	403	355	7.59%	6.85%	90.15%	330
Chug	467	428	15.29%	19.51%	127.62%	563
CSL	161	136			100.00%	140
Daic	1459	1357	20.23%	18.94%	93.62%	1308
Dain	350	253	15.37%	9.71%	63.19%	165
Eisa	926	797	16.08%	12.99%	80.78%	663
EliL	3129	3026	20.66%	19.21%	92.99%	2898
Fore	941	410	13.84%	9.26%	66.87%	282
Gene	1773	1262	19.03%	27.43%	144.16%	1874
Genz	650	503	18.39%	20.52%	111.60%	578
Gile	384	278			100.00%	286
GSK	6373	5781	14.48%	13.63%	94.14%	5605
John	7125	6462	12.50%	11.05%	88.41%	5885
King	254	263			100.00%	271
Kyow	268	264	13.51%	38.49%	284.91%	775
Lund	329	300	19.83%	18.58%	93.72%	290
Merc	4783	3848	17.48%	14.02%	80.21%	3179
Merk	772	728	14.87%	9.67%	65.00%	487

Mits	403	410	20.31%	18.81%	92.64%	391
Nova	5349	4825	15.04%	14.21%	94.48%	4696
Novo	1063	856	15.06%	15.84%	105.16%	927
Nyco	47	36			100.00%	37
Pfiz	7599	7256	14.51%	15.99%	110.20%	8236
Roch	5258	4526	16.07%	15.13%	94.19%	4391
Sano	5565	5080	14.81%	13.40%	90.52%	4736
Schr	2188	1865	19.62%	16.39%	83.58%	1606
Shio	320	276	16.70%	14.30%	85.65%	243
Shir	387	339			100.00%	349
Solv	533	441	15.46%	14.84%	95.95%	436
Tais	244	197	8.49%	9.84%	115.87%	235
Take	1620	1417	15.43%	13.22%	85.66%	1250
Teva	495	369	7.03%	6.32%	89.96%	342
UCB	1024	888	21.83%	14.94%	68.44%	626
Wats	131	125			100.00%	129
Wyet	3109	2749	14.64%	13.69%	93.51%	2648

A.5 Conclusion

The historic R&D data has been adjusted to arrive at a figure that best reflects the inputs to the R&D process by adjusting for changes to the policy of R&D expenditure (expressed as a expenditure as a percentage of Revenue) from 2001 onwards and applying an adjustment to the 2005 R&D expenditure and adjusting for inflation. However the historic figure remains highly correlated to the current figure (for 2006) and so the impact on the DEA results may be limited as is the application or removal of input weight restrictions on the relative weight of the current and historic R&D expenditure.

B. Staff Data

B.1 Introduction

Some of the DEA models require the numbers of staff as an input. The model input has been calculated by forming the arithmetic means of staff numbers from 2001 to 2005, where that information is available; where not, estimates are made from other sources. The primary data are summarised below.

B.2 Staff Data

The staff data are shown in Table B.1.

Table B.1 Staff Numbers

Company	*Staff*	*Staff 2005*	*Staff 2004*	*Staff 2003*	*Staff 2002*	*Staff 2001*
Abbt	67155.6	59735	60617	72181	71819	71426
Akzo	64314	61340	61450	64580	67900	66300
Alco	12040	12700	12200	11900	11800	11600
Alle	5270.2	5055	5030	4930	4900	6436
Amg	12320	16500	14400	12900	10118	7682
Astel	11505.4	15000	15000	9062	9278	9187
Astr	60820	63500	64200	62600	59200	54600
Baus	12220	14000	12400	11600	11500	11600

Baxt	49780	47000	48000	51300	54600	48000
Baye	108060	93700	91700	115400	122600	116900
Biog	3777.667	3340	4266	3727		
BMS	44000	43000	43000	44000	44000	46000
Boeh	33395.8	37406	35529	34221	31843	27980
Ceph	3851.75	3844	3851	3983	3729	
Chug	5420.4	5357	5327	5680	5774	4964
CSL	10000					
Daic	18605.5	18434	18777			
Dain	3016.2	5142	2427	2480	2480	2552
Eisa	7953.8	9081	8295	7700	7433	7260
EliL	43100	42600	44500	45000	42900	40500
Fore	4624.8	5050	5136	4967	4240	3731
Gene	6727.4	9563	7646	6226	5252	4950
Genz	6325	8200	7000	5625	5600	5200
Gile	4000					
GSK	102727	100728	100019	100919	104499	107470
John	109240	115600	109900	110600	108300	101800

King	2600					
Kyow	6429.4	5800	5960	6294	6794	7299
Lund	4618		5155	5223	4534	3560
Merc	68540	61500	62600	63200	77300	78100
Merk	32202.8	29133	28877	34206	34504	34294
Mits	7138.8	5902	5917	6122	8733	9020
Nova	78970	90924	81392	78541	72877	71116
Novo	19038.8	22007	20285	18756	18005	16141
Nyco	12000					
Pfiz	106200	106000	115000	122000	98000	90000
Roch	66309	68218	64594	65357	69659	63717
Sano	69942.8	97181	96439	93144	32436	30514
Schr	30780	32600	30500	30500	30500	29800
Shio	6285.2	4997	5522	5589	6149	9169
Shir	4000					
Solv	29502	28730	26926	30139	30302	31413
Tais	5141.4	5191	5339	5477	4806	4894
Take	14645.8	15069	14510	14592	14547	14511

Teva	11606.6	14698	13813	10960	9576	8986
UCB	9804.2	8525	8598	11559	10326	10013
Wats	5830					
Wyet	51713.6	49732	51401	52384	52762	52289

C. Power Laws

C.1 Introduction

This appendix summarises the main features of a 'power law' and some of the pitfalls in identifying a power law from empirical data. Power laws have recently attracted attention by their apparent ubiquity; however this has now been matched by a critical attitude to their identification. This appendix first defines a power-law distribution and notes alternative distributions which might also give rise to a similar 'signature', namely a straight line when the distribution is plotted on a log/log scales. It concludes with a summary of the relevance to the literature of this research and potential future work.

C.2 Definition of a Power Law

The characteristics of a power law are its scale invariance. To illustrate with the simplest expression of a power law:

$$f(x) = k\, x^{a} \qquad \text{Eq. (C.1)}$$

where x is an independent variable

k is a constant

a is a constant

If there is a scaling transformation given by:

$$y = c \bullet .x \qquad \text{Eq. (C.2)}$$

where c is a constant

then:

$$f(y) = c^{a} \cdot f(x) \qquad \text{Eq. (C.3)}$$

that is the functional form repaints the same with a change in scale. Eq. (C.1) can be written in logarithmic form:

$$\log f(x) = -a.\log(x) + \log(k) \qquad \text{Eq. (C.4)}$$

where x is an independent variable

k is a constant

a is a constant

Eq. (C.4) gives rise to a common means of identification of a power law, a 'signature', namely the observance of a straight line on a log/log graph. Although this is a characteristic of a power law as defined above, two issues arise.

The first is that power laws only apply for a range of variables and it is necessary to establish the range over which the law holds. The second is that other mathematical functions also can show a linear plot on a log/log graph therefore it is necessary to eliminate these possibilities before a power law is confirmed. These issues are now considered further.

C.3 Alternative Distributions

Clauset et al. (2009) considered four discrete and five continuous nonlinear distributions, with the five continuous distributions were a power law; a power law with cut-off, exponential, stretched exponential and log-normal.

After developing statistical testing methods using synthetic data, 24 actual data sets which showed a straight-line log/log plot were tested in order to

confirm a power law with empirical data. In only one case, the frequency of words in the English language, could power law be confirmed and all other possibilities excluded. In all but three cases the exponential could be excluded but the log-normal and stretched exponential distributions were plausible alternatives in nine cases. The authors then emphasise the importance of looking at the underlying processes giving rise to the distribution rather than relying on tests alone.

Farmer & Geanakoplos (2008) outlined several mechanisms for generating power laws (as opposed to log-normal which are produced by multiplicative processes) including maximisation of entropy (i.e. randomness), preferential attachment (i.e. a quantity is allocated on the basis of how much is already held) and critical systems (an example of a pile of sand is use to illustrate, where a steady stream of sand will eventually lead to an avalanche of sand). Mitzenmacher (2001) also considers generative models that produce both power law and log-normal distributions.

C.4 Relevance to this Thesis

A linear plot on a log–log graph has been observed, which could represent either a power law or log-normal behaviour. A plausible explanation for power-law behaviour has been proposed by Park et al. (2010), namely self-organising criticality (with an initial mega-merger leading to a cascade of smaller events); the findings of the thesis are consistent with this hypothesis but are not definitive in establishing a power law. Confirmation of that would require further statistical analysis.

D. DEA Model Data

Table D.1 DEA Model Inputs

Symbol for Input		x_1	x_2	x_3
Name of Firm	Code	R&D Expense US$m, 2006	R&D Expense US$m, Historic Mean	Staff Numbers
Abbot Laboratories	Abbt	2255	2208	67156
Akzo Nobell NV	Akzo	741	676	64314
Alcon Inc.	Alco	512	416	12040
Allergan Inc.	Alle	1056	546	5270
Amgen Inc.	Amg	3366	2615	12320
Astellas Pharma Inc.	Astel	1435	1477	11505
AstraZeneca Plc	Astr	3902	4066	60820
Bausch & Lomb Inc.	Baus	197	175	12220
Baxter International Inc.	Baxt	614	599	49780
Bayer AG	Baye	1791	1511	108060
Biogen Idec Inc.	Biog	718	747	3778

Bristol Myers Squibb Co.	BMS	3067	2558	44000
Boehringer Ingelheim	Boeh	1977	1958	33396
Cephalon	Ceph	403	330	3852
Chugai Pharmaceutical	Chug	467	563	5420
CSL Ltd	CSL	161	140	10000
Daiichi Sankyo Co.	Daii	1459	1308	18606
Dainippon Sumiformo	Dain	350	165	3016
Eisai Co.	Eisa	926	663	7954
Eli Lilly and Co.	EliL	3129	2898	43100
Forest Pharmaceuticals	Fore	941	282	4625
Genentech Inc.	Gene	1773	1874	6727
Genzyme Corp.	Genz	650	578	6325
Gilead Sciences Inc.	Gile	384	286	4000

GlaxoSmithKline Plc.	GSK	6373	5605	102727
Johnson & Johnson	John	7125	5885	109240
King Pharmaceuticals	King	254	271	2600
Kyowa Hakko Kogyo	Kyow	268	247	6429
H Lundbeck	Lund	329	290	4618
Merck & Co.	Merc	4783	3179	68540
Merck KgaA	Merk	772	487	32203
Mitsubishi Pharma	Mits	403	391	7139
Novartis	Nova	5349	4696	78970
Novo Nordisk As	Novo	1063	927	19039
Nycomed	Nyco	47	37	12000
Pfizer Inc.	Pfiz	7599	8236	106200
Roche	Roch	5258	4391	66309
Sanofi Aventis Group	Sano	5565	4736	69943

Schering-Plough Corp.	Scher	2188	1606	30780
Shionogi & Co.	Shio	320	243	6285
Shire Plc	Shir	387	349	4000
Solvay SA	Solv	533	436	29502
Taisho Pharmaceutical	Tais	244	235	5141
Takeda Pharmaceutical	Take	1620	1250	14646
Teva Pharmaceutical	Teva	495	342	11607
UCB SA	UCB	1024	626	9804
Watson Pharmaceutical	Wats	131	129	5830
Wyeth	Wyet	3109	2648	51714

Table D.2 DEA Model Compounds (Comp.) Output Data

Symbol	y_5	y_4	y_3	y_2	y_1
Phase	Awaiting Approval	Phase 3 Comp.	Phase 2 Comp.	Phase 1 Comp.	Preclinical Comp.
Abbt	3	9	7	11	10
Akzo	2	4	4	9	7
Alco	4	3	2	0	0
Alle	4	5	6	0	2
Amg	2	8	11	14	1
Astel	15	6	15	1	3
Astr	5	14	14	25	38
Baus	0	1	1	0	1
Baxt	0	1	1	0	2
Baye	9	15	16	14	2
Biog	1	8	11	1	10
BMS	9	7	4	8	1
Boeh	2	2	3	0	0
Ceph	1	5	5	0	4

Chug	7	5	10	5	0
CSL	6	4	1	1	2
Daii	4	10	10	13	1
Dain	4	1	11	1	0
Eisa	8	7	7	8	2
EliL	6	11	21	12	8
Fore	3	4	3	0	3
Gene	1	13	12	15	3
Genz	6	8	8	8	8
Gile	2	3	1	2	3
GSK	23	24	30	40	1
John	8	23	8	8	1
King	1	4	3	0	0
Kyow	2	2	3	3	1
Lund	0	3	2	4	0
Merc	11	7	17	30	2
Merk	3	7	14	8	8
Mits	4	7	9	0	0

Nova	15	30	28	26	9
Novo	2	5	5	6	0
Nyco	1	5	4	1	4
Pfiz	5	11	52	42	5
Roch	7	18	22	30	6
Sano	14	24	35	34	39
Scher	10	13	13	2	2
Shio	3	1	7	4	0
Shir	4	1	2	1	4
Solv	8	10	7	4	1
Tais	0	0	8	3	0
Take	7	14	12	5	1
Teva	0	5	6	0	4
UCB	4	7	4	0	1
Wats	2	2	0	1	0
Wyet	7	10	13	2	1

Table D.3 DEA Model Clinical Trials Output Data

Sym-bol	y_5	y_4	y_3	y_2	y_1	*Ratio Trials to Compounds*				
Phase (Ph.)	Await .Appr (AA)	Ph. 3 (P3)	Ph. 2 (P2)	Ph. 1 (P1)	Preclinic (PC)	AA	P3	P2	P1	PC
Abbt	8	10	10	15	11	2.67	1.11	1.43	1.36	1.10
Akzo	3	8	6	9	9	1.50	2.00	1.50	1.00	1.29
Alco	4	6	2	0	0	1.00	2.00	1.00		
Alle	4	10	8	0	2	1.00	2.00	1.33		1.00
Amg	3	16	12	15	1	1.50	2.00	1.09	1.07	1.00
Astel	22	12	17	1	4	1.47	2.00	1.13	1.00	1.33
Astr	8	42	33	53	45	1.60	3.00	2.36	2.12	1.18
Baus	0	1	1	0	1		1.00	1.00		1.00
Baxt	0	1	1	1	2		1.00	1.00		1.00
Baye	11	24	32	15	2	1.22	1.60	2.00	1.07	1.00
Biog	3	24	18	1	11	3.00	3.00	1.64	1.00	1.10
BMS	11	14	8	9	1	1.22	2.00	2.00	1.13	1.00
Boeh	2	4	3	0	0	1.00	2.00	1.00		

Ceph	1	8	5	0	4	1.00	1.60	1.00		1.00
Chug	9	7	17	6	0	1.29	1.40	1.70	1.20	
CSL	6	5	1	1	3	1.00	1.25	1.00	1.00	1.50
Daii	5	12	22	26	2	1.25	1.20	2.20	2.00	2.00
Dain	4	1	19	1	0	1.00	1.00	1.73	1.00	
Eisa	10	12	24	10	2	1.25	1.71	3.43	1.25	1.00
EliL	7	19	28	12	12	1.17	1.73	1.33	1.00	1.50
Fore	4	5	4	0	4	1.33	1.25	1.33		1.33
Gene	1	46	21	20	4	1.00	3.54	1.75	1.33	1.33
Genz	6	12	10	10	10	1.00	1.50	1.25	1.25	1.25
Gile	4	3	2	3	4	2.00	1.00	2.00	1.50	1.33
GSK	27	35	87	49	1	1.17	1.46	2.90	1.23	1.00
John	15	48	9	9	1	1.88	2.09	1.13	1.13	1.00
King	1	4	7	0	0	1.00	1.00	2.33		
Kyow	2	2	3	4	1	1.00	1.00	1.00	1.33	1.00
Lund	0	3	2	4	0		1.00	1.00	1.00	
Merc	14	12	29	33	2	1.27	1.71	1.71	1.10	1.00
Merk	3	10	34	19	10	1.00	1.43	2.43	2.38	1.25

Mits	5	11	11	0	0	1.25	1.57	1.22		
Nova	21	42	38	30	10	1.40	1.40	1.36	1.15	1.11
Novo	7	7	9	11	0	3.50	1.40	1.80	1.83	
Nyco	1	7	7	1	8	1.00	1.40	1.75	1.00	2.00
Pfiz	10	19	64	42	5	2.00	1.73	1.23	1.00	1.00
Roch	14	60	38	35	6	2.00	3.33	1.73	1.17	1.00
Sano	14	37	53	42	52	1.00	1.54	1.51	1.24	1.33
Scher	10	26	18	2	2	1.00	2.00	1.38	1.00	1.00
Shio	3	1	7	4	0	1.00	1.00	1.00	1.00	
Shir	4	2	2	1	4	1.00	2.00	1.00	1.00	1.00
Solv	11	11	9	4	1	1.38	1.10	1.29	1.00	1.00
Tais	0	0	14	5	0			1.75	1.67	
Take	8	23	29	10	1	1.14	1.64	2.42	2.00	1.00
Teva	0	6	8	0	4		1.20	1.33		1.00
UCB	6	13	6	0	1	1.50	1.86	1.50		1.00
Wats	2	2	0	1	0	1.00	1.00		1.00	
Wyet	10	16	19	2	1	1.43	1.60	1.46	1.00	1.00

