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

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# Acknowledgements

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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<br>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

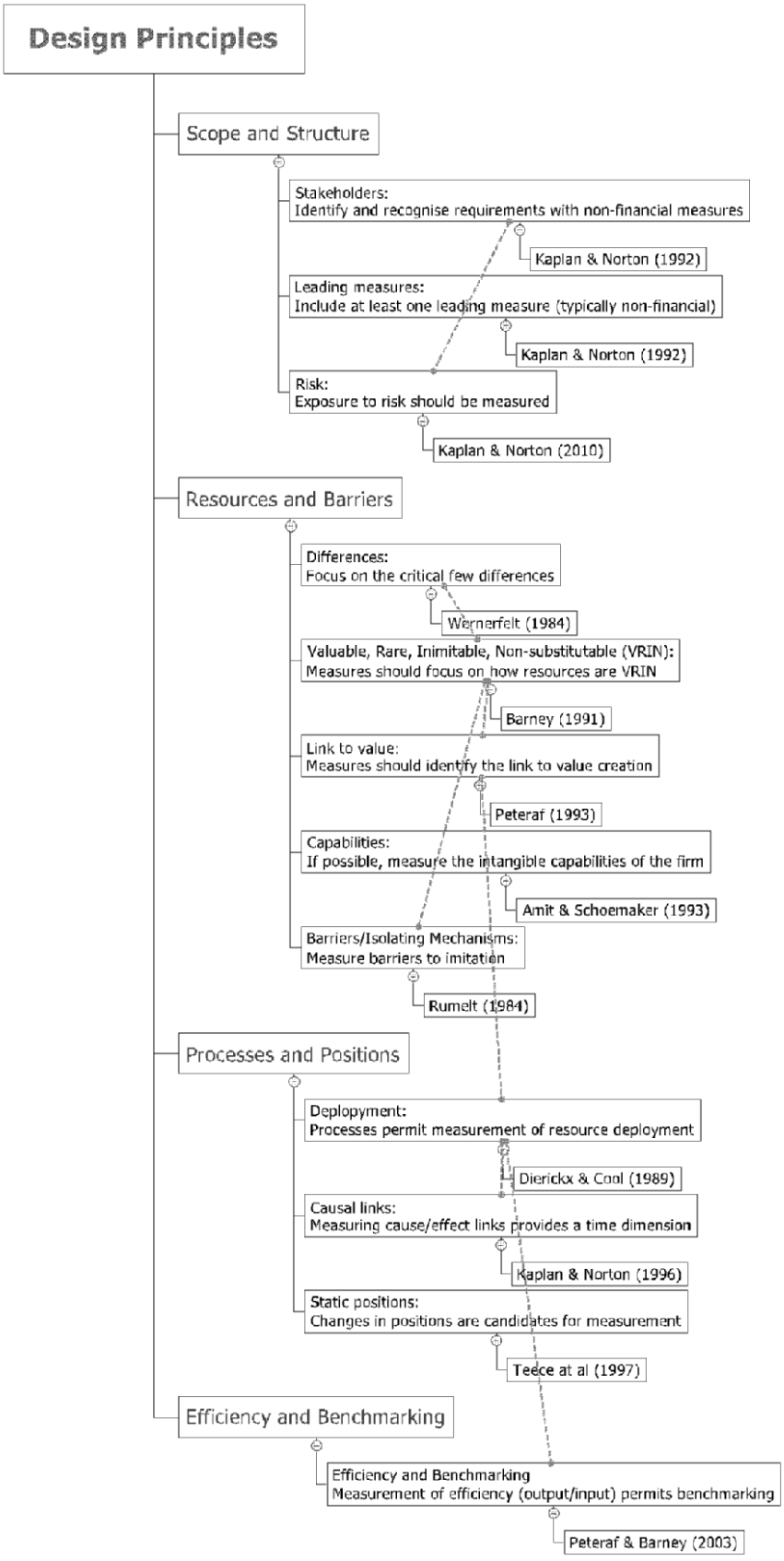
| *Category* | *No.* | *Principle* | *Ref.* |
|---|---|---|---|
| *Scope and Structure* | | | |
| Stakeholders | 1 | Recognise requirements of major stakeholders of the firm (e.g. the firm's owner and customers) with non-financial measures. | (i) |
| Leading measures | 2 | Include at least one leading 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<br>►Earning per Share<br>►Litigation liability (-ve) | ►Market share by therapeutic category<br>►Future loss of sales to therapeutic substitutes (-ve)<br>►Future loss of sales to expiring patents (-ve) | ►Research employees as % total<br>►Value added per employee<br>►Employee turnover (-ve) | ►# compounds in pipeline, by stage<br>►# clinical trials in pipeline, by stage<br>►R&D/Sales<br>►Marketing/Sales<br>►Attrition rates in pipeline (-ve) | ► Patent life lost to submission process (-ve)<br>► # adverse drug reports (-ve)<br>► # 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<br>• Training compliance rate<br>• Successful job rotation | • Audit recommendation<br>• Implementation score<br>• Information sharing score | • Business improvement rate<br>• Management satisfaction rate<br>• External rating score | • Risk management score<br>• Expense spending control<br>• Performance score<br>• 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 |
| $\eta_k$ | Relative technical output efficiency of each DMU (CRS) | Technical output efficiency score for each firm from CRS model | 48 |
| $\theta_k$ | 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 $\theta_k$ | 1 |
| $b_l$ | MCT of $b_k$ for those DMUs with below-median $\theta_k$ | 1 |
| $c_l$ | MCT of $c_k$ for those DMUs with below-median $\theta_k$ | 1 |
| $a_h$ | MCT of $a_k$ for those DMUs with above-median $\theta_k$ | 1 |
| $b_h$ | MCT of $b_k$ for those DMUs with above-median $\theta_k$ | 1 |
| $c_h$ | MCT of $c_k$ for those DMUs with above-median $\theta_k$ | 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 $\theta_k$ | 1 |
| $Var(b)_l$ | Variance of $b_k$ for those DMUs with below-median $\theta_k$ | 1 |
| $Var(c)_l$ | Variance of $c_k$ for those DMUs with below-median $\theta_k$ | 1 |
| $Var(a)_h$ | Variance of $a_k$ for those DMUs with above-median $\theta_k$ | 1 |