Table D.4 DEA Efficiency Scores for Compounds as Outputs

Symbol	η_k	θ_k	e_k	$\ln(e_k)$	$\ln((x_{1k}+x_{2k})/2)$
Firm	VRS Eff.	CRS Eff.	Scale Eff.	Log Scale Eff.	Log Avg. R&D
Abbt	53.3%	5.6%	10.5%	-2.25494	7.711
Akzo	63.5%	11.4%	17.9%	-1.7209	6.563
Alco	50.0%	22.6%	45.2%	-0.79386	6.140
Alle	53.1%	15.8%	29.7%	-1.21273	6.686
Amg	47.5%	4.5%	9.4%	-2.36105	8.003
Astel	100.0%	27.9%	27.9%	-1.27773	7.284
Astr	83.2%	7.1%	8.5%	-2.46574	8.290
Baus	14.6%	4.6%	31.5%	-1.15603	5.226
Baxt	10.7%	1.9%	17.9%	-1.72307	6.408
Baye	100.0%	17.9%	17.9%	-1.72284	7.409
Biog	78.5%	12.4%	15.8%	-1.84477	6.596
BMS	55.1%	8.7%	15.8%	-1.84215	7.942
Boeh	16.7%	3.0%	17.9%	-1.72215	7.585
Ceph	55.9%	12.7%	22.7%	-1.48295	5.903

Chug	93.3%	41.2%	44.2%	-0.81673	6.244
CSL	100.0%	100.0%	100.0%	0	5.014
Daii	77.1%	11.4%	14.8%	-1.91103	7.233
Dain	97.2%	50.7%	52.2%	-0.65005	5.550
Eisa	90.0%	29.4%	32.7%	-1.1189	6.678
EliL	71.9%	7.5%	10.5%	-2.25524	8.011
Fore	40.8%	16.4%	40.1%	-0.91263	6.416
Gene	74.2%	9.0%	12.1%	-2.10854	7.508
Genz	100.0%	30.4%	30.4%	-1.19204	6.420
Gile	43.0%	17.9%	41.5%	-0.87945	5.815
GSK	100.0%	12.0%	12.0%	-2.12224	8.698
John	66.0%	4.2%	6.3%	-2.7648	8.780
King	46.8%	15.2%	32.5%	-1.12311	5.570
Kyow	38.6%	14.5%	37.6%	-0.97846	5.552
Lund	41.4%	11.3%	27.3%	-1.29768	5.734
Merc	75.8%	9.3%	12.3%	-2.09723	8.289
Merk	100.0%	20.5%	20.5%	-1.58451	6.445
Mits	92.3%	32.7%	35.5%	-1.0367	5.984

Nova	100.0%	10.2%	10.2%	-2.28306	8.522
Novo	45.2%	7.8%	17.2%	-1.75763	6.903
Nyco	100.0%	100.0%	100.0%	0	3.739
Pfiz	94.9%	5.6%	5.9%	-2.83154	8.977
Roch	75.6%	6.2%	8.1%	-2.50842	8.481
Sano	100.0%	9.8%	9.8%	-2.31827	8.547
Scher	90.6%	15.5%	17.1%	-1.76349	7.548
Shio	72.8%	33.2%	45.7%	-0.78342	5.641
Shir	54.3%	28.4%	52.4%	-0.64683	5.908
Solv	100.0%	46.8%	46.8%	-0.75987	6.183
Tais	58.6%	18.1%	30.9%	-1.1732	5.479
Take	91.2%	15.6%	17.1%	-1.76728	7.269
Teva	52.0%	11.3%	21.7%	-1.52662	6.037
UCB	55.7%	15.0%	27.0%	-1.31015	6.715
Wats	43.8%	41.5%	94.9%	-0.05219	4.867
Wyet	58.2%	7.4%	12.7%	-2.06679	7.965

Table D.5 DEA Efficiency Scores for Trials as Outputs

Symbol	η_k	θ_k	e_k	$\ln(e_k)$	$\ln((x_{1k}+x_{2k})/2)$
Firm	VRS Eff.	CRS Eff.	Scale Eff.	Log Scale Eff.	Log Avg. R&D
Abbt	53.4%	21.0%	39.4%	-0.93182	7.711
Akzo	56.2%	22.1%	39.4%	-0.93184	6.563
Alco	54.8%	48.5%	88.6%	-0.12149	6.140
Alle	72.5%	72.3%	99.8%	-0.00152	6.686
Amg	52.5%	30.7%	58.4%	-0.53722	8.003
Astel	100.0%	100.0%	100.0%	0	7.284
Astr	100.0%	47.7%	47.7%	-0.7397	8.290
Baus	9.2%	8.7%	94.3%	-0.0584	5.226
Baxt	7.8%	3.9%	49.4%	-0.70459	6.408
Baye	100.0%	35.4%	35.4%	-1.03815	7.409
Biog	100.0%	100.0%	100.0%	0	6.596
BMS	53.9%	25.8%	47.9%	-0.73658	7.942
Boeh	14.1%	7.5%	53.1%	-0.63236	7.585
Ceph	80.8%	67.7%	83.8%	-0.17712	5.903

Chug	100.0%	100.0%	100.0%	0	6.244
CSL	100.0%	100.0%	100.0%	0	5.014
Daii	84.5%	55.3%	65.5%	-0.42351	7.233
Dain	100.0%	100.0%	100.0%	0	5.550
Eisa	100.0%	100.0%	100.0%	0	6.678
EliL	61.8%	27.7%	44.8%	-0.80197	8.011
Fore	86.3%	85.7%	99.3%	-0.0068	6.416
Gene	100.0%	100.0%	100.0%	0	7.508
Genz	98.0%	91.3%	93.1%	-0.07112	6.420
Gile	77.6%	76.8%	99.0%	-0.01027	5.815
GSK	100.0%	36.8%	36.8%	-0.99975	8.698
John	88.4%	23.9%	27.0%	-1.30784	8.780
King	100.0%	68.1%	68.1%	-0.38465	5.570
Kyow	47.3%	42.5%	89.9%	-0.10641	5.552
Lund	35.6%	33.3%	93.4%	-0.06852	5.734
Merc	70.7%	23.3%	32.9%	-1.11208	8.289
Merk	100.0%	78.5%	78.5%	-0.2424	6.445
Mits	99.0%	98.0%	98.9%	-0.01093	5.984

Nova	99.1%	33.9%	34.2%	-1.07342	8.522
Novo	58.8%	40.4%	68.7%	-0.37484	6.903
Nyco	100.0%	100.0%	100.0%	0	3.739
Pfiz	70.4%	21.2%	30.1%	-1.20163	8.977
Roch	100.0%	41.6%	41.6%	-0.87618	8.481
Sano	100.0%	40.6%	40.6%	-0.90077	8.547
Scher	91.5%	50.0%	54.6%	-0.6047	7.548
Shio	57.9%	56.9%	98.2%	-0.01797	5.641
Shir	68.9%	64.5%	93.7%	-0.06514	5.908
Solv	100.0%	71.0%	71.0%	-0.34217	6.183
Tais	100.0%	85.8%	85.8%	-0.15332	5.479
Take	100.0%	66.6%	66.6%	-0.40593	7.269
Teva	44.5%	36.4%	81.9%	-0.19981	6.037
UCB	82.1%	75.3%	91.8%	-0.08594	6.715
Wats	100.0%	52.9%	52.9%	-0.63668	4.867
Wyet	55.9%	21.2%	38.0%	-0.96742	7.965

Table D.6 DEA Efficiency Scores for VRS for Alternative Input Assumptions

	η_k	η_k
Firm	Input: R&D Only	Input: R&D plus Staff
Abbt	53.3%	53.3%
Akzo	63.5%	63.5%
Alco	50.0%	53.0%
Alle	53.1%	76.1%
Amg	47.5%	75.3%
Astel	100.0%	100.0%
Astr	83.2%	83.2%
Baus	14.6%	14.8%
Baxt	10.7%	10.7%
Baye	100.0%	100.0%
Biog	78.5%	100.0%
BMS	55.1%	55.1%
Boeh	16.7%	16.9%
Ceph	55.9%	77.8%
Chug	93.3%	100.0%

CSL	100.0%	100.0%
Daii	77.1%	86.0%
Dain	97.2%	100.0%
Eisa	90.0%	99.2%
EliL	71.9%	74.0%
Fore	40.8%	68.9%
Gene	74.2%	100.0%
Genz	100.0%	100.0%
Gile	43.0%	68.0%
GSK	100.0%	100.0%
John	66.0%	66.0%
King	46.8%	100.0%
Kyow	38.6%	57.8%
Lund	41.4%	47.6%
Merc	75.8%	77.5%
Merk	100.0%	100.0%
Mits	92.3%	100.0%
Nova	100.0%	100.0%

Novo	45.2%	48.6%
Nyco	100.0%	100.0%
Pfiz	94.9%	94.9%
Roch	75.6%	76.0%
Sano	100.0%	100.0%
Scher	90.6%	93.1%
Shio	72.8%	80.9%
Shir	54.3%	76.5%
Solv	100.0%	100.0%
Tais	58.6%	68.6%
Take	91.2%	100.0%
Teva	52.0%	55.8%
UCB	55.7%	69.6%
Wats	43.8%	100.0%
Wyet	58.2%	59.1%

Table D.7 ROS, ROA and SOA

Firm	ROS (%)	ROA (%)	SOA
Abbt	7.64	6.17	0.81
AkzN	8.39	11.42	1.36
Alcn	27.53	26.26	0.95
Allg	-4.16	-2.08	0.50
Amgn	20.68	9.62	0.47
Astel	11.79	8.50	0.72
AstrZ	22.83	23.04	1.01
BausL	0.65	1.85	2.85
Baxt	13.46	11.38	0.85
Bayr	6.06	6.29	1.04
Biog	12.20	2.50	0.20
Boeh	15.67	14.54	0.93
BrMS	8.85	7.74	0.87
Ceph	8.20	4.76	0.58
Chug	11.78	8.60	0.73
CSL	16.30	18.40	1.13

Daic	9.47	6.89	0.73
Dain	6.26	5.20	0.83
Eisa	10.55	9.32	0.88
EliL	16.97	12.11	0.71
Fore	25.36	20.82	0.82
Gene	22.76	16.21	0.71
Genz	-0.53	-0.10	0.18
Gild	-39.30	-29.10	0.74
GSK	23.20	23.28	1.00
Hlun	12.00	10.11	0.84
John	20.73	17.74	0.86
King	14.53	8.68	0.60
Kyow	4.60	4.34	0.94
Merc	19.59	10.49	0.54
MerK	15.71	13.83	0.88
Mits	9.02	5.64	0.63
Nova	19.91	12.40	0.62
Novo	16.65	15.88	0.95

Nyco	-9.59	-0.91	0.09
Pfiz	39.98	17.01	0.43
RocH	18.74	11.70	0.62
Sano	14.12	5.47	0.39
Schr	10.79	7.96	0.74
Shio	11.58	5.53	0.48
Shir	15.50	8.30	0.54
Solv	8.42	8.25	0.98
Tais	13.22	5.66	0.43
Take	25.84	11.27	0.44
Teva	6.49	4.53	0.70
UCB	16.77	5.56	0.33
Wats	-22.50	-0.12	0.01
Wyet	20.62	13.09	0.63

Table D.8 SDV, Cost of Sales and NDV Data for Firms

DMU	A_k	B_k	C_k	D_k	a_k	b_k	c_k
	Aggreg. SDV	X-border SDV	X-product SDV	Cost of Sales	Aggreg. NDV	X-border NDV	X-product NDV
Abbt	11938	7674	3027	20759	0.58	0.37	0.15
AkzN	4452	4452	711	3245	1.37	1.37	0.22
Alcn	0	0	0	3549	0.00	0.00	0.00
Allg	490	0	230	3190	0.15	0.00	0.07
Amgn	18276	138	0	11318	1.61	0.01	0.00
Astl	0	0	0	6728	0.00	0.00	0.00
Astz	39021	39021	644	20412	1.91	1.91	0.03
Baus	1237	427	1009	2277	0.54	0.19	0.44
Baxt	2652	1055	801	8981	0.30	0.12	0.09
Bayr	14530	14530	10469	37750	0.38	0.38	0.28
Biog	0	0	0	2465	0.00	0.00	0.00
Boeh	0	0	0	11121	0.00	0.00	0.00
BrMS	8212	150	0	16329	0.50	0.01	0.00
Ceph	1998	810	0	1619	1.23	0.50	0.00
Chug	2590	0	0	2459	1.05	0.00	0.00

CSL	1669	1669	0	2334	0.72	0.72	0.00
Daii	6290	0	0	6487	0.97	0.00	0.00
Dain	2224	0	0	1570	1.42	0.00	0.00
Eisi	265	265	0	4979	0.05	0.05	0.00
EliL	4381	0	0	13028	0.34	0.00	0.00
Fors	0	0	0	2988	0.00	0.00	0.00
Gene	408	0	0	7171	0.06	0.00	0.00
Genz	4710	107	250	3204	1.47	0.03	0.08
Gild	1396	0	0	4216	0.33	0.00	0.00
GSK	102218	10035	1453	32678	3.13	0.31	0.04
Hlun	236	0	236	1366	0.17	0.00	0.17
John	27524	489	5083	42271	0.65	0.01	0.12
King	5741	637	235	1700	3.38	0.37	0.14
Kyow	0	0	0	1590	0.00	0.00	0.00
Merc	6567	0	0	18202	0.36	0.00	0.00
MerK	2551	0	0	3917	0.65	0.00	0.00
Mits	0	0	0	1737	0.00	0.00	0.00
Nova	14629	14629	1859	29818	0.49	0.49	0.06

Novo	0	0	0	5434	0.00	0.00	0.00
Nyco	0	0	0	4369	0.00	0.00	0.00
Pfiz	163448	7667	356	29034	5.63	0.26	0.01
RocH	25129	17138	2430	26229	0.96	0.65	0.09
Sano	71858	0	0	30612	2.35	0.00	0.00
Sche	1572	1167	405	9537	0.16	0.12	0.04
Shio	120	120	0	1481	0.08	0.08	0.00
Shir	6528	6528	0	1519	4.30	4.30	0.00
Slvy	112	0	0	2242	0.05	0.00	0.00
Tais	0	0	0	1937	0.00	0.00	0.00
Take	270	270	0	7414	0.04	0.04	0.00
Teva	3988	0	0	7862	0.51	0.00	0.00
UCBs	2973	2973	0	3934	0.76	0.76	0.00
Wats	2259	0	0	2424	0.93	0.00	0.00
Wyet	0	0	0	16154	0.00	0.00	0.00

Table D.9 NDV and Pure Technical Efficiency (Base Model)

Firm	VRS Efficiency	a_k θ_k <M	a_k θ_k >M	b_k θ_k <M	b_k θ_k >M	c_k θ_k <M	c_k θ_k >M
Abbt	53.3%	0.58		0.37		0.15	
AkzN	63.5%	1.37		1.37		0.22	
Alcn	50.0%	0.00		0.00		0.00	
Allg	53.1%	0.15		0.00		0.07	
Amgn	47.5%	1.61		0.01		0.00	
Astel	100.0%		0.00		0.00		0.00
AstrZ	83.2%		1.91		1.91		0.03
BausL	14.6%	0.54		0.19		0.44	
Baxt	10.7%	0.30		0.12		0.09	
Bayr	100.0%		0.38		0.38		0.28
Biog	78.5%		0.00		0.00		0.00
Boeh	55.1%	0.00		0.00		0.00	
BrMS	16.7%	0.50		0.01		0.00	
Ceph	55.9%	1.23		0.50		0.00	
Chug	93.3%		1.05		0.00		0.00
CSL	100.0%		0.72		0.72		0.00
Daic	77.1%		0.97		0.00		0.00
Dain	97.2%		1.42		0.00		0.00
Eisa	90.0%		0.05		0.05		0.00
EliL	71.9%	0.34		0.00		0.00	
Fore	40.8%	0.00		0.00		0.00	
Gene	74.2%		0.06		0.00		0.00
Genz	100.0%		1.47		0.03		0.08

Gild	43.0%	0.33		0.00		0.00	
GSK	100.0%		3.13		0.31		0.04
Hlun	66.0%	0.17		0.00		0.17	
John	46.8%	0.65		0.01		0.12	
King	38.6%	3.38		0.37		0.14	
Kyow	41.4%	0.00		0.00		0.00	
Merc	75.8%		0.36		0.00		0.00
MerK	100.0%		0.65		0.00		0.00
Mits	92.3%		0.00		0.00		0.00
Nova	100.0%		0.49		0.49		0.06
Novo	45.2%	0.00		0.00		0.00	
Nyco	100.0%		0.00		0.00		0.00
Pfiz	94.9%		5.63		0.26		0.01
RocH	75.6%		0.96		0.65		0.09
Sano	100.0%		2.35		0.00		0.00
Schr	90.6%		0.16		0.12		0.04
Shio	72.8%		0.08		0.08		0.00
Shir	54.3%	4.30		4.30		0.00	
Solv	100.0%		0.05		0.00		0.00
Tais	58.6%	0.00		0.00		0.00	
Take	91.2%		0.04		0.04		0.00
Teva	52.0%	0.51		0.00		0.00	
UCB	55.7%	0.76		0.76		0.00	
Wats	43.8%	0.93		0.00		0.00	
Wyet	58.2%	0.00		0.00		0.00	
Mean		0.74	0.91	0.33	0.21	0.06	0.03

Table D.10 NDV and Pure Technical Efficiency (Staff Input)

Firm	VRS Efficiency	a_k θ_k <M	a_k θ_k >M	b_k θ_k <M	b_k θ_k >M	c_k θ_k <M	c_k θ_k >M
Abbt	53.3%	0.58		0.37		0.15	
AkzN	63.5%	1.37		1.37		0.22	
Alcn	53.0%	0.00		0.00		0.00	
Allg	76.1%	0.15		0.00		0.07	
Amgn	75.3%	1.61		0.01		0.00	
Astel	100.0%		0.00		0.00		0.00
AstrZ	83.2%		1.91		1.91		0.03
BausL	14.8%	0.54		0.19		0.44	
Baxt	10.7%	0.30		0.12		0.09	
Bayr	100.0%		0.38		0.38		0.28
Biog	100.0%		0.00		0.00		0.00
Boeh	55.1%	0.00		0.00		0.00	
BrMS	16.9%	0.50		0.01		0.00	
Ceph	77.8%	1.23		0.50		0.00	
Chug	100.0%		1.05		0.00		0.00
CSL	100.0%		0.72		0.72		0.00
Daic	86.0%		0.97		0.00		0.00
Dain	100.0%		1.42		0.00		0.00
Eisa	99.2%		0.05		0.05		0.00
EliL	74.0%	0.34		0.00		0.00	
Fore	68.9%	0.00		0.00		0.00	
Gene	100.0%		0.06		0.00		0.00
Genz	100.0%		1.47		0.03		0.08
Gild	68.0%	0.33		0.00		0.00	

GSK	100.0%		3.13		0.31		0.04
Hlun	66.0%	0.17		0.00		0.17	
John	100.0%		0.65		0.01		0.12
King	57.8%	3.38		0.37		0.14	
Kyow	47.6%	0.00		0.00		0.00	
Merc	77.5%	0.36		0.00		0.00	
MerK	100.0%		0.65		0.00		0.00
Mits	100.0%		0.00		0.00		0.00
Nova	100.0%		0.49		0.49		0.06
Novo	48.6%	0.00		0.00		0.00	
Nyco	100.0%		0.00		0.00		0.00
Pfiz	94.9%		5.63		0.26		0.01
RocH	76.0%	0.96		0.65		0.09	
Sano	100.0%		2.35		0.00		0.00
Schr	93.1%		0.16		0.12		0.04
Shio	80.9%		0.08		0.08		0.00
Shir	76.5%	4.30		4.30		0.00	
Solv	100.0%		0.05		0.00		0.00
Tais	68.6%	0.00		0.00		0.00	
Take	100.0%		0.04		0.04		0.00
Teva	55.8%	0.51		0.00		0.00	
UCB	69.6%	0.76		0.76		0.00	
Wats	100.0%		0.93		0.00		0.00
Wyet	59.1%	0.00		0.00		0.00	
Mean		0.72	0.92	0.36	0.18	0.06	0.03

Table D.11 SDV and Pure Technical Efficiency (Base Model)

Firm	VRS Efficiency	A_k θ_k <M	A_k θ_k >M	B_k θ_k <M	B_k θ_k >M	C_k θ_k <M	C_k θ_k >M
Abbt	53.3%	11938		7674		3027	
AkzN	63.5%	4452		4452		711	
Alcn	53.0%	0		0		0	
Allg	76.1%	490		0		230	
Amgn	75.3%	18276		138		0	
Astel	100.0%		0		0		0
AstrZ	83.2%		39021		39021		644
BausL	14.8%	1237		427		1009	
Baxt	10.7%	2652		1055		801	
Bayr	100.0%		14530		14530		10469
Biog	100.0%		0		0		0
Boeh	55.1%	0		0		0	
BrMS	16.9%	8212		150		0	
Ceph	77.8%	1998		810		0	
Chug	100.0%		2590		0		0
CSL	100.0%		1669		1669		0

Daic	86.0%		6290		0		0
Dain	100.0%		2224		0		0
Eisa	99.2%		265		265		0
EliL	74.0%	4381		0		0	
Fore	68.9%	0		0		0	
Gene	100.0%		408		0		0
Genz	100.0%		4710		107		250
Gild	68.0%	1396		0		0	
GSK	100.0%		102218		10035		1453
Hlun	66.0%	236		0		236	
John	100.0%	27524		489		5083	
King	57.8%	5741		637		235	
Kyow	47.6%	0		0		0	
Merc	77.5%		6567		0		0
MerK	100.0%		2551		0		0
Mits	100.0%		0		0		0
Nova	100.0%		14629		14629		1859
Novo	48.6%	0		0		0	

Nyco	100.0%		0		0		0
Pfiz	94.9%		163448		7667		356
RocH	76.0%		25129		17138		2430
Sano	100.0%		71858		0		0
Schr	93.1%		1572		1167		405
Shio	80.9%		120		120		0
Shir	76.5%	6528		6528		0	
Solv	100.0%		112		0		0
Tais	68.6%	0		0		0	
Take	100.0%		270		270		0
Teva	55.8%	3988		0		0	
UCB	69.6%	2973		2973		0	
Wats	100.0%	2259		0		0	
Wyet	59.1%	0		0		0	
Mean		4345	19174	1056	4442	472	744

Table D.12 Association of NDV and ROS

Firm	ROS	a'_k r_k <M	a'_k r_k >M	b'_k r_k <M	b'_k r_k >M	c'_k r_k <M	c'_k r_k >M
Abbt	7.64	0.58		0.37		0.15	
AkzN	8.39	1.37		1.37		0.22	
Alcn	27.53		0.00		0.00		0.00
Allg	-4.16	0.15		0.00		0.07	
Amgn	20.68		1.61		0.01		0.00
Astel	11.79	0.00		0.00		0.00	
AstrZ	22.83		1.91		1.91		0.03
BausL	0.65	0.54		0.19		0.44	
Baxt	13.46		0.30		0.12		0.09
Bayr	6.06	0.38		0.38		0.28	
Biog	12.20	0.00		0.00		0.00	
Boeh	15.67		0.00		0.00		0.00
BrMS	8.85	0.50		0.01		0.00	
Ceph	8.20	1.23		0.50		0.00	
Chug	11.78	1.05		0.00		0.00	
CSL	16.30		0.72		0.72		0.00
Daic	9.47	0.97		0.00		0.00	

Dain	6.26	1.42		0.00		0.00	
Eisa	10.55	0.05		0.05		0.00	
EliL	16.97		0.34		0.00		0.00
Fore	25.36		0.00		0.00		0.00
Gene	22.76		0.06		0.00		0.00
Genz	-0.53	1.47		0.03		0.08	
Gild	-39.30	0.33		0.00		0.00	
GSK	23.20		3.13		0.31		0.04
Hlun	12.00	0.17		0.00		0.17	
John	20.73		0.65		0.01		0.12
King	14.53		3.38		0.37		0.14
Kyow	4.60	0.00		0.00		0.00	
Merc	19.59		0.36		0.00		0.00
MerK	15.71		0.65		0.00		0.00
Mits	9.02	0.00		0.00		0.00	
Nova	19.91		0.49		0.49		0.06
Novo	16.65		0.00		0.00		0.00
Nyco	-9.59	0.00		0.00		0.00	
Pfiz	39.98		5.63		0.26		0.01

RocH	18.74		0.96		0.65		0.09
Sano	14.12		2.35		0.00		0.00
Schr	10.79	0.16		0.12		0.04	
Shio	11.58	0.08		0.08		0.00	
Shir	15.50		4.30		4.30		0.00
Solv	8.42	0.05		0.00		0.00	
Tais	13.22		0.00		0.00		0.00
Take	25.84		0.04		0.04		0.00
Teva	6.49	0.51		0.00		0.00	
UCB	16.77		0.76		0.76		0.00
Wats	-22.50	0.93		0.00		0.00	
Wyet	20.62		0.00		0.00		0.00
Mean		0.50	1.15	0.13	0.41	0.06	0.02

Table D.13 Association of NDV and ROA

Firm	ROA	a'_k r_k <M	a'_k r_k >M	b'_k r_k <M	b'_k r_k >M	c'_k r_k <M	c'_k r_k >M
Abbt	6.17	0.58		0.37		0.15	
AkzN	11.42		1.37		1.37		0.22
Alcn	26.26		0.00		0.00		0.00
Allg	-2.08	0.15		0.00		0.07	
Amgn	9.62		1.61		0.01		0.00
Astel	8.50	0.00		0.00		0.00	
AstrZ	23.04		1.91		1.91		0.03
BausL	1.85	0.54		0.19		0.44	
Baxt	11.38		0.30		0.12		0.09
Bayr	6.29	0.38		0.38		0.28	
Biog	2.50	0.00		0.00		0.00	
Boeh	14.54		0.00		0.00		0.00
BrMS	7.74	0.50		0.01		0.00	
Ceph	4.76	1.23		0.50		0.00	
Chug	8.60		1.05		0.00		0.00
CSL	18.40		0.72		0.72		0.00
Daic	6.89	0.97		0.00		0.00	

Dain	5.20	1.42		0.00		0.00	
Eisa	9.32		0.05		0.05		0.00
EliL	12.11		0.34		0.00		0.00
Fore	20.82		0.00		0.00		0.00
Gene	16.21		0.06		0.00		0.00
Genz	-0.10	1.47		0.03		0.08	
Gild	-29.10	0.33		0.00		0.00	
GSK	23.28		3.13		0.31		0.04
Hlun	10.11		0.17		0.00		0.17
John	17.74		0.65		0.01		0.12
King	8.68		3.38		0.37		0.14
Kyow	4.34	0.00		0.00		0.00	
Merc	10.49		0.36		0.00		0.00
MerK	13.83		0.65		0.00		0.00
Mits	5.64	0.00		0.00		0.00	
Nova	12.40		0.49		0.49		0.06
Novo	15.88		0.00		0.00		0.00
Nyco	-0.91	0.00		0.00		0.00	
Pfiz	17.01		5.63		0.26		0.01

RocH	11.70		0.96		0.65		0.09
Sano	5.47	2.35		0.00		0.00	
Schr	7.96	0.16		0.12		0.04	
Shio	5.53	0.08		0.08		0.00	
Shir	8.30	4.30		4.30		0.00	
Solv	8.25	0.05		0.00		0.00	
Tais	5.66	0.00		0.00		0.00	
Take	11.27		0.04		0.04		0.00
Teva	4.53	0.51		0.00		0.00	
UCB	5.56	0.76		0.76		0.00	
Wats	-0.12	0.93		0.00		0.00	
Wyet	13.09		0.00		0.00		0.00
Mean		0.70	0.95	0.28	0.26	0.044	0.041

Table D.14 Association of Acquisition History and SOA

Firm	SOA	a'_k r_k <M	a'_k r_k >M	b'_k r_k <M	b'_k r_k >M	c'_k r_k <M	c'_k r_k >M
Abbt	0.81		0.58		0.37		0.15
AkzN	1.36		1.37		1.37		0.22
Alcn	0.95		0.00		0.00		0.00
Allg	0.50	0.15		0.00		0.07	
Amgn	0.47	1.61		0.01		0.00	
Astel	0.72	0.00		0.00		0.00	
AstrZ	1.01		1.91		1.91		0.03
BausL	2.85		0.54		0.19		0.44
Baxt	0.85		0.30		0.12		0.09
Bayr	1.04		0.38		0.38		0.28
Biog	0.20	0.00		0.00		0.00	
Boeh	0.93		0.00		0.00		0.00
BrMS	0.87		0.50		0.01		0.00
Ceph	0.58	1.23		0.50		0.00	
Chug	0.73		1.05		0.00		0.00
CSL	1.13		0.72		0.72		0.00
Daic	0.73		0.97		0.00		0.00

Dain	0.83		1.42		0.00		0.00
Eisa	0.88		0.05		0.05		0.00
EliL	0.71	0.34		0.00		0.00	
Fore	0.82		0.00		0.00		0.00
Gene	0.71	0.06		0.00		0.00	
Genz	0.18	1.47		0.03		0.08	
Gild	0.74		0.33		0.00		0.00
GSK	1.00		3.13		0.31		0.04
Hlun	0.84		0.17		0.00		0.17
John	0.86		0.65		0.01		0.12
King	0.60	3.38		0.37		0.14	
Kyow	0.94		0.00		0.00		0.00
Merc	0.54	0.36		0.00		0.00	
MerK	0.88		0.65		0.00		0.00
Mits	0.63	0.00		0.00		0.00	
Nova	0.62	0.49		0.49		0.06	
Novo	0.95		0.00		0.00		0.00
Nyco	0.09	0.00		0.00		0.00	
Pfiz	0.43	5.63		0.26		0.01	

RocH	0.62	0.96		0.65		0.09	
Sano	0.39	2.35		0.00		0.00	
Schr	0.74		0.16		0.12		0.04
Shio	0.48	0.08		0.08		0.00	
Shir	0.54	4.30		4.30		0.00	
Solv	0.98		0.05		0.00		0.00
Tais	0.43	0.00		0.00		0.00	
Take	0.44	0.04		0.04		0.00	
Teva	0.70	0.51		0.00		0.00	
UCB	0.33	0.76		0.76		0.00	
Wats	0.01	0.93		0.00		0.00	
Wyet	0.63	0.00		0.00		0.00	
Mean		1.03	0.62	0.31	0.23	0.02	0.07

E. Acquisition Data

E.1 Introduction

The Thomson Banker database was the source of acquisition data. The search criteria used are explained below and an annual analysis of the acquisitions that arose is then presented. There is then a record of each acquisition, characterised by date, value, and the sector and nation of the acquirer and acquired company, sorted by eventual 'surviving' parent.

E.2 Search Criteria

The search criteria are shown in Table E.1

Table E.1 Database Search Criteria

Request	*Operator*	*Description*	*Hits*
Acquirer NAIC (Code)	Include	Medicinal and Botanical Manufacturing Pharmaceutical Preparation Manufacturing In-Vitro Diagnostic Substance Manufacturing Biological Product (except Diagnostic) Manufacturing	13500
Acquirer Ultimate Parent Primary NAIC (Code)	Include	Medicinal and Botanical Manufacturing Pharmaceutical Preparation Manufacturing In-Vitro Diagnostic Substance Manufacturing Biological Product (except Diagnostic) Manufacturing	8906
Logical Set		Request # 2 UNION Request # 3	13500
Date Effective/ Unconditional	Between	01/01/1993 to 31/12/2006	5816

Ranking Value inc. Net Debt of Target ($Mil)	Between	100 to HI	699
Per cent of Shares Owned after Transaction	Between	51 to HI	591

Four sectors have been chosen for the analysis namely Medicinal and Botanical Manufacturing, Pharmaceutical Preparation Manufacturing, In-Vitro Diagnostic Substance Manufacturing, and Biological Product (except Diagnostic) Manufacturing. The acquisitions of interest are when the acquiring firm or the ultimate acquiring firm fall within these sectors. There are 13,500 such deals.

The period of the analysis was from the start of 1993 to the end of 2006. This reduces the numbers of deals within the criteria to 5,818. A threshold of the deal value being above $100million was also set, reducing the number of deals to 689. Finally, only deals leading to majority control were considered, reducing the deal total to 591.

E.3 Annual Analysis

A breakdown of deals by year is given in Table E.2.

Table E.2 Date Analysis

Date	Value ($Mil)	Share (%)	No. Deals
1992	1,022.75	0.1	3
1993	8,962.57	1.0	13
1994	36,332.34	3.9	24
1995	31,792.50	3.4	24
1996	13,501.48	1.5	34
1997	25,894.22	2.8	36
1998	62,700.57	6.7	40
1999	145,714.96	15.7	42
2000	116,194.32	12.5	49
2001	65,090.71	7.0	46
2002	72,760.70	7.8	37
2003	33,593.12	3.6	48
2004	105,818.15	11.4	51
2005	137,117.64	14.8	82
2006	72,537.12	7.8	62

Industry Total	929,033.13	100.0	591

The period of analysis encompasses both the peak of a merger wave and the trough at its beginning.

E.4 Detailed Merger Data

The detailed merger data are provided along with an initial analysis. The columns are described below:

- The first three columns provide details of the acquirer, the fourth and fifth the value and date of the deal, and next three columns the details of the acquired firm.
- There then follows three columns of analysis, namely whether the acquisition can be traced to one of the Top 48 companies in the analysis and whether it is a cross-border or cross-sector deal (a '1' signifies that this is the case).
- The next three columns give the values of the deals that are included in the three cases.

The data in Table E.3 are presented in a table overleaf in landscape format.