| | | |
|---|---|---|
| $Var(b)_h$ | Variance of $b_k$ for those DMUs with above-median $\theta_k$ | 1 |
| $Var(c)_h$ | Variance of $c_k$ for those DMUs with above-median $\theta_k$ | 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* |
|---|---|
| $\mu_l$ | Mean of below-median group |
| $\mu_h$ | Mean of above-median group |
| $\sigma_l^2$ | Variance of below-median group |
| $\sigma_h^2$ | Variance of above-median group |
| $\pi_l$ | Number in below-median group |
| $\pi_h$ | 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, $\eta_0$. 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, $\theta_k$. 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<br><br>*or*<br><br>Acquirer Ultimate Parent Primary NAIC (Code) | Medicinal and Botanical Manufacturing<br><br>Pharmaceutical Preparation Manufacturing<br><br>In-Vitro Diagnostic Substance Manufacturing<br><br>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), $\mu_l$ to $\mu_h$ were set equal to $w_l$ and $w_h$ respectively and the variances $\sigma_l^2$ and $\sigma_h^2$ 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 $\theta_k$, for k = 1 … n was used to divide the firms into two subgroups with lower-median and upper-

median values of $\theta_k$. 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 $\mu_l$ was set equal to $a_l$, $b_l$, $c_l$;
- the value of $\mu_h$ was set equal to $a_h$, $b_h$, $c_h$;
- the variance $\sigma_l^2$ and were set equal to $Var(a)_l$, $Var(b)_l$, and $Var(c)_l$;
- the variance $\sigma_h^2$ 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)