Table E.3 Detailed Merger Data

Key:

Column	Title	Meaning
A	Acquirer Name	The name of the acquiring company
B	Acquirer NAIC	The NAIC code of the acquiring company
C	Acquirer Nation	The location of the acquiring company
D	Value ($m)	The value of the deal in US$ (million)
E	Date	The date of the transaction
F	Target Name	The name of the acquired company
G	Target NAIC	The NAIC code of the acquired company
H	Target Nation	The location of the acquired company
I	Code	The abbreviated code given to the acquirer for the subtotal analysis
J	Ag	Value equals 1 if the deal is part of the aggregate total
K	Xb	Value equals 1 if the deal is a cross-border total
L	Xs	Value equals 1 if the deal is a cross-sector total
M	V(Ag)	Value of deal if part of aggregate total
N	V(Xb)	Value of deal if part of cross-border total
O	V(Xs)	Value of deal if part of cross-sector total

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Acquirer Name	Acquirer NAIC	Acquirer Nation	Value ($m)	Date	Target Name	Target NAIC	Target Nation	Code	Ag	Xb	Xs	V(Ag)	V(Xb)	V(Xs)
3M Co	Surgical and medical instruments and apparatus	United States	1403	02/08/05	Cuno Inc	Fluid power pumps and motors	United States							
3M Co	Surgical and medical instruments and apparatus	United States	140	02/03/04	Hornell International AB	Ophthalmic goods	Sweden							
3M Co	Surgical and medical instruments and apparatus	United States	850	13/12/02	Corning Precision Lens Inc	Plastics products, nec	United States							
Abbott Laboratories	Pharmaceutical preparations	United States	320	17/11/04	Experimental & Applied Science	Food preparations, nec	United States		1		1	320		320
Abbott Laboratories	Pharmaceutical preparations	United States	1170	06/04/04	TheraSense Inc	Surgical and medical instruments and apparatus	United States		1		1	1170		1170
Abbott Laboratories	Pharmaceutical preparations	United States	407	30/01/04	i-Stat Corp	Surgical and medical instruments and apparatus	United States		1		1	407		407
Abbott Laboratories	Pharmaceutical preparations	United States	160	27/08/03	ZonePerfect Nutrition Co	Cereal breakfast foods	United States		1		1	160		160
Abbott Laboratories	Pharmaceutical preparations	United States	210	30/06/03	Spinal Concepts Inc	Orthopedic, prosthetic, and surgical supplies	United States		1		1	210		210
Abbott Laboratories	Pharmaceutical preparations	United States	252	31/05/02	Hokuriku Seiyaku Co Ltd	Pharmaceutical preparations	Japan		1	1		252	252	
Abbott Laboratories	Pharmaceutical preparations	United States	234	08/05/02	Biocompatibles Int-Cardio Bus	Pharmaceutical preparations	United Kingdom		1	1		234	234	
Abbott Laboratories	Pharmaceutical preparations	United States	355	05/12/01	Vysis Inc(BP PLC)	In vitro and in vivo diagnostic substances	United States		1			355		
Abbott Laboratories	Pharmaceutical preparations	United States	6900	02/03/01	Knoll AG(BASF AG)	Pharmaceutical preparations	Germany		1	1		6900	6900	
Abbott Laboratories	Pharmaceutical preparations	United States	640	19/11/99	Perclose Inc	Surgical and medical instruments and apparatus	United States		1		1	640		640
Abbott Laboratories	Pharmaceutical preparations	United States	167	10/07/98	International Murex Tech Corp	In vitro and in vivo diagnostic substances	Canada		1	1		167	167	
Abbott Laboratories	Pharmaceutical preparations	United States	200	01/05/97	Sanofi Pharmaceuticals-Parente	Pharmaceutical preparations	United States		1			200		
Abbott Laboratories	Pharmaceutical preparations	United States	802	07/08/96	MediSense Inc	In vitro and in vivo diagnostic substances	United States		1			802		

Abbott Laboratories	Pharmaceutical preparations	United States	120	14/12/94	Puleva-Nutrition Division	Fluid milk	Spain		1	1	1	120	120	120
								Abbt	14	5	7	11938	7674	3027
Actavis Group hf	Pharmaceutical preparations	Iceland	810	19/12/05	Alpharma Inc-Generics Business	Pharmaceutical preparations	United States							
Actavis Group hf	Pharmaceutical preparations	Iceland	600	28/07/05	Amide Pharmaceutical Inc	Pharmaceutical preparations	United States							
Actelion Pharmaceuticals Ltd	Pharmaceutical preparations	Switzerland	191	13/10/03	Axovan AG	Pharmaceutical preparations	Switzerland							
Advanced Medical Inc	Pharmaceutical preparations	United States	400	26/11/96	IVAC Corp	Surgical and medical instruments and apparatus	United States							
Affymetrix Inc	Laboratory analytical instruments	United States	114	21/10/05	ParAllele BioScience Inc	Commercial physical and biological research	United States							
Ajinomoto Co Inc	Flavoring extracts and flavoring syrups, nec	Japan	183	02/12/02	Shimizu Pharmaceutical Co	Pharmaceutical preparations	Japan							
Akzo Nobel NV	Paints, varnishes, lacquers, & allied products	Netherlands	711	26/11/99	Hoechst Roussel Vet	Pharmaceutical preparations	Germany		1	1	1	711	711	711
Akzo Nobel NV	Paints, varnishes, lacquers, & allied products	Netherlands	3741	07/07/98	Courtaulds PLC	Cellulosic manmade fibers	United Kingdom		1	1		3741	3741	
								AkzN	2	2	1	4452	4452	711
Alkermes Inc	Biological products, except diagnostic substances	United States	115	01/02/99	Advanced Inhalation Research	Pharmaceutical preparations	United States							
Allergan Inc	Pharmaceutical preparations	United States	230	20/11/03	Oculex Pharmaceuticals Inc	Surgical and medical instruments and apparatus	United States		1		1	230		230
Allergan Inc	Pharmaceutical preparations	United States	260	16/05/03	Bardeen Sciences Co LLC	Pharmaceutical preparations	United States		1			260		
								Allg	2	0	1	490	0	230
Alpharma Inc	Pharmaceutical preparations	United States	660	12/12/01	FH Faulding & Co-Oral Pharma	Pharmaceutical preparations	United States							
Alpharma Inc	Pharmaceutical preparations	United States	300	02/05/00	Roche Hldg-Animal Drug Bus	Pharmaceutical preparations	United States							
Alpharma Inc	Pharmaceutical preparations	United States	152	18/06/99	Isis Pharma GmbH(Schwarz)	Pharmaceutical preparations	Germany							
Alpharma Inc	Pharmaceutical preparations	United States	198	07/05/98	Arthur H Cox & Co Ltd(Hoechst)	Pharmaceutical preparations	United Kingdom							
Altana Chemie AG	Chemicals and chemical preparations, nec	Germany	769	01/10/05	Eckart GmbH & Co KG	Inorganic pigments	Germany							
ALZA Corp	Pharmaceutical preparations	United States	557	17/03/99	SEQUUS Pharmaceuticals Inc	Pharmaceutical preparations	United States							

ALZA Corp	Pharmaceutical preparations	United States	100	26/08/97	Therapeutic Discovery Corp	Commercial physical and biological research	United States								
American Cyanamid Co	Chemicals and chemical preparations, nec	United States	742	03/06/93	Immunex Corp	Biological products, except diagnostic substances	United States								
American Home Products Corp	Pharmaceutical preparations	United States	449	21/03/97	Solvay Duphar BV(Solvay SA)	Pharmaceutical preparations	Netherlands								
American Home Products Corp	Pharmaceutical preparations	United States	1006	17/12/96	Genetics Institute Inc	Pharmaceutical preparations	United States								
American Home Products Corp	Pharmaceutical preparations	United States	10054	21/12/94	American Cyanamid Co	Chemicals and chemical preparations, nec	United States								
American Pacific Corp	Chemicals and chemical preparations, nec	United States	119	30/11/05	Aerojet Fine Chemicals LLC	Pharmaceutical preparations	United States								
American Tropical Plants Inc	Medicinal chemicals and botanical products	United States	105	30/01/98	OPM-USA Inc	Radio & TV broadcasting & communications equipment	United States								
Amersham International PLC	Biological products, except diagnostic substances	United Kingdom	1345	22/10/97	Nycomed ASA	Pharmaceutical preparations	Denmark								
Amersham Life Science	Biological products, except diagnostic substances	United Kingdom	202	21/09/98	Molecular Dynamics Inc	Laboratory analytical instruments	United States								
Amersham Life Science	Biological products, except diagnostic substances	United Kingdom	373	06/08/97	Pharmacia Biotech AB	Pharmaceutical preparations	Sweden								
Amersham PLC	Biological products, except diagnostic substances	United Kingdom	1000	21/03/02	Amersham Biosciences AB	Biological products, except diagnostic substances	Sweden								
Amgen Inc	Biological products, except diagnostic substances	United States	1285	13/08/04	Tularik Inc	Pharmaceutical preparations	United States		1			1285			
Amgen Inc	Biological products, except diagnostic substances	United States	16685	16/07/02	Immunex Corp	Biological products, except diagnostic substances	United States		1			16685			
Amgen Inc	Biological products, except diagnostic substances	United States	138	31/05/02	Roche-Filgrastm & Pegrilgrastm	Pharmaceutical preparations	Switzerland		1	1		138	138		
Amgen Inc	Biological products, except diagnostic substances	United States	169	14/12/00	Kinetix Pharmaceuticals Inc	Biological products, except diagnostic substances	United States		1			169			
								Amgn	4	1	0	18276	138	0	
Arch Chemicals Inc	Chemicals and chemical preparations, nec	United States	219	05/04/04	Avecia Inc	Chemicals and chemical preparations, nec	United States								
Arch Chemicals Inc	Chemicals and chemical preparations, nec	United States	184	22/08/00	Hickson International PLC	Plastics materials and synthetic resins	United Kingdom								
Arris Pharmaceuticals Corp	Pharmaceutical preparations	United States	170	09/01/98	Sequana Therapeutics	In vitro and in vivo diagnostic substances	United States								
Asahi Breweries Ltd	Malt beverages	Japan	151	02/09/02	Kyowa Hakko Kogyo-Alcohol Sale	Beer and ale	Japan								
Astra AB	Pharmaceutical preparations	Sweden	6090	01/07/98	Astra Merck Inc(Merck & Co)	Drugs, drug proprietaries, and druggists' sundries	United States		1	1		6090	6090		
Astra AB	Pharmaceutical preparations	Sweden	320	16/05/95	Fisons PLC-Pharmaceutical	Commercial physical and biological research	United Kingdom		1	1		320	320		

ZENECA Group PLC	Pharmaceutical preparations	United Kingdom	31774	06/04/99	Astra AB	Pharmaceutical preparations	Sweden		1	1		31774	31774	
ZENECA Group PLC	Pharmaceutical preparations	United Kingdom	193	04/09/98	Orica Ltd-Pharm Business	Pharmaceutical preparations	Australia		1	1		193	193	
ZENECA Group PLC	Pharmaceutical preparations	United Kingdom	410	04/02/98	Ishihara Sangyo Kaisha Ltd-US	Pesticides and agricultural chemicals, nec	United States		1	1	1	410	410	410
ZENECA Group PLC	Pharmaceutical preparations	United Kingdom	234	14/04/97	Salick Health Care Inc	Kidney dialysis centers	United States		1	1	1	234	234	234
								AstrZ	6	6	2	39021	39021	644
Axcan Pharma Inc	Pharmaceutical preparations	Canada	145	18/11/03	Aventis SA-Carafete,4 Others	Pharmaceutical preparations	United States							
Axcan Pharma Inc	Pharmaceutical preparations	Canada	108	30/09/99	Scandipharm Inc	Drugs, drug proprietaries, and druggists' sundries	United States							
Barr Laboratories Inc	Pharmaceutical preparations	United States	638	24/10/01	Duramed Pharmaceuticals Inc	Pharmaceutical preparations	United States							
Bausch & Lomb Inc	Ophthalmic goods	United States	200	26/09/05	Sino Concept Technology Ltd	Investors, nec	Hong Kong		1	1	1	200	200	200
Bausch & Lomb Inc	Ophthalmic goods	United States	227	08/08/00	Chauvin	Pharmaceutical preparations	France		1	1		227	227	
Bausch & Lomb Inc	Ophthalmic goods	United States	380	05/01/98	Storz Instrument Co	Surgical and medical instruments and apparatus	United States		1		1	380		380
Bausch & Lomb Inc	Ophthalmic goods	United States	300	29/12/97	Chiron Vision(Chiron Corp)	Surgical and medical instruments and apparatus	United States		1		1	300		300
Bausch & Lomb Inc	Ophthalmic goods	United States	129	02/08/93	Dahlberg Inc	Orthopedic, prosthetic, and surgical supplies	United States		1		1	129		129
								BausL	5	2	4	1237	427	1009
Baxter Healthcare Corp	Pharmaceutical preparations	United States	305	20/12/02	Wyeth-Certain ESI Lederle Asts	Pharmaceutical preparations	United States		1			305		
Baxter Healthcare Corp	Pharmaceutical preparations	United States	219	20/08/01	Cook Pharmaceutical Solutions	Pharmaceutical preparations	United States		1			219		
Baxter International Inc	Biological products, except diagnostic substances	United States	148	05/05/02	Fusion Medical Technologies	Surgical and medical instruments and apparatus	United States		1		1	148		148
Baxter International Inc	Biological products, except diagnostic substances	United States	396	26/06/00	North American Vaccine Inc	Biological products, except diagnostic substances	United States		1			396		
Baxter International Inc	Biological products, except diagnostic substances	United States	182	07/03/00	Althin Medical AB	Surgical and medical instruments and apparatus	Sweden		1	1	1	182	182	182
Baxter International Inc	Biological products, except diagnostic substances	United States	189	04/05/98	Somatogen Inc	Biological products, except diagnostic substances	United States		1			189		
Baxter International Inc	Biological products, except diagnostic substances	United States	104	03/04/98	Ohmeda-Pharmaceutical Prod Div	Medicinal chemicals and botanical products	United States		1			104		
Baxter International Inc	Biological products, except diagnostic substances	United States	235	31/03/98	Bieffe Medital SpA-Dialysis	Electromedical and electrotherapeutic apparatus	Switzerland		1	1	1	235	235	235

Baxter International Inc	Biological products, except diagnostic substances	United States	236	17/03/97	Research Medical Inc	Surgical and medical instruments and apparatus	United States		1		1	236		236
Baxter International Inc	Biological products, except diagnostic substances	United States	213	17/02/97	Immuno International AG	Pharmaceutical preparations	Switzerland		1	1		213	213	
Baxter International Inc	Biological products, except diagnostic substances	United States	206	30/01/97	Immuno International AG	Pharmaceutical preparations	Switzerland		1	1		206	206	
Baxter International Inc	Biological products, except diagnostic substances	United States	219	19/12/96	Immuno International AG	Pharmaceutical preparations	Switzerland		1	1		219	219	
								Baxt	12	5	4	2652	1055	801
Bayer AG	Medicinal chemicals and botanical products	Germany	2961	03/01/05	Roche Holding AG-Over-The	Pharmaceutical preparations	Switzerland		1	1		2961	2961	
Bayer AG	Medicinal chemicals and botanical products	Germany	6646	03/06/02	Aventis CropScience Hldg SA	Pesticides and agricultural chemicals, nec	France		1	1	1	6646	6646	6646
Bayer AG	Medicinal chemicals and botanical products	Germany	106	01/02/01	Syngenta AG-Mikado Herbicide	Pesticides and agricultural chemicals, nec	Switzerland		1	1	1	106	106	106
Bayer AG	Medicinal chemicals and botanical products	Germany	327	24/10/00	Sybron Chemicals Inc	Chemicals and chemical preparations, nec	United States		1	1	1	327	327	327
Bayer AG	Medicinal chemicals and botanical products	Germany	2450	31/03/00	Lyondell Chemical-Polyls Bus	Petroleum refining	United States		1	1	1	2450	2450	2450
Bayer AG	Medicinal chemicals and botanical products	Germany	1100	30/11/98	Chiron Diagnostics Corp	Pharmaceutical preparations	United States		1	1		1100	1100	
Bayer AG	Medicinal chemicals and botanical products	Germany	580	02/01/96	Monsanto Co-Styrenics Plastics	Plastics products, nec	United States		1	1	1	580	580	580
Bayer(India)Ltd	Pharmaceutical preparations	India	360	16/05/03	Bayer CropScience India Ltd	Pesticides and agricultural chemicals, nec	India		1	1	1	360	360	360
								Bayr	8	8	6	14530	14530	10469
Becton Dickinson & Co	Surgical and medical instruments and apparatus	United States	195	26/08/99	Clontech Laboratories Inc	Biological products, except diagnostic substances	United States							
Becton Dickinson & Co	Surgical and medical instruments and apparatus	United States	452	03/04/98	Ohmeda-Medical Devices Div	Surgical and medical instruments and apparatus	United States							
Berna Biotech AG	Biological products, except diagnostic substances	Switzerland	234	05/08/02	Rhein Biotech NV	Biological products, except diagnostic substances	Netherlands							
Berna Biotech AG	Biological products, except diagnostic substances	Switzerland	110	04/03/00	Green Cross Vaccine Corp	Biological products, except diagnostic substances	South Korea							
BioMarin Pharmaceutical Inc	Pharmaceutical preparations	United States	190	18/05/04	Ascent Pediatrics Inc	Pharmaceutical preparations	United States							
BioMarin Pharmaceutical Inc	Pharmaceutical preparations	United States	141	22/08/02	Glyko Biomedical Ltd	In vitro and in vivo diagnostic substances	United States							
bioMerieux Pierre Fabre	Surgical and medical instruments and apparatus	France	285	03/07/01	Organon Tek-In Vitro Diagn Bus	In vitro and in vivo diagnostic substances	Netherlands							
Bio-Rad Laboratories Inc	Laboratory analytical instruments	United States	210	04/10/99	Pasteur Sanofi Diagnostics	Medicinal chemicals and botanical products	France							