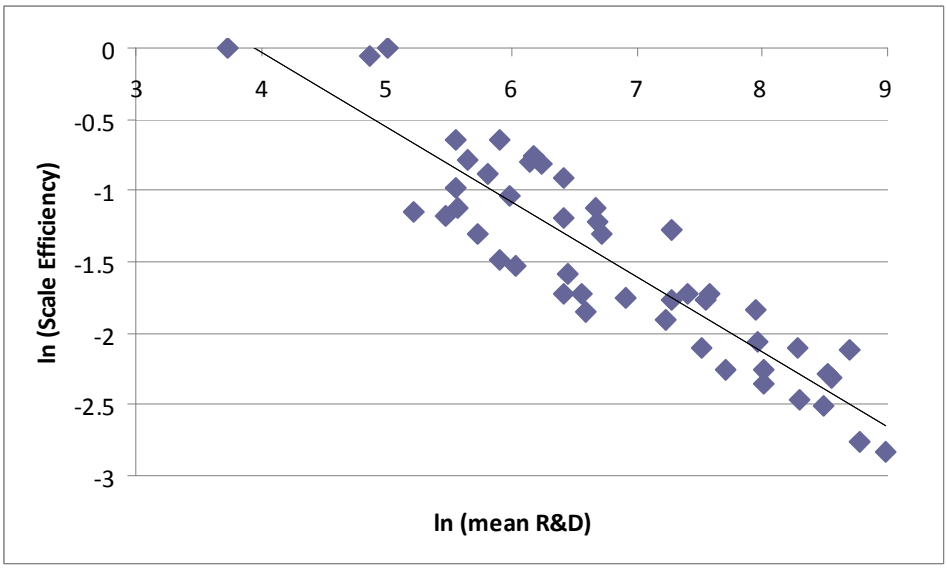
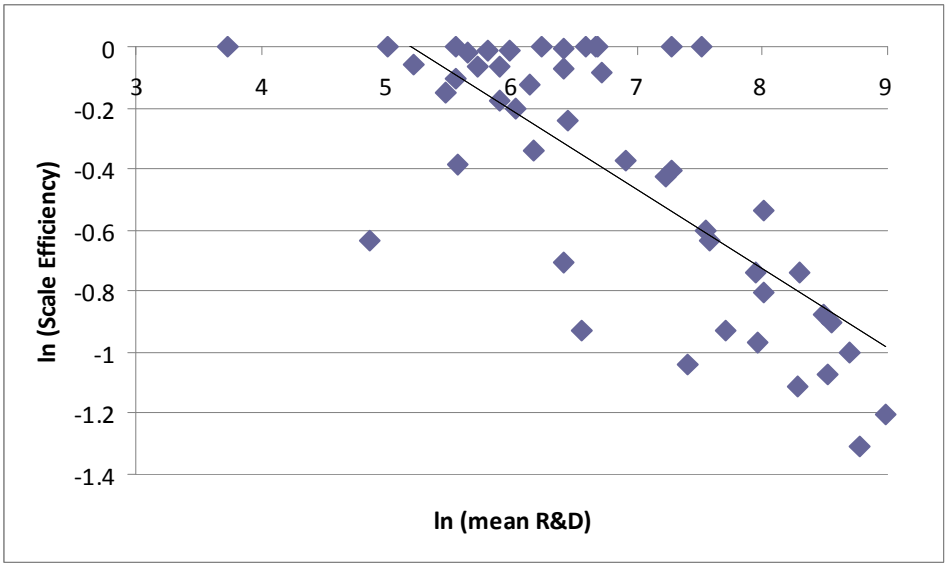



Figure 6.2 shows an equivalent graph but with the number of trials as an output. The linear relationship is still apparent but the degree of scatter is higher. This could imply that there are fewer exogenous influences on production when the output of the R&D processes is taken to be the number of compounds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

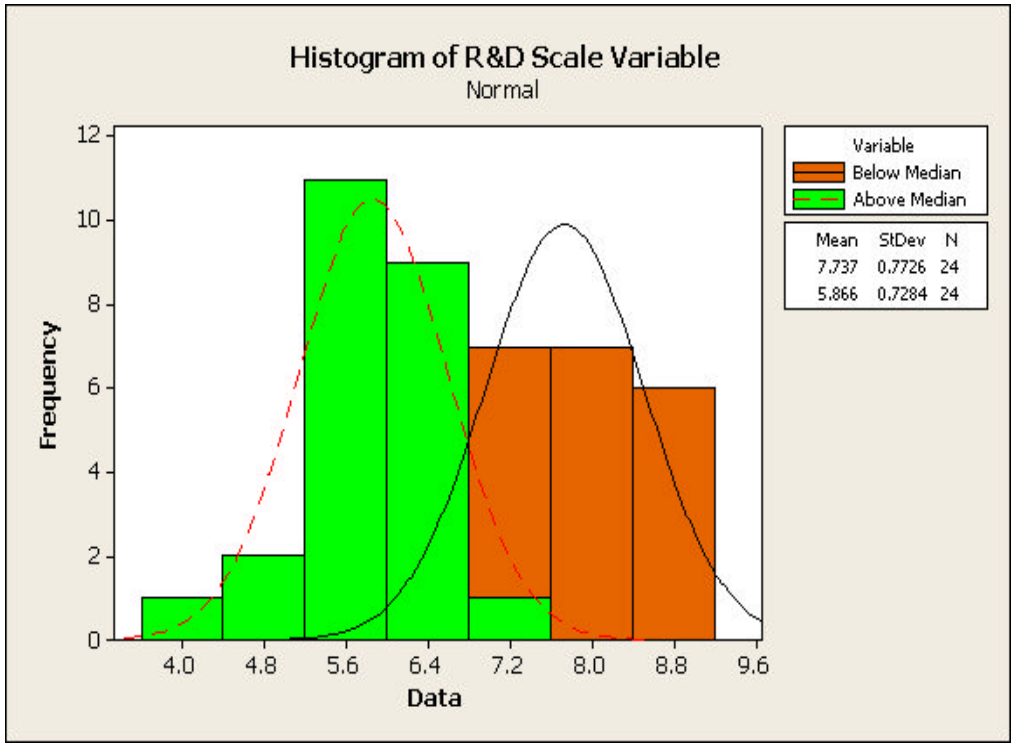
Figure 6.2 Graph of Scale Efficiency Versus Mean R&D (Trials as Output)



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



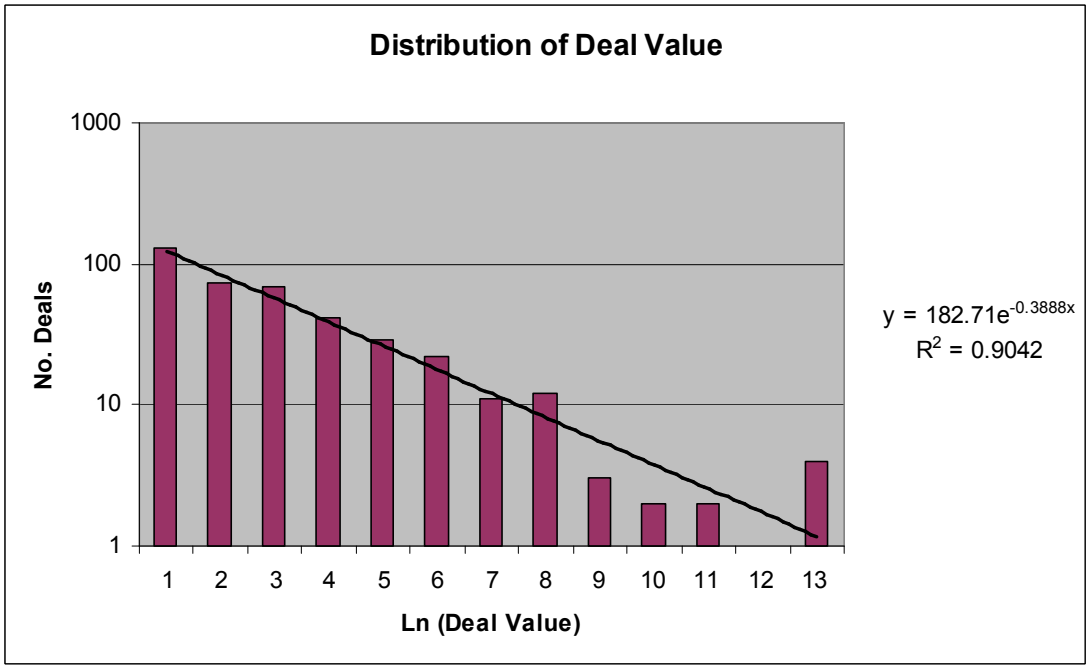

Visually it is apparent that the subgroups have markedly different distributions however formal hypothesis testing is problematic. The subgroup with below-median scale efficiency does not have a normal distribution and therefore the assumptions of the Welch test, which requires normally distributed data,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