Biovail Corp	Pharmaceutical preparations	Canada	130	02/06/03	Wyeth-Ativan & Isordil Rights	Pharmaceutical preparations	United States									
Biovail Corp	Pharmaceutical preparations	Canada	190	11/12/02	Pharma PASS LLC	Pharmaceutical preparations	United States									
Biovail Corp	Pharmaceutical preparations	Canada	410	29/12/01	Aventis-Product Line	Pharmaceutical preparations	United States									
Biovail Corp	Pharmaceutical preparations	Canada	213	06/10/00	DJ Pharma	Pharmaceutical preparations	United States									
Biovail Corp International	Pharmaceutical preparations	Canada	166	12/11/99	Fuisz Technologies Ltd	Pharmaceutical preparations	United States									
BOC Group PLC	Industrial gases	United Kingdom	109	12/07/93	Huels AG-Hydrogen Business	Industrial gases	Germany									
Boots Co PLC	Pharmaceutical preparations	United Kingdom	340	07/12/00	Procter & Gamble-Clearasil	Pharmaceutical preparations	United States									
Boots Co PLC	Pharmaceutical preparations	United Kingdom	278	01/10/97	Hermal Kurt Herrman(Merck E)	Pharmaceutical preparations	Germany									
Boots Healthcare International	Pharmaceutical preparations	United Kingdom	179	26/09/96	Lutsia(Roussel-Uclaf/Hoechst)	Perfumes, cosmetics, and other toilet preparations	France									
Boots Healthcare International	Pharmaceutical preparations	United Kingdom	179	20/09/96	Laboratoires Lutsia(Roussel)	Perfumes, cosmetics, and other toilet preparations	France									
Bracco SpA	Pharmaceutical preparations	Italy	881	22/03/00	Merck,Bracco-Contrast Imaging	X-Ray apparatus & tubes & other irradiation equip.	Italy									
Bradley Pharmaceuticals Inc	Pharmaceutical preparations	United States	183	10/08/04	Bioglan Pharma Inc	Pharmaceutical preparations	United States									
Bristol-Myers Squibb Co	Pharmaceutical preparations	United States	7800	02/10/01	DuPont Pharmaceuticals Co	Pharmaceutical preparations	United States		1			7800				
Bristol-Myers Squibb Co	Pharmaceutical preparations	United States	150	11/03/96	Argentia SA	Pharmaceutical preparations	Argentina		1	1		150	150			
Bristol-Myers Squibb Co	Pharmaceutical preparations	United States	262	04/01/95	Calgon Vestal Laboratories	Medicinal chemicals and botanical products	United States		1			262				
								BrMS	3	1	0	8212	150	0		
Cambrex Corp	Pharmaceutical preparations	United States	145	04/06/01	Bio Science Contract Prodn Cor	Medicinal chemicals and botanical products	United States									
Cambrex Corp	Industrial organic chemicals, nec	United States	132	03/10/97	BioWhittaker Inc	In vitro and in vivo diagnostic substances	United States									
Cambrex Corp	Industrial organic chemicals, nec	United States	130	12/10/94	Akzo Nobel-Nobel Pharma	Medicinal chemicals and botanical products	Netherlands									
Cargill Inc	Soybean oil mills	United States	284	12/04/05	Seara Alimentos SA	Sausages and other prepared meat products	Brazil									
Cargill Inc	Soybean oil mills	United States	1068	10/05/02	Cerestar	Wet corn milling	France									
Cargill Inc	Soybean oil mills	United States	429	04/04/02	Cerestar	Wet corn milling	France									
Cargill Inc	Soybean oil mills	United States	440	30/04/01	Agribrands International Inc	Prepared animal feeds, except for dogs and cats	United States									

Cargill Inc	Soybean oil mills	United States	140	02/12/98	Grandes Molinos de Venezuela	Flour and other grain mill products	Venezuela								
Celera Genomics Corp	Commercial physical and biological research	United States	140	16/11/01	AXYS Pharmaceuticals Inc	Pharmaceutical preparations	United States								
Celgene Corp	Pharmaceutical preparations	United States	110	21/10/04	Penn T	Pharmaceutical preparations	United Kingdom								
Celgene Corp	Pharmaceutical preparations	United States	198	01/09/00	Signal Pharmaceuticals Inc	Commercial physical and biological research	United States								
Cell Pathways Holdings Inc	Pharmaceutical preparations	United States	151	03/11/98	Tseng Laboratories Inc	Computer peripheral equipment, nec	United States								
Cell Therapeutics Inc	Pharmaceutical preparations	United States	137	02/01/04	Novuspharma SpA	Pharmaceutical preparations	Italy								
Centocor Inc	In vitro and in vivo diagnostic substances	United States	335	24/03/98	Roche Healthcare-Centocor Mktg	Drugs, drug proprietaries, and druggists' sundries	United States								
Cephalon Inc	Pharmaceutical preparations	United States	360	22/12/05	Zeneus Holdings Ltd	Pharmaceutical preparations	United Kingdom		1	1		360	360		
Cephalon Inc	Pharmaceutical preparations	United States	170	19/07/05	CTI Technologies Inc-Trisenox	Pharmaceutical preparations	United States		1			170			
Cephalon Inc	Pharmaceutical preparations	United States	150	14/06/05	Salmedix Inc	Commercial physical and biological research	United States		1			150			
Cephalon Inc	Pharmaceutical preparations	United States	430	12/08/04	CIMA Labs Inc	Pharmaceutical preparations	United States		1			430			
Cephalon Inc	Pharmaceutical preparations	United States	450	28/12/01	Laboratoire L Lafon	Pharmaceutical preparations	France		1	1		450	450		
Cephalon Inc	Pharmaceutical preparations	United States	438	11/10/00	Anesta Corp	Biological products, except diagnostic substances	United States		1			438			
								Ceph	6	2	0	1998	810	0	
Chattem Inc	Pharmaceutical preparations	United States	165	24/03/98	Bristol-Myers-Ban Anti-Perspir	Perfumes, cosmetics, and other toilet preparations	United States								
Chiron Corp	Biological products, except diagnostic substances	United States	789	08/07/03	PowderJect Pharmaceuticals PLC	Biological products, except diagnostic substances	United Kingdom								
Chiron Corp	Biological products, except diagnostic substances	United States	699	22/09/00	PathoGenesis Corp	Biological products, except diagnostic substances	United States								
Chiron Corp	Biological products, except diagnostic substances	United States	125	01/04/98	Behringwerke AG-Human Vaccine	Biological products, except diagnostic substances	Germany								
Chiron Corp	Biological products, except diagnostic substances	United States	110	31/03/98	Chiron Behring GmbH & Co	Biological products, except diagnostic substances	Germany								
Chiron Corp	Biological products, except diagnostic substances	United States	112	02/10/95	Viagene Inc	Commercial physical and biological research	United States								
Chiron Corp	Biological products, except diagnostic substances	United States	616	05/01/95	Ciba-Corning Diag,Biocine	Pharmaceutical preparations	United States								
Chiroscience Group PLC	Pharmaceutical preparations	United Kingdom	112	19/12/96	Darwin Molecular Corp	Commercial physical and biological research	United States								

Christian Hansen Holding A/S	Food preparations, nec	Denmark	103	09/12/98	Ingredients Technology Corp	Food preparations, nec	United States									
Chugai Pharmaceutical Co Ltd	Pharmaceutical preparations	Japan	2590	01/10/02	Nippon Roche KK	Pharmaceutical preparations	Japan		1			2590				
								Chug	1	0	0	2590	0	0		
Ciba Specialty Chemicals	Chemicals and chemical preparations, nec	Switzerland	584	03/06/04	Raisio Chemicals Oy	Industrial inorganic chemicals, nec	Finland									
Ciba Specialty Chemicals	Chemicals and chemical preparations, nec	Switzerland	2501	12/03/98	Allied Colloids Group PLC	Industrial organic chemicals, nec	United Kingdom									
Ciba-Geigy AG	Pharmaceutical preparations	Switzerland	357	22/12/94	Rhone-Poulenc Rorer-US and Can	Pharmaceutical preparations	United States									
Ciba-Geigy AG	Pharmaceutical preparations	Switzerland	140	07/01/93	Fisons PLC-North American	Pharmaceutical preparations	United States									
Connetics Corp	Pharmaceutical preparations	United States	123	04/03/04	Hoffman-Soriatane Rights	Pharmaceutical preparations	United States									
Cooper Cos Inc	Ophthalmic goods	United States	1130	06/01/05	Ocular Sciences Inc	Ophthalmic goods	United States									
Cordis Corp	Surgical and medical instruments and apparatus	United States	400	16/10/97	Biosense Inc	Electromedical and electrotherapeutic apparatus	Israel									
Corgentech Inc	Biological products, except diagnostic substances	United States	130	15/12/05	AlgoRx Pharmaceuticals Inc	Pharmaceutical preparations	United States									
Corixa Corp	Biological products, except diagnostic substances	United States	819	22/12/00	Coulter Pharmaceuticals Inc	Biological products, except diagnostic substances	United States									
Creative BioMolecules Inc	Biological products, except diagnostic substances	United States	104	01/08/00	Ontogeny Inc	Health and allied services, nec	United States									
CSL Ltd	Pharmaceutical preparations	Australia	925	31/03/04	Aventis Behring LLC	Biological products, except diagnostic substances	United States		1	1		925	925			
CSL Ltd	Pharmaceutical preparations	Australia	152	08/09/01	Nabi Inc-Plasma Collection	Biological products, except diagnostic substances	United States		1	1		152	152			
CSL Ltd	Pharmaceutical preparations	Australia	592	30/08/00	ZLB Central Laboratory Blood	Biological products, except diagnostic substances	Switzerland		1	1		592	592			
								CSL	3	3	0	1669	1669	0		
Dade International Inc	In vitro and in vivo diagnostic substances	United States	525	08/05/96	El du Pont de Nemmours-In	Inorganic pigments	United States									
Sankyo Co Ltd	Pharmaceutical preparations	Japan	6290	28/09/05	Daiichi Pharmaceutical Co Ltd	Pharmaceutical preparations	Japan		1			6290				
								Daic	1	0	0	6290	0	0		
Dainippon Pharm Co Ltd	Pharmaceutical preparations	Japan	2224	01/10/05	Sumitomo Pharmaceuticals Co	Pharmaceutical preparations	Japan		1			2224				
								Dain	1	0	0	2224	0	0		

Diosynth BV	Pharmaceutical preparations	Netherlands	190	15/06/01	Covance Biotechnology Services	Pharmaceutical preparations	United States									
Dow Italia Spa(Dow Chemicals)	Medicinal chemicals and botanical products	Italy	300	04/01/96	INCA Intl(Enichem SpA/ENI/IT)	Custom compounding of purchased plastics resins	Italy									
Dr Reddy's Laboratories Ltd	Pharmaceutical preparations	India	211	01/04/00	Cheminor Drugs Ltd	Pharmaceutical preparations	India									
DSM NV	Chemicals and chemical preparations, nec	Netherlands	686	02/02/05	NeoResins	Plastics materials and synthetic resins	Netherlands									
DSM NV	Chemicals and chemical preparations, nec	Netherlands	1915	30/09/03	Roche Holding AG-Vitamins	Medicinal chemicals and botanical products	Switzerland									
DSM NV	Chemicals and chemical preparations, nec	Netherlands	800	14/12/00	Catalytica Pharmaceuticals Inc	Industrial inorganic chemicals, nec	United States									
DSM NV	Chemicals and chemical preparations, nec	Netherlands	1729	11/05/98	Koninklijke Gist-Brocades NV	Industrial organic chemicals, nec	Netherlands									
Duramed Pharmaceuticals Inc	Pharmaceutical preparations	United States	282	10/11/05	FEI Womens Health LLC	Medical, dental, and hospital equipment & supplies	United States									
Duramed Pharmaceuticals Inc	Pharmaceutical preparations	United States	142	08/09/05	Organon Pharm USA Inc-Mircette	Pharmaceutical preparations	United States									
Eisai Co Ltd	Pharmaceutical preparations	Japan	265	27/04/04	Elan Corp-Zonegan Rights	Pharmaceutical preparations	United States		1	1		265	265	
								Eisa	1	1	0	265	265	0
Elan Corp PLC	Biological products, except diagnostic substances	Ireland-Rep	1860	10/11/00	Dura Pharmaceuticals Inc	Pharmaceutical preparations	United States									
Elan Corp PLC	Biological products, except diagnostic substances	Ireland-Rep	601	15/05/00	Liposome Co Inc	Pharmaceutical preparations	United States									
Elan Corp PLC	Biological products, except diagnostic substances	Ireland-Rep	183	31/12/99	Axogen Ltd	Pharmaceutical preparations	Bermuda									
Elan Corp PLC	Biological products, except diagnostic substances	Ireland-Rep	150	01/10/98	NanoSystems LLC(Eastman Kodak)	Pharmaceutical preparations	United States									
Elan Corp PLC	Biological products, except diagnostic substances	Ireland-Rep	773	14/08/98	Neurex Corp	Biological products, except diagnostic substances	United States									
Elan Corp PLC	Biological products, except diagnostic substances	Ireland-Rep	150	01/06/98	Carnrick Laboratories Inc	Drugs, drug proprietaries, and druggists' sundries	United States									
Elan Corp PLC	Biological products, except diagnostic substances	Ireland-Rep	398	02/03/98	Sano Corp	Pharmaceutical preparations	United States									
Elan Corp PLC	Biological products, except diagnostic substances	Ireland-Rep	141	30/10/96	Advanced Therapeutic Systems	Pharmaceutical preparations	Bermuda									
Elan Corp PLC	Biological products, except diagnostic substances	Ireland-Rep	576	01/07/96	Athena Neurosciences Inc	Pharmaceutical preparations	United States									
Elders Australia Ltd	Farm management services	Australia	207	28/10/93	Elders Ltd	Farm management services	Australia									

Eli Lilly & Co	Pharmaceutical preparations	United States	381	12/02/04	Applied Molecular Evolution	Biological products, except diagnostic substances	United States		1			381		
Eli Lilly & Co	Pharmaceutical preparations	United States	4000	21/11/94	PCS Health Systems	Data processing services	United States		1			4000		
								EliL	2	0	0	4381	0	0
Enaleni Pharmaceuticals(Pty)	Pharmaceutical preparations	South Africa	186	31/10/05	Cipla Medpro(Pty)Ltd	Pharmaceutical preparations	South Africa							
Enzon Inc	Biological products, except diagnostic substances	United States	360	22/11/02	Elan Corp Plc-Abelcet Rights &	Pharmaceutical preparations	United States							
Epitope Inc	In vitro and in vivo diagnostic substances	United States	255	28/09/00	STC Technologies Inc	Pharmaceutical preparations	United States							
Ercros SA	Chemicals and chemical preparations, nec	Spain	218	02/06/05	Uralita SA-Chemical Divisions	Chemicals and chemical preparations, nec	Spain							
Evotech BioSystems AG	Pharmaceutical preparations	Germany	459	29/09/00	Oxford Asymmetry International	Pharmaceutical preparations	United Kingdom							
Exelixis Inc	Biological products, except diagnostic substances	United States	104	08/01/02	Genomica Corp	Computer programming services	United States							
Fidia Farmaceutici SpA	Pharmaceutical preparations	Italy	186	29/05/03	Antibioticos SA	Pharmaceutical preparations	Spain							
Fisher Scientific Intl Inc	Surgical and medical instruments and apparatus	United States	150	03/08/05	Lancaster Laboratories Inc	Commercial physical and biological research	United States							
Fisher Scientific Intl Inc	Surgical and medical instruments and apparatus	United States	3669	02/08/04	Apogent Technologies Inc	Laboratory apparatus and furniture	United States							
Fisher Scientific Intl Inc	Surgical and medical instruments and apparatus	United States	330	01/03/04	Oxoid Holdings Ltd	In vitro and in vivo diagnostic substances	United Kingdom							
Fisher Scientific Intl Inc	Surgical and medical instruments and apparatus	United States	786	03/09/03	Perbio Science AB	Surgical and medical instruments and apparatus	Sweden							
Fisher Scientific Intl Inc	Surgical and medical instruments and apparatus	United States	205	05/11/01	Cole-Parmer Instrument Co	Chemicals and allied products, nec	United States							
Fisher Scientific Intl Inc	Surgical and medical instruments and apparatus	United States	138	15/02/01	Covance Inc-Pharmaceutical	Packing and crating	United States							
Fisher Scientific Intl Inc	Surgical and medical instruments and apparatus	United States	310	17/10/95	Fisons Scientific Equip,Curtin	Medical, dental, and hospital equipment & supplies	United Kingdom							
Fresenius AG	Pharmaceutical preparations	Germany	472	11/12/98	Pharmacia & Upjohn-Nutrition	Pharmaceutical preparations	Sweden							
Fresenius AG	Pharmaceutical preparations	Germany	4236	30/09/96	National Medical Care Inc	Medical, dental, and hospital equipment & supplies	United States							
Fujirebio Inc	Pharmaceutical preparations	Japan	168	11/11/04	SRL Inc	Commercial physical and biological research	Japan							
Fukujin Co Ltd	Pharmaceutical preparations	Japan	205	29/09/03	Azwell Inc	Pharmaceutical preparations	Japan							
Galen Holdings PLC	Pharmaceutical preparations	United Kingdom	484	27/03/03	Pfizer Inc-Estrostep,Loestrin	Pharmaceutical preparations	United States							

Galen Holdings PLC	Pharmaceutical preparations	United Kingdom	295	23/01/03	Eli Lilly-Sales,Marketing Rts	Pharmaceutical preparations	United States								
Galen Holdings PLC	Pharmaceutical preparations	United Kingdom	551	28/09/00	Warner Chilcott PLC	Pharmaceutical preparations	Ireland-Rep								
Genentech Inc	Biological products, except diagnostic substances	United States	408	24/06/05	Biogen Idec-Biologics Mnfr Fac	Biological products, except diagnostic substances	United States		1			408			
								Gene	1	0	0	408	0	0	
Genome Therapeutics Corp	Biological products, except diagnostic substances	United States	104	06/02/04	Genesoft Inc	Biological products, except diagnostic substances	United States								
Gensia Sicor Inc	Pharmaceutical preparations	United States	140	28/02/97	Rakepoll Holding BV(Rakepoll)	Offices of holding companies, nec	Netherlands				1			140	
Genzyme Biosurgery	Biological products, except diagnostic substances	United States	427	18/12/00	Biomatrix Inc	Medicinal chemicals and botanical products	United States		1			427			
Genzyme Corp	Biological products, except diagnostic substances	United States	595	01/07/05	Bone Care Intl Inc	Pharmaceutical preparations	United States		1			595			
Genzyme Corp	Biological products, except diagnostic substances	United States	415	06/01/05	Wyeth-Sales,Marketing Rights	Pharmaceutical preparations	United States		1			415			
Genzyme Corp	Biological products, except diagnostic substances	United States	949	21/12/04	ILEX Oncology Inc	Pharmaceutical preparations	United States		1			949			
Genzyme Corp	Biological products, except diagnostic substances	United States	215	03/05/04	Impath Physician Services	Commercial nonphysical research	United States		1			215			
Genzyme Corp	Biological products, except diagnostic substances	United States	535	15/09/03	SangStat Medical Corp	Pharmaceutical preparations	United States		1			535			
Genzyme Corp	Biological products, except diagnostic substances	United States	225	27/09/01	Novazyme Pharmaceuticals Inc	Pharmaceutical preparations	United States		1			225			
Genzyme Corp	Biological products, except diagnostic substances	United States	993	14/12/00	GelTex Pharmaceuticals Inc	Biological products, except diagnostic substances	United States		1			993			
Genzyme Corp	Biological products, except diagnostic substances	United States	107	29/10/96	Neozyme II Corp	Pharmaceutical preparations	British Virgin		1	1		107	107		
Genzyme Corp	Biological products, except diagnostic substances	United States	250	02/07/96	Deknatel Snowden Pencer	Surgical and medical instruments and apparatus	United States		1		1	250		250	
								Genz	10	1	1	4710	107	250	
Gilead Sciences Inc	Biological products, except diagnostic substances	United States	123	15/09/03	Equity Office-Foster City	Colleges, universities, and professional schools	United States		1			123			
Gilead Sciences Inc	Biological products, except diagnostic substances	United States	407	23/01/03	Triangle Pharmaceuticals Inc	Pharmaceutical preparations	United States		1			407			
Gilead Sciences Inc	Biological products, except diagnostic substances	United States	866	29/07/99	NeXstar Pharmaceuticals Inc	Pharmaceutical preparations	United States		1			866			
								Gild	3	0	0	1396	0	0	

Glaxo Holdings PLC	Pharmaceutical preparations	United Kingdom	605	21/11/96	Nippon Glaxo	Pharmaceutical preparations	Japan		1	1		605	605	
Glaxo Holdings PLC	Pharmaceutical preparations	United Kingdom	13408	16/03/95	Wellcome PLC	Pharmaceutical preparations	United Kingdom		1			13408		
Glaxo Wellcome PLC	Pharmaceutical preparations	United Kingdom	78775	27/12/00	SmithKline Beecham PLC	Medicinal chemicals and botanical products	United Kingdom		1			78775		
Glaxo Wellcome PLC	Pharmaceutical preparations	United Kingdom	106	08/01/99	Amoun Pharmaceuticals (APIC)	Pharmaceutical preparations	Egypt		1	1		106	106	
Glaxo Wellcome PLC	Pharmaceutical preparations	United Kingdom	220	28/01/98	Polfa Poznan(Poland)	Pharmaceutical preparations	Poland		1	1		220	220	
GlaxoSmithKline PLC	Pharmaceutical preparations	United Kingdom	1388	08/12/05	ID Biomedical Corp	Biological products, except diagnostic substances	Canada		1	1		1388	1388	
GlaxoSmithKline PLC	Pharmaceutical preparations	United Kingdom	349	12/07/05	Corixa Corp	Biological products, except diagnostic substances	United States		1	1		349	349	
GlaxoSmithKline PLC	Pharmaceutical preparations	United Kingdom	547	03/09/04	Sanofi-Synthelabo-Drugs	Pharmaceutical preparations	France		1	1		547	547	
SmithKline Beecham Corp	Pharmaceutical preparations	United States	2300	27/05/94	Diversified Pharmaceutical	Offices and clinics of doctors of medicine	United States		1	1		2300	2300	
SmithKline Beecham PLC	Medicinal chemicals and botanical products	United Kingdom	1453	16/01/01	Block Drug Co	Dental equipment and supplies	United States		1	1	1	1453	1453	1453
SmithKline Beecham PLC	Medicinal chemicals and botanical products	United Kingdom	141	05/01/96	Abtei Pharma-Vertriebs GmbH	Drugs, drug proprietaries, and druggists' sundries	Germany		1	1		141	141	
SmithKline Beecham PLC	Medicinal chemicals and botanical products	United Kingdom	2925	02/11/94	Sterling Winthrop Inc	Pharmaceutical preparations	United States		1	1		2925	2925	
								GSK	12	10	1	102218	10035	1453
Global Pharm Dvlp Inc	Biological products, except diagnostic substances	United States	125	30/09/05	Quintiles-Business Units(3)	Biological products, except diagnostic substances	United States							
Global Pharmaceutical Corp	Pharmaceutical preparations	United States	139	15/12/99	Impax Pharmaceuticals Inc	Pharmaceutical preparations	United States							
Grasim Industries Ltd	Pulp mills	India	275	06/07/04	Larsen & Toubro Ltd-Cement	Cement, hydraulic	India							
Guidant Corp	Surgical and medical instruments and apparatus	United States	291	15/11/99	CardioThoracic Systems Inc	Electromedical and electrotherapeutic apparatus	United States							
Guidant Corp	Surgical and medical instruments and apparatus	United States	810	01/02/99	SulzerMedica-Electrophysiology	Electromedical and electrotherapeutic apparatus	United States							
Guidant Corp	Surgical and medical instruments and apparatus	United States	121	31/12/98	InControl Inc	Orthopedic, prosthetic, and surgical supplies	United States							
Guidant Corp	Surgical and medical instruments and apparatus	United States	190	19/12/97	EndoVascular Technologies Inc	Surgical and medical instruments and apparatus	United States							
H Lundbeck A/S	Pharmaceutical preparations	Denmark	135	06/03/03	Synaptic Pharmaceutical Corp	Pharmaceutical preparations	United States		1		1	135		135
H Lundbeck A/S	Pharmaceutical preparations	Denmark	101	02/02/01	Lundbeck GmbH	Pharmaceutical preparations	Germany		1		1	101		101

						Hlun	2	0	2	236	0	236
Hafslund Nycomed AS	Pharmaceutical preparations	Norway	450	03/10/94	Sterling Winthrop-Med Image	Electromedical and electrotherapeutic apparatus	United States
Herba-Apotheker AG	Medicinal chemicals and botanical products	Austria	125	12/09/97	Chemosan-Union AG	Medicinal chemicals and botanical products	Austria
Hisamitsu Pharmaceutical	Pharmaceutical preparations	Japan	136	01/04/05	Biomedics	Pharmaceutical preparations	Japan
Human Genome Sciences Inc	In vitro and in vivo diagnostic substances	United States	120	08/09/00	Principia Pharmaceutical Corp	Biological products, except diagnostic substances	United States
ICN Pharmaceuticals Inc	Pharmaceutical preparations	United States	187	22/08/03	Ribapharm Inc	Biological products, except diagnostic substances	United States
ID Biomedical Corp	Biological products, except diagnostic substances	Canada	116	09/09/04	Shire Biologics	Biological products, except diagnostic substances	Canada
IDEC Pharmaceuticals Corp	Biological products, except diagnostic substances	United States	6059	12/11/03	Biogen Inc	Biological products, except diagnostic substances	United States
Immunex Corp	Biological products, except diagnostic substances	United States	468	01/01/02	Greenwich Holdings Inc	Pharmaceutical preparations	United States
Inhale Therapeutic Systems Inc	Pharmaceutical preparations	United States	191	29/06/01	Shearwater Corp	Pharmaceutical preparations	United States
Inhale Therapeutic Systems Inc	Pharmaceutical preparations	United States	200	09/01/01	Bradford Particle Design PLC	Commercial physical and biological research	United Kingdom
Intercare Group PLC	Pharmaceutical preparations	United Kingdom	122	26/10/00	Macarthy Group Ltd(Cinven)	Pharmaceutical preparations	United Kingdom
Inverness Med Innovations Inc	In vitro and in vivo diagnostic substances	United States	149	20/12/01	Unipath Ltd(Unilever PLC)	Surgical and medical instruments and apparatus	United Kingdom
Invitrogen Corp	Biological products, except diagnostic substances	United States	131	06/10/05	BioSource International Inc	In vitro and in vivo diagnostic substances	United States
Invitrogen Corp	Biological products, except diagnostic substances	United States	388	01/04/05	Dynal Biotech ASA	Biological products, except diagnostic substances	Norway
Invitrogen Corp	Biological products, except diagnostic substances	United States	486	10/02/04	BioReliance Corp	Commercial physical and biological research	United States
Invitrogen Corp	Biological products, except diagnostic substances	United States	325	22/08/03	Molecular Probes Inc	Chemicals and allied products, nec	United States
Invitrogen Corp	Biological products, except diagnostic substances	United States	402	14/09/00	Life Technologies Inc(Dexter)	Biological products, except diagnostic substances	United States
Invitrogen Corp	Biological products, except diagnostic substances	United States	1660	14/09/00	Dexter Corp	Adhesives and sealants	United States
Invitrogen Corp	Biological products, except diagnostic substances	United States	127	02/02/00	Research Genetics Inc	Commercial physical and biological research	United States
Ion Beam Applications SA	Electromedical and electrotherapeutic apparatus	Belgium	225	22/07/99	Sterigenics International Inc	Business services, nec	United States
IVAX Corp	Pharmaceutical preparations	United States	272	11/05/05	Phoenix Scientific Inc	Pharmaceutical preparations	United States
IVAX Corp	Pharmaceutical preparations	United States	453	29/06/01	Laboratorio Chile SA	Pharmaceutical preparations	Chile

IVAX Corp	Pharmaceutical preparations	United States	605	30/12/94	Zenith Laboratories Inc	Pharmaceutical preparations	United States									
IVAX Corp	Pharmaceutical preparations	United States	585	28/03/94	McGaw Inc	Pharmaceutical preparations	United States									
Jazz Pharmaceuticals Inc	Pharmaceutical preparations	United States	131	27/06/05	Orphan Medical Inc	Pharmaceutical preparations	United States									
Johnson & Johnson	Pharmaceutical preparations	United States	387	03/06/05	Closure Medical Corp	Surgical and medical instruments and apparatus	United States		1		1	387		387		
Johnson & Johnson	Pharmaceutical preparations	United States	230	04/04/05	TransForm Pharmaceuticals Inc	Pharmaceutical preparations	United States		1			230				
Johnson & Johnson	Pharmaceutical preparations	United States	2449	29/04/03	Scios Inc	Pharmaceutical preparations	United States		1			2449				
Johnson & Johnson	Pharmaceutical preparations	United States	320	18/04/02	Tibotec-Virco NV	Medical laboratories	Belgium		1	1		320	320			
Johnson & Johnson	Pharmaceutical preparations	United States	1300	21/11/01	Inverness Medical-Diabetes	Electromedical and electrotherapeutic apparatus	United States		1		1	1300		1300		
Johnson & Johnson	Pharmaceutical preparations	United States	10213	22/06/01	ALZA Corp	Pharmaceutical preparations	United States		1			10213				
Johnson & Johnson	Pharmaceutical preparations	United States	4861	06/10/99	Centocor Inc	In vitro and in vivo diagnostic substances	United States		1			4861				
Johnson & Johnson	Pharmaceutical preparations	United States	3360	05/11/98	Depuy Inc(Corange Ltd)	Orthopedic, prosthetic, and surgical supplies	United States		1			3360				
Johnson & Johnson	Pharmaceutical preparations	United States	296	31/07/97	Biopsys Medical Inc	Surgical and medical instruments and apparatus	United States		1		1	296		296		
Johnson & Johnson	Pharmaceutical preparations	United States	118	24/03/97	Innotech Inc	Electromedical and electrotherapeutic apparatus	United States		1		1	118		118		
Johnson & Johnson	Pharmaceutical preparations	United States	1789	23/02/96	Cordis Corp	X-Ray apparatus & tubes & other irradiation equip	United States		1		1	1789		1789		
Johnson & Johnson	Pharmaceutical preparations	United States	124	05/04/95	Mitek Surgical Products	Surgical and medical instruments and apparatus	United States		1		1	124		124		
Johnson & Johnson	Pharmaceutical preparations	United States	1008	30/11/94	Eastman Kodak-Clinical	In vitro and in vivo diagnostic substances	United States		1			1008				
Johnson & Johnson	Pharmaceutical preparations	United States	900	03/10/94	Neutrogena Corp	Soap & other detergents, except specialty cleaners	United States		1		1	900		900		
Johnson & Johnson	Pharmaceutical preparations	United States	169	09/12/93	Roc(LVMH-Moet Hennessy L Vuit)	Perfumes, cosmetics, and other toilet preparations	France		1	1	1	169	169	169		
								John	15	2	8	27524	489	5083		
Johnson Matthey PLC	Chemicals and chemical preparations, nec	United Kingdom	404	01/11/02	ICI Synetix	Industrial inorganic chemicals, nec	United Kingdom									
Johnson Matthey PLC	Chemicals and chemical preparations, nec	United Kingdom	206	09/07/01	Meconic PLC	Drugs, drug proprietaries, and druggists' sundries	United Kingdom									
Johnson Matthey PLC	Chemicals and chemical preparations, nec	United Kingdom	216	06/02/98	Cookson Matthey Ceramics and	Pottery products, nec	United Kingdom									
Johnson Matthey PLC	Chemicals and chemical preparations, nec	United Kingdom	164	06/10/95	Advance Circuits Inc	Printed circuit boards	United States									
Kalbe Farma PT	Pharmaceutical preparations	Indonesia	473	20/12/05	Enseval	Drugs, drug proprietaries, and druggists' sundries	Indonesia									

KCP Income Fund	Perfumes, cosmetics, and other toilet preparations	Canada	215	17/05/05	CCL Industries Inc-North Amer	Metal cans	United States								
Kemira Oyj	Chemicals and chemical preparations, nec	Finland	191	06/04/05	Verdugt BV	Chemicals and chemical preparations, nec	Netherlands								
Kemira Oyj	Chemicals and chemical preparations, nec	Finland	444	01/04/05	Finnish Chemicals Oy	Chemicals and chemical preparations, nec	Finland								
Kemira Oyj	Chemicals and chemical preparations, nec	Finland	138	30/01/02	Vinings Industries	Industrial organic chemicals, nec	United States								
King Pharmaceuticals Inc	Pharmaceutical preparations	United States	750	13/06/03	Elan Corp PLC-Primary Care	Pharmaceutical preparations	United States		1			750			
King Pharmaceuticals Inc	Pharmaceutical preparations	United States	235	08/01/03	Meridian Medical Technologies	Electromedical and electrotherapeutic apparatus	United States		1		1	235		235	
King Pharmaceuticals Inc	Pharmaceutical preparations	United States	275	31/12/02	Aventis-Intale,Tilade,Sunercid	Pharmaceutical preparations	France		1	1		275	275		
King Pharmaceuticals Inc	Pharmaceutical preparations	United States	115	29/05/02	Ortho-McNeil Pharmaceutical	Pharmaceutical preparations	United States		1			115			
King Pharmaceuticals Inc	Pharmaceutical preparations	United States	285	09/08/01	Bristol-Myers Squibb-US Rights	Pharmaceutical preparations	United States		1			285			
King Pharmaceuticals Inc	Pharmaceutical preparations	United States	3363	31/08/00	Jones Pharmaceutical Inc	Pharmaceutical preparations	United States		1			3363			
King Pharmaceuticals Inc	Pharmaceutical preparations	United States	356	25/02/00	Medco Research Inc	Pharmaceutical preparations	United States		1			356			
King Pharmaceuticals Inc	Pharmaceutical preparations	United States	363	22/12/98	Hoechst Marion Roussel-Prods	Pharmaceutical preparations	Germany		1	1		363	363		
								King	8	2	1	5741	637	235	
Knoll Pharmaceuticals(Abbott)	Pharmaceutical preparations	United States	450	05/03/01	Hokuriku Seiyaku Co Ltd	Pharmaceutical preparations	Japan								
Koninklijke Numico NV	Dry, condensed, and evaporated dairy products	Netherlands	529	24/06/05	Mellin SpA	Canned specialties	Italy								
Koninklijke Numico NV	Dry, condensed, and evaporated dairy products	Netherlands	1747	10/07/00	Rexall Sundown Inc	Pharmaceutical preparations	United States								
Koninklijke Numico NV	Dry, condensed, and evaporated dairy products	Netherlands	2546	11/08/99	General Nutrition Cos Inc	Miscellaneous food stores	United States								
Kos Pharmaceuticals Inc	Pharmaceutical preparations	United States	200	05/03/04	Aventis Pharm-Azmacort Rights	Pharmaceutical preparations	United States								
Kowa Co Ltd	Pharmaceutical preparations	Japan	130	13/11/03	Nikken Chemicals Co Ltd	Pharmaceutical preparations	Japan								
Kuraray Co Ltd	Chemicals and chemical preparations, nec	Japan	238	17/01/02	Clariant AG-PVA/PVB	Plastics materials and synthetic resins	Switzerland								
Mallinckrodt Inc	In vitro and in vivo diagnostic substances	United States	1864	15/09/97	Nellcor Puritan-Bennett	Electromedical and electrotherapeutic apparatus	United States								

Marion Merrell Dow Inc	Pharmaceutical preparations	United States	275	05/10/93	Rugby-Darby Group Cos-Drug Bus	Medical, dental, and hospital equipment & supplies	United States									
Matrix Laboratories Ltd	Pharmaceutical preparations	India	203	04/10/05	Docpharma NV	Pharmaceutical preparations	Belgium									
Mayne Group Ltd	Pharmaceutical preparations	Australia	105	26/04/04	aaiPharma-Injectable Prod	Pharmaceutical preparations	United States									
Mayne Group Ltd	Pharmaceutical preparations	Australia	153	29/09/02	Queensland Med Laboratory Grp	Medical laboratories	Australia									
Meda AB	Pharmaceutical preparations	Sweden	909	28/09/05	VIATRIS GmbH & Co KG	Pharmaceutical preparations	Germany									
Meda AB	Pharmaceutical preparations	Sweden	135	20/01/05	Novartis AG-Brand Rights(2)	Pharmaceutical preparations	Switzerland									
Medeus Pharma Ltd	Pharmaceutical preparations	United Kingdom	120	12/02/04	Elan-Certain European Bus	Pharmaceutical preparations	Ireland-Rep									
Medicis Pharmaceutical Corp	Pharmaceutical preparations	United States	160	10/03/03	HA North American Sales AB	In vitro and in vivo diagnostic substances	United States									
Medicis Pharmaceutical Corp	Pharmaceutical preparations	United States	136	15/11/01	Ascent Pediatrics Inc	Pharmaceutical preparations	United States									
MedImmune Inc	Biological products, except diagnostic substances	United States	1740	15/01/02	Aviron	Biological products, except diagnostic substances	United States									
MedImmune Inc	Biological products, except diagnostic substances	United States	393	23/11/99	US Bioscience Inc	Pharmaceutical preparations	United States									
Merck & Co Inc	Pharmaceutical preparations	United States	461	19/07/01	Rosetta Inpharmatics Inc	Commercial physical and biological research	United States		1			461				
Merck & Co Inc	Pharmaceutical preparations	United States	185	21/06/00	Provantage Health Services	Management consulting services	United States		1			185				
Merck & Co Inc	Pharmaceutical preparations	United States	5921	18/11/93	Medco Containment Services Inc	Drugs, drug proprietaries, and druggists' sundries	United States		1			5921				
								Merc	3	0	0	6567	0	0		
Merck KGaA	Pharmaceutical preparations	Germany	935	28/07/99	VWR Scientific Products Corp	Professional equipment and supplies, nec	United States		1			935				
Merck KGaA	Pharmaceutical preparations	Germany	225	02/05/96	Seven Seas Ltd(Hanson PLC)	Medicinal chemicals and botanical products	United Kingdom		1			225				
Merck KGaA	Pharmaceutical preparations	Germany	1391	17/10/95	Merck AG	Pharmaceutical preparations	Switzerland		1			1391				
								MerK	3	0	0	2551	0	0		
MGI PHARMA Inc	Pharmaceutical preparations	United States	203	03/10/05	Guilford Pharmaceuticals Inc	Pharmaceutical preparations	United States									
Miles Inc	Pharmaceutical preparations	United States	1000	03/11/94	Sterling Winthrop-NA OTC Drug	Drugs, drug proprietaries, and druggists' sundries	United States									
Miles Inc	Pharmaceutical preparations	United States	101	18/04/94	ChemDesign Corp(Bayer Corp)	Industrial organic chemicals, nec	United States									

Millennium Pharmaceuticals Inc	Pharmaceutical preparations	United States	2174	12/02/02	COR Therapeutics Inc	Pharmaceutical preparations	United States
Millennium Pharmaceuticals Inc	Pharmaceutical preparations	United States	557	22/12/99	LeukoSite Inc	Pharmaceutical preparations	United States
Millipore Corp	Laboratory analytical instruments	United States	151	27/01/97	Tylan General Inc	Process control instruments	United States
Millipore Corp	Laboratory analytical instruments	United States	125	31/12/96	Amicon Inc(Natl Med Care Inc)	Laboratory analytical instruments	United States
Monsanto Co	Pesticides and agricultural chemicals, nec	United States	26772	31/03/00	Pharmacia & Upjohn Inc	Pharmaceutical preparations	United States
Monsanto Co	Pesticides and agricultural chemicals, nec	United States	2382	07/12/98	DeKalb Genetics Corp	Commercial physical and biological research	United States
Monsanto Co	Pesticides and agricultural chemicals, nec	United States	1400	30/10/98	Cargill-International Seed Ope	Grain and field beans	Mexico
Monsanto Co	Pesticides and agricultural chemicals, nec	United States	523	16/07/98	Plant Breeding Intl Cambridge	Ornamental floriculture and nursery products	United Kingdom
Monsanto Co	Pesticides and agricultural chemicals, nec	United States	945	04/09/97	Holden's Foundation Seeds	Ornamental floriculture and nursery products	United States
Monsanto Co	Pesticides and agricultural chemicals, nec	United States	243	21/05/97	Calgene Inc(Monsanto Co)	Ornamental floriculture and nursery products	United States
Monsanto Co	Pesticides and agricultural chemicals, nec	United States	240	03/02/97	Asgrow Agronomics(Semin is)	Ornamental floriculture and nursery products	United States
Monsanto Co	Pesticides and agricultural chemicals, nec	United States	150	21/05/96	Agracetus-Transgenic Plant Bus	Commercial physical and biological research	United States
Monsanto Co	Pesticides and agricultural chemicals, nec	United States	1075	21/02/95	Kelco Biopolymers	Industrial organic chemicals, nec	United States
Monsanto Co	Pesticides and agricultural chemicals, nec	United States	400	14/05/93	Chevron Chemical Co-Ortho	Pesticides and agricultural chemicals, nec	United States
Mylan Laboratories Inc	Pharmaceutical preparations	United States	188	05/10/98	Penederm Inc	Pharmaceutical preparations	United States
Nabi Biopharmaceuticals	Biological products, except diagnostic substances	United States	101	05/08/03	Braintree Labs Inc-PhosLo	Pharmaceutical preparations	United States
Natraceutical SA	Biological products, except diagnostic substances	Spain	104	04/05/05	Braes Group Ltd	Flavoring extracts and flavoring syrups, nec	United Kingdom
NBTY Inc	Pharmaceutical preparations	United States	115	01/08/05	Solgar Vitamin & Herb Co	Medicinal chemicals and botanical products	United States
NBTY Inc	Pharmaceutical preparations	United States	250	25/07/03	Rexall Sundown Inc	Pharmaceutical preparations	United States
NBTY Inc	Pharmaceutical preparations	United States	169	08/08/97	Holland & Barrett(Lloyds)	Miscellaneous food stores	United Kingdom
NeoSan Pharm(AaiPharma Inc)	Pharmaceutical preparations	United States	100	30/08/01	Astrazeneca AB-Critical Care	Pharmaceutical preparations	Sweden

North American Biologicals Inc	Biological products, except diagnostic substances	United States	160	30/11/95	Univax Biologics Inc	Biological products, except diagnostic substances	United States								
NOVA Chemicals Corp	Plastics materials and synthetic resins	Canada	185	31/01/00	Royal Dutch/Shell Group-	Plastics materials and synthetic resins	Netherlands								
Novartis AG	Pharmaceutical preparations	Switzerland	660	31/08/05	Bristol-Myers Squibb Co-US	Pharmaceutical preparations	United States		1	1		660	660		
Novartis AG	Pharmaceutical preparations	Switzerland	933	26/07/05	Eon Labs Inc	Pharmaceutical preparations	United States		1	1		933	933		
Novartis AG	Pharmaceutical preparations	Switzerland	1504	21/07/05	Eon Labs Inc	Pharmaceutical preparations	United States		1	1		1504	1504		
Novartis AG	Pharmaceutical preparations	Switzerland	5685	06/06/05	Hexal AG	Pharmaceutical preparations	Germany		1	1		5685	5685		
Novartis AG	Pharmaceutical preparations	Switzerland	225	01/04/03	Pfizer Inc-Enablex Brand	Pharmaceutical preparations	United States		1	1		225	225		
Novartis AG	Pharmaceutical preparations	Switzerland	851	18/11/02	Lek(Slovenia)	Pharmaceutical preparations	Slovenia		1	1		851	851		
Novartis AG	Pharmaceutical preparations	Switzerland	421	24/04/01	Hazal Finance(Neqma)	Investment advice	France		1	1	1	421	421	421	
Novartis AG	Pharmaceutical preparations	Switzerland	1634	21/12/00	SB-Famvir,Vectavir/Denavir	Pharmaceutical preparations	United Kingdom		1	1		1634	1634		
Novartis AG	Pharmaceutical preparations	Switzerland	143	31/08/98	Oriental Chemical Inds-Crop	Pesticides and agricultural chemicals, nec	South Korea		1	1	1	143	143	143	
Novartis AG	Pharmaceutical preparations	Switzerland	910	03/07/97	Merck-Crop Protection Business	Pesticides and agricultural chemicals, nec	United States		1	1	1	910	910	910	
Novartis Generics(Novartis AG)	Pharmaceutical preparations	Austria	101	01/01/01	BASF Pharma-Euro Generics Bus	Pharmaceutical preparations	Germany		1	1		101	101		
Novartis Medical Nutrition	Medicinal chemicals and botanical products	Switzerland	385	17/02/04	Mead Johnson-Adult Nut Bus	Food preparations, nec	United States		1	1	1	385	385	385	
Novartis Pharma AG	Pharmaceutical preparations	Switzerland	612	09/05/03	Idenix Pharmaceuticals Inc	Pharmaceutical preparations	United States		1	1		612	612		
Sandoz GmbH	Pharmaceutical preparations	Austria	565	16/08/04	Sabex Inc	Pharmaceutical preparations	Canada		1	1		565	565		
								Nova	14	14	4	14629	14629	1859	
Omega Pharma NV	Pharmaceutical preparations	Belgium	122	03/09/04	Medestea International Srl	Pharmaceutical preparations	Italy								
Omega Pharma NV	Pharmaceutical preparations	Belgium	164	28/06/04	Pfizer-European Brands	Pharmaceutical preparations	Belgium								
Omega Pharma NV	Pharmaceutical preparations	Belgium	118	15/12/00	Chefaro International(Akzo NV)	Pharmaceutical preparations	Netherlands								
Omega Pharma NV	Pharmaceutical preparations	Belgium	139	08/09/00	Fagron Farmaceuticals(Fagron)	Drugs, drug proprietaries, and druggists' sundries	Netherlands								
Omnicare Inc	Drug stores and proprietary stores	United States	235	15/08/05	RxCrossroads LLC	Health and allied services, nec	United States								

Omnicare Inc	Drug stores and proprietary stores	United States	269	12/08/05	ExcelleRx Inc	Pharmaceutical preparations	United States					
Omnicare Inc	Drug stores and proprietary stores	United States	2067	28/07/05	NeighborCare Inc	Skilled nursing care facilities	United States					
Omnicare Inc	Drug stores and proprietary stores	United States	402	16/01/03	NCS HealthCare Inc	Drug stores and proprietary stores	United States					
Omnicare Inc	Drug stores and proprietary stores	United States	115	08/01/02	American Pharmaceutical Svcs	Drug stores and proprietary stores	United States					
Omnicare Inc	Drug stores and proprietary stores	United States	255	17/09/98	United Professional Cos	Drugs, drug proprietaries, and druggists' sundries	United States					
Omnicare Inc	Drug stores and proprietary stores	United States	152	29/06/98	IBAH Inc	Pharmaceutical preparations	United States					
Omnicare Inc	Drug stores and proprietary stores	United States	252	16/09/97	American Medserve Corp	Drugs, drug proprietaries, and druggists' sundries	United States					
Oriental Chemical Inds Co Ltd	Chemicals and chemical preparations, nec	South Korea	208	30/04/00	Korea Steel Chem(Pohang Iron)	Steel works, blast furnaces, and rolling mills	South Korea					
Ortho Biotech Products LP	Biological products, except diagnostic substances	United States	134	09/08/01	Pharmamar	Pharmaceutical preparations	Spain					
Ortho-McNeil Pharm Inc	Pharmaceutical preparations	United States	245	30/06/05	Peninsula Pharmaceuticals Inc	Biological products, except diagnostic substances	United States					
OSI Pharmaceuticals Inc	Pharmaceutical preparations	United States	721	14/11/05	Eyetech Pharmaceuticals Inc	Pharmaceutical preparations	United States					
OSI Pharmaceuticals Inc	Pharmaceutical preparations	United States	200	21/12/01	Gilead Sciences Inc-Oncology A	Pharmaceutical preparations	United States					
PAREXEL International Corp	Biological products, except diagnostic substances	United States	109	01/03/98	PPS Europe Ltd	Management consulting services	United Kingdom					
Patheon Inc	Pharmaceutical preparations	Canada	442	23/12/04	Mova Pharmaceuticals Corp	Pharmaceutical preparations	Puerto Rico					
Perrigo Co	Biological products, except diagnostic substances	United States	922	17/03/05	Agis Industries(1983)Ltd	Pharmaceutical preparations	Israel					
Pfizer Inc	Pharmaceutical preparations	United States	1791	14/09/05	Vicuron Pharmaceuticals Inc	Biological products, except diagnostic substances	United States	1		1791		
Pfizer Inc	Pharmaceutical preparations	United States	527	05/05/05	Angiosyn Inc	Biological products, except diagnostic substances	United States	1		527		
Pfizer Inc	Pharmaceutical preparations	United States	118	12/11/04	Meridica Ltd	Pharmaceutical preparations	United Kingdom	1	1	118	118	
Pfizer Inc	Pharmaceutical preparations	United States	372	02/11/04	Slough-Global Research Center	Commercial physical and biological research	United States	1		372		

Pfizer Inc	Pharmaceutical preparations	United States	620	01/10/04	Aventis SA-Campto Cancer Drug	Pharmaceutical preparations	France		1	1		620	620	
Pfizer Inc	Pharmaceutical preparations	United States	126	26/03/04	CSL Ltd-Animal Health Business	Biological products, except diagnostic substances	Australia		1	1		126	126	
Pfizer Inc	Pharmaceutical preparations	United States	1198	11/02/04	Esperion Therapeutics Inc	Pharmaceutical preparations	United States		1			1198		
Pfizer Inc	Pharmaceutical preparations	United States	60704	15/04/03	Pharmacia Corp	Pharmaceutical preparations	United States		1			60704		
Pfizer Inc	Pharmaceutical preparations	United States	88771	19/06/00	Warner-Lambert Co	Pharmaceutical preparations	United States		1			88771		
Pfizer Inc	Pharmaceutical preparations	United States	156	16/03/95	NAMIC USA Corp	Surgical and medical instruments and apparatus	United States		1		1	156		156
Pfizer Inc	Pharmaceutical preparations	United States	1450	19/01/95	SmithKline Beecham Animal Hlth	Drugs, drug proprietaries, and druggists' sundries	United States		1			1450		
Pharmacia & Upjohn Inc	Pharmaceutical preparations	United States	613	31/08/99	SUGEN Inc	Commercial physical and biological research	United States		1			613		
Pharmacia Corp	Pharmaceutical preparations	United States	200	01/07/02	AT&T Corp-Headquarters,Basking	Operators of nonresidential buildings	United States		1		1	200		200
Upjohn Co	Pharmaceutical preparations	United States	6802	02/11/95	Pharmacia AB	Pharmaceutical preparations	Sweden		1	1		6802	6802	
								Pfiz	14	4	2	163448	7667	356
Pharm Prod Dvlp Inc	Commercial physical and biological research	United States	481	26/09/96	Applied Bioscience Intl(IMS)	Testing laboratories	United States							
Pharmaceutical Resources Inc	Pharmaceutical preparations	United States	145	10/06/04	Kali Laboratories Inc	Pharmaceutical preparations	United States							
Pharmacopeia Inc	Biological products, except diagnostic substances	United States	127	14/06/98	Molecular Simulations Inc	Prepackaged Software	United States							
Phoenix Int Beteligungs GmbH	Pharmaceutical preparations	Germany	231	15/12/03	Tamro Oyj	Drugs, drug proprietaries, and druggists' sundries	Finland							
Phoenix Int Beteligungs GmbH	Pharmaceutical preparations	Germany	102	14/08/03	Tamro Oyj	Drugs, drug proprietaries, and druggists' sundries	Finland							
PLIVA dd	Pharmaceutical preparations	Croatia	212	22/06/02	Sobel USA Inc(Sobel BV)	Pharmaceutical preparations	United States							
Prestige Brands International	Perfumes, cosmetics, and other toilet preparations	United States	335	10/01/03	Abbott Laboratories-Murine	Pharmaceutical preparations	United States							
Probitas Pharma SA	Pharmaceutical preparations	Spain	149	25/09/01	SeraCare Inc	Specialty outpatient facilities, nec	United States							
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	57227	01/10/05	Gillette Co	Cutlery	United States							
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	208	03/07/04	Laboratorios Vita-Commercial	Pharmaceutical preparations	Spain							

Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	2000	30/06/04	Procter & Gamble-Hutchison Ltd	Soap & other detergents, except specialty cleaners	China
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	1214	30/06/04	Wella AG	Perfumes, cosmetics, and other toilet preparations	Germany
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	1591	10/09/03	Wella AG	Perfumes, cosmetics, and other toilet preparations	Germany
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	4530	02/09/03	Wella AG	Perfumes, cosmetics, and other toilet preparations	Germany
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	4950	16/11/01	Bristol-Myers Squibb-Clairol	Perfumes, cosmetics, and other toilet preparations	United States
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	259	08/10/99	Recovery Engineering Inc	Service industry machines, nec	United States
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	2300	01/09/99	IAMs Co	Dog, cat, and pet food	United States
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	113	17/08/99	Long Chen Paper Co Ltd-	Paper mills	Taiwan
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	375	15/04/99	Prosan(CMPC,Procter & Gamble)	Paper mills	Argentina
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	170	31/12/97	Loreta y Pena Pobre SA de CV	Paper mills	Mexico
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	169	26/11/97	Ssangyong Paper Co	Sanitary paper products	South Korea
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	1976	21/07/97	Tambrands Inc	Sanitary paper products	United States
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	220	28/06/96	Kimberly-Clark-4 Businesses	Sanitary paper products	United States
Procter & Gamble Co	Soap & other detergents, except specialty cleaners	United States	150	29/08/94	Giorgio Beverly Hills(Avon)	Perfumes, cosmetics, and other toilet preparations	United States
Procyon Biopharma Inc	Biological products, except diagnostic substances	Canada	155	21/04/03	Pharmacor Inc	In vitro and in vivo diagnostic substances	Canada
Protein Design Labs Inc	Biological products, except diagnostic substances	United States	509	24/03/05	ESP Pharma Inc	Pharmaceutical preparations	United States
Protein Design Labs Inc	Biological products, except diagnostic substances	United States	108	07/04/03	Eos Biotechnology	Pharmaceutical preparations	United States
Proteo Inc(Proteo Mkgt Inc)	Commercial physical and biological research	United States	183	25/04/02	Proteo Marketing Inc	Pharmaceutical preparations	United States
pSiVida Ltd	Pharmaceutical preparations	Australia	104	13/10/05	Control Delivery Systems Inc	Pharmaceutical preparations	United States
Qiagen NV	Biological products, except diagnostic substances	Netherlands	120	30/06/00	Operon Technologies Inc	Biological products, except diagnostic substances	United States
QLT Inc	Biological products, except diagnostic substances	Canada	734	19/11/04	Atrix Laboratories Inc	Commercial physical and biological research	United States
Recordati SpA	Pharmaceutical preparations	Italy	102	28/06/00	Bouchara SA	Pharmaceutical preparations	France
Rengo Co Ltd	Corrugated and solid fiber boxes	Japan	638	01/04/99	Settsu Corp	Paperboard mills	Japan

Revco DS Inc	Pharmaceutical preparations	United States	379	23/12/96	Big B Inc	Drug stores and proprietary stores	United States									
Revco DS Inc	Pharmaceutical preparations	United States	658	15/07/94	Hook-SupeRx Inc	Drug stores and proprietary stores	United States									
Rexall Sundown Inc	Pharmaceutical preparations	United States	108	10/01/00	MET-Rx Nutrition Inc	Medicinal chemicals and botanical products	United States									
Roche Holding AG	Pharmaceutical preparations	Switzerland	181	25/07/05	GlycArt Biotechnology AG	Biological products, except diagnostic substances	Switzerland		1			181				
Roche Holding AG	Pharmaceutical preparations	Switzerland	1254	13/02/04	IGEN International Inc	Pharmaceutical preparations	United States		1	1		1254	1254			
Roche Holding AG	Pharmaceutical preparations	Switzerland	1189	28/11/03	Disetronic Holding AG	Surgical and medical instruments and apparatus	Switzerland		1		1	1189		1189		
Roche Holding AG	Pharmaceutical preparations	Switzerland	1230	31/12/00	SmithKline Beecham PLC-Kytril	Pharmaceutical preparations	United Kingdom		1	1		1230	1230			
Roche Holding AG	Pharmaceutical preparations	Switzerland	4313	16/06/99	Genentech Inc	Biological products, except diagnostic substances	United States		1	1		4313	4313			
Roche Holding AG	Pharmaceutical preparations	Switzerland	10200	05/03/98	Corange Ltd	Pharmaceutical preparations	Bermuda		1	1		10200	10200			
Roche Holding AG	Pharmaceutical preparations	Switzerland	1100	31/03/97	Tastemaker	Industrial organic chemicals, nec	United States		1		1	1100		1100		
Roche Holding AG	Pharmaceutical preparations	Switzerland	5371	03/11/94	Syntex Corp	Pharmaceutical preparations	United States		1			5371				
Roche Holding AG	Pharmaceutical preparations	Switzerland	141	08/02/93	Fisons PLC-Australian.New	Perfumes, cosmetics, and other toilet preparations	Australia		1	1	1	141	141	141		
Hoffmann-La Roche Inc	Pharmaceutical preparations	United States	150	31/07/02	Memory Pharmaceuticals Corp-	Pharmaceutical preparations	United States		1			150				
								RocH	10	5	3	25129	17138	2430		
Roussel-Uclaf SA	Pharmaceutical preparations	France	140	04/07/95	Dow Chemical Co-Latin American	Pharmaceutical preparations	Brazil									
Roussel-Uclaf SA	Pharmaceutical preparations	France	239	11/02/94	Albert Roussel Pharma,1 other	Pharmaceutical preparations	Germany									
Salix Pharmaceuticals Ltd	Pharmaceutical preparations	United States	182	30/09/05	InKine Pharmaceutical Co	Biological products, except diagnostic substances	United States									
Sanofi-Aventis SA	Pharmaceutical preparations	France	664	12/07/05	Hoechst AG	Manmade organic fibers, except cellulosic	Germany		1	1	1	664	664	664		
Sanofi-Synthelabo SA	Pharmaceutical preparations	France	65657	20/08/04	Aventis SA	Pharmaceutical preparations	France		1			65657				
Rhone-Poulenc Rorer Inc	Pharmaceutical preparations	United States	2559	20/10/95	Fisons PLC	Pharmaceutical preparations	United Kingdom		1	1		2559	2559			
Rhone-Poulenc Rorer Inc	Pharmaceutical preparations	United States	150	13/02/95	Applied Immune Sciences Inc	Surgical and medical instruments and apparatus	United States		1		1	150		150		
Elf Sanofi SA	Pharmaceutical preparations	France	1825	03/10/94	Sterling Winthrop-Prescription	Drugs, drug proprietaries, and druggists' sundries	United States		1	1		1825	1825			
Elf Sanofi SA	Pharmaceutical preparations	France	1003	18/06/93	Yves Saint Laurent SA	Men's and boys' clothing, nec	France		1		1	1003		1003		
								Sano	6			71858				

Saturn Pharmaceuticals Inc	Pharmaceutical preparations	United States	140	01/07/05	Odyssey Pharm Inc-Sanctura	Pharmaceutical preparations	United States								
Schein Pharmaceutical Inc	Pharmaceutical preparations	United States	229	01/09/95	Marsam Pharmaceuticals Inc	Pharmaceutical preparations	United States								
Schering AG	Pharmaceutical preparations	Germany	380	16/07/02	Immunex Corp-Leukine Business	Pharmaceutical preparations	United States		1	1		380	380		
Schering AG	Pharmaceutical preparations	Germany	137	03/07/02	Collateral Therapeutics Inc	Commercial physical and biological research	United States		1	1		137	137		
Schering AG	Pharmaceutical preparations	Germany	314	02/08/96	Leiras(Huhtamaki Oy)	Biological products, except diagnostic substances	Finland		1	1		314	314		
Schering AG	Pharmaceutical preparations	Germany	336	23/07/96	Jenapharm GmbH(Gehe AG)	Medicinal chemicals and botanical products	Germany		1	1		336	336		
Schering-Plough Corp	Pharmaceutical preparations	United States	405	01/07/97	Mallinckrodt Veterinary Inc	Prepared animal feeds, except for dogs and cats	United States		1		1	405		405	
								Schr	5	4	1	1572	1167	405	
Schwarz Pharma AG	Pharmaceutical preparations	Germany	116	15/08/95	Reed & Carnrick(Block Drug Co)	Pharmaceutical preparations	United States								
Schwarz Pharma Kremers-Urban	Pharmaceutical preparations	United States	178	06/06/95	Central Pharmaceuticals	Pharmaceutical preparations	United States								
Schwarz Pharma Kremers-Urban	Pharmaceutical preparations	United States	116	06/06/95	Reed & Carnrick-Certain Assets	Pharmaceutical preparations	United States								
Serologicals Corp	Biological products, except diagnostic substances	United States	202	14/10/04	Upstate Group Inc	In vitro and in vivo diagnostic substances	United States								
Serono International SA	Biological products, except diagnostic substances	Switzerland	162	05/11/02	Genset SA	Biological products, except diagnostic substances	France								
Shanghai Indl Hldg Ltd	Offices of holding companies, nec	Hong Kong	120	05/07/00	Active Services Group Ltd	Investors, nec	Hong Kong								
Shield Diagnostics Group PLC	In vitro and in vivo diagnostic substances	United Kingdom	118	27/05/99	Axis Biochemicals AS	Medicinal chemicals and botanical products	Norway								
Shionogi & Co Ltd	Pharmaceutical preparations	Japan	120	14/01/93	Eli Lilly & Co-Capsule Bus	Pharmaceutical preparations	United States		1	1		120	120		
								Shio	1	1	0	120	120	0	
Shire Pharmaceuticals Group	Pharmaceutical preparations	United Kingdom	163	29/12/97	Richwood Pharmaceutical Co Inc	Drugs, drug proprietaries, and druggists' sundries	United States		1	1		163	163		
Shire Pharmaceuticals Group	Pharmaceutical preparations	United Kingdom	171	24/03/97	Pharmavene Inc	Pharmaceutical preparations	United States		1	1		171	171		
Shire Pharmaceuticals Grp PLC	Pharmaceutical preparations	United Kingdom	1347	28/07/05	Transkaryotic Therapies Inc	Biological products, except diagnostic substances	United States		1	1		1347	1347		
Shire Pharmaceuticals Grp PLC	Pharmaceutical preparations	United Kingdom	3782	11/05/01	BioChem Pharma Inc	Pharmaceutical preparations	Canada		1	1		3782	3782		

Shire Pharmaceuticals Grp PLC	Pharmaceutical preparations	United Kingdom	1066	23/12/99	Roberts Pharmaceutical Corp	Pharmaceutical preparations	United States		1	1		1066	1066	
								Shir	5	5	0	6528	6528	0
Sigma Co Ltd	Pharmaceutical preparations	Australia	513	02/12/05	Arrow Pharmaceuticals Ltd	Pharmaceutical preparations	Australia							
Sigma-Aldrich Corp	Chemicals and chemical preparations, nec	United States	370	01/03/05	JRH Biosciences Inc	Biological products, except diagnostic substances	United States							
Sika AG	Chemicals and chemical preparations, nec	Switzerland	458	19/12/05	Sarna Kunststoff Holding AG	Plastics materials and synthetic resins	Switzerland							
SkyePharma PLC	Pharmaceutical preparations	United Kingdom	446	03/05/96	Jago Holding AG	Offices of holding companies, nec	Switzerland							
Snia SpA	Industrial organic chemicals, nec	Italy	116	22/01/03	Centerpulse-Heart Valve Bus	Orthopedic, prosthetic, and surgical supplies	United States							
Solvay Pharmaceuticals SA	Pharmaceutical preparations	Belgium	112	21/07/99	Unimed Pharmaceuticals Inc	Pharmaceutical preparations	United States		1			112		
								Solv	1	0	0	112	0	0
Sorin Biomedica SpA	Pharmaceutical preparations	Italy	267	18/05/99	COBE Cardiovascular(CO BE Lab)	Surgical and medical instruments and apparatus	United States							
Sosei Co Ltd	Biological products, except diagnostic substances	Japan	185	30/08/05	Arakis Ltd	Pharmaceutical preparations	United Kingdom							
SRF Ltd	Synthetic rubber (vulcanizable elastomers)	India	103	28/10/96	Ceat Tyres-Nylon Tyre Cord Uni	Tire cord and fabrics	India							
STADA Arzneimittel AG	Pharmaceutical preparations	Germany	108	08/02/05	OAO Nizhpharm	Pharmaceutical preparations	Russian Fed							
Suzuken Co Ltd	Pharmaceutical preparations	Japan	160	30/07/98	Akiyama Inc	Drugs, drug proprietaries, and druggists' sundries	Japan							
Takeda Pharmaceutical Co Ltd	Pharmaceutical preparations	Japan	270	01/03/05	Syrrx Inc	Biological products, except diagnostic substances	United States		1	1		270	270	
								Take	1	1	0	270	270	0
Talecris Biotherapeutics Hldg	Pharmaceutical preparations	United States	590	01/04/05	NPS BioTherapeutics Inc	Biological products, except diagnostic substances	United States							
Terumo Corp	Laboratory analytical instruments	Japan	170	18/11/02	Vascutek Ltd(Centerpulse AG)	Orthopedic, prosthetic, and surgical supplies	United Kingdom							
Terumo Corp	Laboratory analytical instruments	Japan	110	30/06/99	3M-Cardiovascular Business	Surgical and medical instruments and apparatus	United States							
Teva Pharm Inds Ltd	Pharmaceutical preparations	Israel	3165	22/01/04	SICOR Inc	Pharmaceutical preparations	United States		1			3165		
Teva Pharm Inds Ltd	Pharmaceutical preparations	Israel	285	05/04/00	Novopharm Ltd(Dan Family Hold)	Pharmaceutical preparations	Canada		1			285		

Teva Pharm Inds Ltd	Pharmaceutical preparations	Israel	350	31/05/96	Biocraft Laboratories Inc	Pharmaceutical preparations	United States		1			350		
Teva Pharmaceutical USA Inc	Pharmaceutical preparations	United States	187	20/09/99	Copley Pharmaceutical Inc	Pharmaceutical preparations	United States		1			187		
								Teva	4	0	0	3988	0	0
UCB SA	Pharmaceutical preparations	Belgium	2473	06/07/04	Celltech Group PLC	Commercial physical and biological research	United Kingdom		1	1		2473	2473	
UCB SA	Pharmaceutical preparations	Belgium	500	31/01/03	Solutia Inc-Specialty Chem Bus	Chemicals and chemical preparations, nec	United States		1	1		500	500	
								UCB	2	2	0	2973	2973	0
Valeant Pharm Intl Inc	Pharmaceutical preparations	United States	324	01/03/05	Xcel Pharmaceuticals Inc	Pharmaceutical preparations	United States							
Versicor Inc	Biological products, except diagnostic substances	United States	153	03/03/03	Biosearch Italia SpA	Biological products, except diagnostic substances	Italy							
Vertex Pharmaceuticals Inc	Pharmaceutical preparations	United States	556	18/07/01	Aurora Biosciences Corp	Laboratory analytical instruments	United States							
VI Technologies Inc	Biological products, except diagnostic substances	United States	152	11/03/05	Panacos Pharmaceuticals Inc	Biological products, except diagnostic substances	United States							
VIMRx Pharmaceuticals Inc	Pharmaceutical preparations	United States	120	18/12/97	Baxter Healthcare Corp	Medical laboratories	United States							
ViroPharma Inc	Pharmaceutical preparations	United States	116	10/11/04	Eli Lilly-Vancocin Rights	Pharmaceutical preparations	United States							
Warner Chilcott PLC	Pharmaceutical preparations	Ireland-Rep	180	16/02/00	Bristol-Myers-Women's Prods(3)	Pharmaceutical preparations	United States							
Warner-Lambert Co	Pharmaceutical preparations	United States	2132	17/05/99	Agouron Pharmaceuticals Inc	Pharmaceutical preparations	United States							
Warner-Lambert Co	Pharmaceutical preparations	United States	1050	01/07/96	Warner Wellcome Consumer Hlth	Drugs, drug proprietaries, and druggists' sundries	United Kingdom							
Warner-Lambert Co	Pharmaceutical preparations	United States	142	22/03/93	Wilkinson Sword Group Ltd	Cutlery	United Kingdom							
Watson Pharmaceuticals Inc	Pharmaceutical preparations	United States	178	12/02/03	Novatis AG-Fiorinal Brands	Pharmaceutical preparations	United States		1			178		
Watson Pharmaceuticals Inc	Pharmaceutical preparations	United States	184	17/11/00	Makoff R&D Laboratories Inc	Pharmaceutical preparations	United States		1			184		
Watson Pharmaceuticals Inc	Pharmaceutical preparations	United States	899	28/08/00	Schein Pharmaceutical Inc	Pharmaceutical preparations	United States		1			899		
Watson Pharmaceuticals Inc	Pharmaceutical preparations	United States	297	18/01/99	TheraTech Inc	Pharmaceutical preparations	United States		1			297		

Watson Pharmaceuticals Inc	Pharmaceutical preparations	United States	131	28/02/97	Oclassen Pharmaceuticals Inc	Pharmaceutical preparations	United States		1			131				
Watson Pharmaceuticals Inc	Pharmaceutical preparations	United States	571	17/07/95	Circa Pharmaceuticals Inc	Pharmaceutical preparations	United States		1			571				
								Wats	6	0	0	2259	0	0		
Welfide Corp	Pharmaceutical preparations	Japan	1207	01/10/01	Mitsubishi-Tokyo Pharmaceutica	Pharmaceutical preparations	Japan									
Whittaker Corp	Pharmaceutical preparations	United States	118	10/04/96	Xyplex Inc(Raytheon Co)	Computer terminals	United States									
Xanodyne Pharmaceuticals Inc	Pharmaceutical preparations	United States	209	25/07/05	aaiPharma Inc-Pharm Division	Biological products, except diagnostic substances	United States									
Yamanouchi Pharmaceutical Co	Pharmaceutical preparations	Japan	7223	01/04/05	Fujisawa Pharmaceutical Co Ltd	Pharmaceutical preparations	Japan									
Yoshitomi Pharmaceutical Inds	Pharmaceutical preparations	Japan	1010	01/04/98	Green Cross Corp	Biological products, except diagnostic substances	Japan									
Zentiva NV	Pharmaceutical preparations	Czech Republic	102	12/10/05	Venoma Holdings Ltd	Investors, nec	Romania									