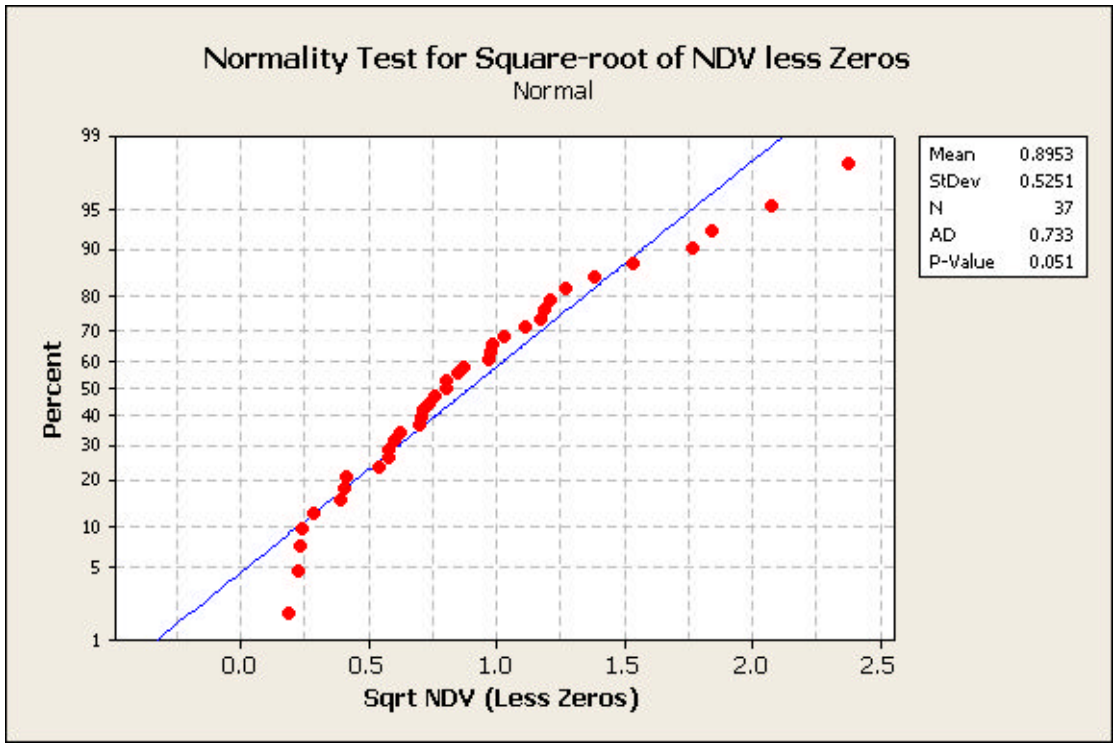
NDV has been used as a measure of acquisition history for the individual firm and the distribution of this parameter was also examined. Park et al. (2010) note that when examining acquisition frequency a Poisson distribution is commonly assumed, and given acquisitions are discrete events this is not 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. | $a_k$ $\theta_k$ <M | $a_k$ $\theta_k$ >M | $b_k$ $\theta_k$ <M | $b_k$ $\theta_k$ >M | $c_k$ $\theta_k$ <M | $c_k$ $\theta_k$ >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. | $a'_k$ $\theta_k$ <M | $a'_k$ $\theta_k$ >M | $b'_k$ $\theta_k$ <M | $b'_k$ $\theta_k$ >M | $c'_k$ $\theta_k$ <M | $c'_k$ $\theta_k$ >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.

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# 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 | $\eta_k$ | $\theta_k$ | $e_k$ | $\ln(e_k)$ | $\ln((x_{1k}+x_{2k})/2)$ |
|---|---|---|---|---|---|
| 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 | $\eta_k$ | $\theta_k$ | $e_k$ | $\ln(e_k)$ | $\ln((x_{1k}+x_{2k})/2)$ |
|---|---|---|---|---|---|
| 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

| | $\eta_k$ | $\eta_k$ |
|---|---|---|
| Firm | Input:<br>R&D Only | Input:<br>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 | $a_k$ $\theta_k$ <M | $a_k$ $\theta_k$ >M | $b_k$ $\theta_k$ <M | $b_k$ $\theta_k$ >M | $c_k$ $\theta_k$ <M | $c_k$ $\theta_k$ >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 | $a_k$ $\theta_k$ <M | $a_k$ $\theta_k$ >M | $b_k$ $\theta_k$ <M | $b_k$ $\theta_k$ >M | $c_k$ $\theta_k$ <M | $c_k$ $\theta_k$ >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 | $A_k$ $\theta_k$ <M | $A_k$ $\theta_k$ >M | $B_k$ $\theta_k$ <M | $B_k$ $\theta_k$ >M | $C_k$ $\theta_k$ <M | $C_k$ $\theta_k$ >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<br>Pharmaceutical Preparation Manufacturing<br>In-Vitro Diagnostic Substance Manufacturing<br>Biological Product (except Diagnostic) Manufacturing | 13500 |
| Acquirer Ultimate Parent Primary NAIC (Code) | Include | Medicinal and Botanical Manufacturing<br>Pharmaceutical Preparation Manufacturing<br>In-Vitro Diagnostic Substance Manufacturing<br>Biological Product (except Diagnostic) Manufacturing | 8906 |
| Logical Set | | Request # 2<br>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 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | | | | | | | | | |

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| 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 | | | | | | | | |

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| 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 | | |

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| 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 | | | | | | | | | |

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| 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 | | | | | | | |

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| 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 | |

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| 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 |

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| | | | | | | **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 |

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| 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 | | | | | | | | | |

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| 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 | | | | | | | | |

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| 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 | | | | | | | | | |

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| 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 |

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| 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 | | | | | | | | |

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| 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 | | |

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| 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 | | | | | | | |

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| 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 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | | | | | | | | | |