Hedonistic pricing models and the valuation of intangible assets

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Hedonic pricing models and the valuation of intangible assets

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Abstract

This thesis investigates the use of hedonic pricing models to value intangible assets that are owned by firms. This novel approach falls within the neoclassical methodology for the valuation of financial assets, and extends the framework by offering an alternative methods by which assets may be compared. The firms performance, as measured by reported financial data and embodied in the DuPont ratios of the firm, is used to derive the characteristics of intangible assets. The shadow prices of these characteristics are estimated and used to derive a market-related value for the intangible assets. The empirical results support using this approach to value intangible assets.

Key words: intangible assets, hedonic pricing models, DuPont ratios.
Acknowledgment

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The Late Dr. Sydney Houston (Hugh) High, colleague, friend and mentor, who got me started in the first place.

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Declaration

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma in any university or equivalent institution, and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Michael B. Cohen
Preface

Material in this thesis has been used in the preparation of the following:

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Chapter 1

Introduction

1.1 Background to the research

The terms ‘the new economy’ and ‘intangible assets’ are closely linked. Intangible assets have become increasingly important to the continued growth of the modern economy and the welfare of its citizens. As a result economic theory has been adapted to better reflect the new composition of the capital stock of the modern economy.

Intangible assets may occur in both the realms of public goods (for example: education and legal infrastructure); as well as private goods (for example: knowledge assets and human capital). The methods of economic and managerial analysis that were successfully applied to economies dominated by physical assets are often sub-optimal when applied to the new economies. This study investigates one aspect of economic theory that may be adapted to better cater for the increasing importance of intangible assets: the valuation of intangible assets held by private firms.

The ability of firms and individuals to value intangible assets correctly is important if economic efficiency is to be achieved. If intangible assets are incorrectly valued then either over- or under-investment is likely, both conditions which would lead
Chapter 1. Introduction

to a mis-allocation of scarce resources. In the case of publicly listed firms there is the additional problem of informing the shareholders of the nature and value of the intangible assets that the firm owns.

Fortunately the tools for solving the problem are readily at hand. Both the Classical and Institutional Schools of economics explicitly incorporated intangible assets, and the development of the hedonic pricing model allow for the valuation of the characteristics of goods within a neoclassical model of the economy. The considerable amount of data relating the price and financial characteristics of publicly listed firms makes it possible to investigate the application of an hedonic pricing model as a means of deriving the value of intangible assets that are held by firms.

1.2 The research problem

The purpose of this thesis is to investigate if:

1. the value of intangible assets, embedded within firms whose equity is traded on stock markets, can be extracted from the market price of such firms via an hedonic pricing model, and

2. the values obtained from the hedonic pricing model can be used to value specific intangible assets of firms.

This study is able to offer an affirmative (albeit tentative) answer to both these questions.

An outline of the approach taken in the thesis is depicted in Figure 1.1. Firstly the the nature and scope of intangible assets are examined. Intangible assets are treated somewhat differently in the economic, financial, management and accounting literatures. These literatures each emphasize different qualities of intangible assets.
Chapter 1. Introduction

The influence of intangible assets on the characteristics of firms is then examined, with special emphasis on the DuPont ratios which are used as an measure of the characteristics of firms which employ intangible assets.

Secondly, the economic theory that forms the foundation of much of modern financial theory is examined. The neoclassical theory of choice describes the setting within which the demand for financial assets originates. The implementation of neoclassical models has however often been problematic; and hedonic pricing models have been one of many attempts to improve the empirical usefulness of the neoclassical approach. The close fit between hedonic models and financial assets is described, and the use of DuPont ratios as a measure for the characteristics of the hedonic model is posited. Once the characteristics are measured, shadow prices for the characteristics can be estimated.

The value of an intangible asset is then estimated in the following manner: given both the magnitude of the expected effects of an intangible asset on the performance of a firm, and the shadow prices (market valuation) of those effects, the value of the assets is simply the sum of the products of the performance benefits and the market value of those benefits. If shadow prices can be estimated they would apply to all intangible assets that confer those characteristics, including those intangible assets owned by non-listed firms.

1.3 Justification for the research

There are important gaps in the theory and practice of the valuation of intangible assets. Resolving these deficiencies leads to greater economic efficiency as well as improved profitability of firms which manage large quantities of intangible assets.
Chapter 1. Introduction

Neoclassic theory of choice
- Financial assets
- Hedonic pricing models
- Valuation of financial assets
- Value of characteristics
- DuPont ratios

Intangible assets
- Nature & scope

Change in characteristics
- DuPont ratios

Value of intangible asset
- (change in characteristics) \( \times \) (value of characteristics)

Figure 1.1: Outline of the research process

The major steps in the research process that lead to the valuation of intangible assets held by firms. The nature and scope of intangible assets and the manner in which intangible assets change the financial performance of the firm, together with an hedonic pricing model (based on neoclassical foundations) combine to form a model that allows for the value of intangible assets to be calculated.

Source: Analysis by author
1.3.1 Importance of intangible assets in the modern economy

The importance of intangible assets in the modern economy is well documented. Intangible assets owned by US firms are estimated to be approximately \( \frac{1}{3} \) of the value of all US corporate assets, and the total investment in intangible assets in the American economy alone was in the region of US$1 trillion p.a. in 2001 (Nakamura 2001).

1.3.2 Existing valuation models are not always suitable for intangible assets

Traditional valuation models can, in some circumstances, be successfully applied to intangible assets. As will be shown in Chapter 2, characteristics such as non-transferability and imperfect property rights are the major factors that cause difficulty in the valuation of this class of assets.

Hedonic pricing models, while well known in some areas of economic research, have not previously been applied to the valuation of intangible assets. This is unfortunate for two reasons: firstly, intangible assets often meet the assumptions of the hedonic model very closely, and secondly hedonic models are implicitly used in the value of many financial assets and especially in the valuation of equities.

The approach proposed in this thesis provides a novel adaptation of the neoclassical framework in order to provide a method by which intangible assets owned by firms can be valued.
1.3.3 The correct valuation of intangible assets owned by firms is important for the efficient operation of the economic system

Internal management of the firm

Firms need to be able to value intangible assets in order to undertake internal management tasks: investment in new intangible assets, licensing of intangible assets, and effective communication with shareholders will all require some method of valuation.

Transactions between firms

External transactions between firms and other parties often involve intangible assets. Raising finance, joint ventures with other parties that involve intangible assets, and acquiring or licensing intellectual property all require valuation of the relevant assets.

Management of investment portfolios, competition policy and reporting requirements

Third parties may also need to be able to value intangible assets; portfolio managers and potential mergers and takeover activity require valuations. In additional reporting to government agencies, both revenue (for the correct depreciation of intangible assets which have been capitalised) and competition authorities (to assess the relative size of the largest firms in the market), may require the firms intangible assets to be objectively valued.
1.4 Methodology

Financial theory is firmly based on the principles of neoclassical economics. The value of any economic good is determined by the interaction of supply and demand, and where an efficient market exists value will be identical to the market price. Efficient markets give rise to the notion of the ‘Law of One Price’;

‘The Law of One price states that identical goods (or securities) should sell for identical prices. In financial markets the law of one price is thought to hold almost exactly, and is the basis for much of financial economic theory.’ (Lamont & Thaler 2003, p.191)

The method of valuation of an asset depends on the type of market in which the asset is traded and the characteristics of the asset to be valued. Table 1.1 illustrates how the valuation process is adapted to accommodate differing asset and market conditions.

Homogeneous assets traded in an active market are valued with reference to the market price. For example many currencies, metals and derivative products are valued by reference to the current market price for the particular asset. This process is usually referred to as ‘mark-to-market’.

Differentiated assets that are traded in active markets can be valued by reference to a group of other similar assets for which a recent market price are available. Each diamond is to some extent unique, but it is possible to value most diamonds very accurately by reference to the size, colour, clarity and other characteristics of the gemstone in question. Similarly houses can be valued in relationship to their characteristics (location, size, amenities, . . . ), and firms are sometimes valued in terms of expected cash flows and risk. Each of these valuation models can be recast into the form of an hedonic pricing model.
<table>
<thead>
<tr>
<th>Type of asset and market conditions</th>
<th>Example</th>
<th>Characteristic</th>
<th>Model</th>
<th>Valuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homogeneous asset, active market</td>
<td>gold, coal</td>
<td>not required</td>
<td>Law of One Price</td>
<td>current market price</td>
</tr>
<tr>
<td>Differentiated asset, active market</td>
<td>diamonds</td>
<td>size, clarity, colour, ...</td>
<td>Hedonic, n characteristics</td>
<td>$V = \sum_i x_i p_i$</td>
</tr>
<tr>
<td></td>
<td>houses</td>
<td>location, size, finishes, amenities, ...</td>
<td>ditto</td>
<td>ditto</td>
</tr>
<tr>
<td></td>
<td>firms</td>
<td>expected cash flow, risk</td>
<td>Hedonic, 2 characteristics</td>
<td>$V = DCF$</td>
</tr>
<tr>
<td>Intangible asset, non-tradable</td>
<td>core competence</td>
<td>enhanced performance of the firm</td>
<td>Hedonic, n characteristics (measured by financial ratios)</td>
<td>$V = \Delta$ value of the firm</td>
</tr>
</tbody>
</table>

Table 1.1: Valuation methodologies

The method of valuation is dependent on the type of market in which the asset is traded and the characteristics of the asset to be valued. Homogeneous assets traded in an active market are valued with reference to the market price. Differentiated assets that are traded in active markets can be valued by the use of hedonic pricing models. Intangible assets can be valued via hedonic models by treating the enhanced performance of the firm as a characteristic of the intangible asset and discovering the shadow price of the characteristic. Further details of the various valuation methodologies are given in the text.

Source: Analysis by author.
Chapter 1. Introduction

Intangible assets owned by firms can similarly be conceived in terms of an hedonic pricing model. In this case the characteristics of the assets are not physical (as in diamonds or houses) but rather indirect. In this thesis the characteristics of intangible assets owned by the firm are conceived of as improvements to the financial performance of the firm. Given this novel manner of viewing the characteristics of intangible assets, the application of an hedonic pricing model to value these assets is then straightforward.

This approach is not dissimilar to that of valuing a firm using the expected net cash flow and risk; in this case the cash flow and risk can be seen as the characteristics of the firm itself. Where an intangible asset (rather than the entire firm) is to be valued, only the characteristics of the intangible asset should be considered. These characteristics can be conceived of as the effects of the asset on the firm, which are captured by one or more measures of overall productivity of the firm.

This is the first study to adopt this novel approach to the problem of valuing intangible assets, but it follows in the tradition of all financial valuations; establish a relationship between the asset to be valued and a set of ‘similar’ assets for which a recent market valuation is available. In the case at hand the method of finding similar assets is to gauge the effect of the asset on the performance of the firm which owns the asset. This thesis examines whether the problems inherent in implementing this approach can be successfully dealt with.

1.5 Outline of the thesis

The second chapter of the thesis discusses the most important characteristics of intangible assets, and how they are defined in the legal, accountancy and economic literatures. The importance of intangible assets in both the public and private sectors of the economy is also documented. Having established the nature and importance
of intangible assets, the chapter then examines how the various schools of economic thought have dealt with intangible assets. Emphasis is given to the Austrian School, the American Institutionalists, and neoclassical growth models. The managerial literature also deals with intangible assets, therefore this literature is reviewed and the importance of the valuation of intangible assets for the efficient management of a firm is discussed. The various methods for the valuation of intangible assets that have been proposed in the management literature are then evaluated.

The effect of intangible assets on the efficiency of the firm will later form the basis for the use of hedonic pricing models. The second chapter therefore concludes with a discussion of how under current accounting principles intangible assets affect the financial reporting of the firm and the influence of these accounting statements on the market value of the firm. The DuPont system of analysis is suggested as a method whereby the influence of intangible assets owned by a firm can be consistently observed. Chapter 2 concludes with a critical discussion of the use of DuPont system as a means of measuring the characteristics of intangible assets.

The third chapter discusses the neoclassical foundations for the pricing of goods in general and of financial assets in particular. The hedonic pricing model incorporates the neoclassical model as a special case and this model is discussed in detail. Examples of the application of the hedonic model are examined and the lack of the explicit application of this model to financial assets is noted.

The methods of estimating the prices of financial assets, and especially equities, has undergone significant change over the last 60 years. The contributions of Benjamin Graham and Harry Markowitz are discussed, as well as the evolution of modern portfolio theory and the capital asset pricing model. The importance of multi-factor models and the practical importance of the Fama-French studies is then discussed in detail. Chapter three concludes with a discussion of how the modern models of
equity valuation can be placed in the form of an hedonic pricing model. It is argued that this is not only a cosmetic change, but that this reformulation allows the full strength of hedonic models to be explicitly evoked and justifies the use of hedonic models to price the intangible assets that are held by publicly listed firms.

The fourth chapter critically examines the various methods that could be used to value intangible assets, and argues that the hedonic pricing model is in general superior to the alternative methods. In order to apply the hedonic pricing model the characteristics of the asset need to be quantified, but the characteristics of intangible assets are however not directly observable. The relevant characteristics can however be estimated by observing the increase in the financial performance of the firm that employs such assets. The evolving XBRL implementation is discussed, and the possibility that this standard will make the specification of the characteristics of the firm a central feature of equity finance is investigated. DuPont ratios are employed as an initial method for measuring the characteristics of firm performance that are related to the presence of intangible assets. A structural form of the hedonic model is developed to test the use of these characteristics, and a suitable set of null hypotheses are suggested which can be used to test the efficacy of the model.

Chapter Five develops an empirical model and discusses the results. Data for American firms over a six year period is analysed. The DuPont ratios for each firm are used to measure the characteristics of the intangible assets that a firm possesses. Firms are combined into portfolios that differ only in respect to the quantity of the characteristic that is being examined, and the returns of the portfolios are compared to identify the possible effect of that characteristic. Some of the characteristics of intangible assets are found to be statistically significant in explaining the returns on these portfolios.

The final chapter describes the conclusions that were reached about the research
issues, and the implications for further research that flow from this study.

1.6 Delimitations of scope and key assumptions

The research is positivist in nature and is placed within a framework of neoclassical economics. This conforms to the usual paradigm of mainstream financial theory.

The model that is developed is only applicable to intangible assets that are held by firms and used as productive resources. Public and personal intangible assets are thus excluded from this analysis. In addition the model is developed to value the broadest range of intangible assets, and is probably inefficient at valuing very specific intangible assets for which more idiosyncratic models may well be superior. Such specific models usually require very detailed knowledge of the firm, the technology and many other factors; where this information is available these models should be considered. However the method proposed in this thesis is well suited to situations when the intangible assets can not be well defined, which forms a very large set of all intangible assets.

Other limitations of the study centre around the data used to estimate the model. Data of American firms over a six year period is analysed. Portfolios are formed at yearly intervals, and monthly portfolio returns are used to investigate the possible effects of differences in characteristics between the portfolios. The primary objective of the thesis is to validate the method rather than to calibrate a model. More extensive data (longer data windows, and alternative economies) would result in better calibrations, but are not necessary to validate the model.

1.7 Conclusion

This chapter has introduced the research problem; to investigate if
Chapter 1. Introduction

1. the value of intangible assets, embedded within firms whose equity is traded on stock markets, can be extracted from the market price of such firms via an hedonic pricing model, and

2. the values obtained from the hedonic pricing model can be used to value specific intangible assets of firms.

This problem is important both because of the rapid growth in intangible assets in the modern economy, and the efficient use of scarce economic resources by firms.

The proposed methodology extends the existing neoclassical model found in finance by incorporating an hedonic approach: intangible assets are viewed as bundles of characteristics that improve a firms performance.

The following chapters of the thesis present a detailed description of the research described in this introduction.
Chapter 2

Research issues in the treatment of intangible assets

2.1 Introduction

In order to value intangible assets it is first necessary to define the precise nature and characteristics of this class of asset. Economics, accountancy, finance, and management theory each emphasize different aspects, or characteristics, of intangible assets. These different approaches are discussed in this chapter, and a working description of an intangible asset is formulated.

Once intangible assets have been clearly defined, the magnitude of intangible assets in the modern economy is documented. Intangible assets are important in both the social capital of a society and as a component of a firm's capital structure. Studies show that intangible assets are not only large in absolute magnitude (over one-third of the capital of American firms), but their importance has been growing rapidly over the last two decades.

A review of the economic literature indicates important differences in the treatment of intangible assets. While the Classical School of economics dealt with intangible assets explicitly, the rise of the Neoclassical School resulted in intangible assets
being amalgamated with other assets into a homogeneous group. The important exceptions (notably the Austrian School and the American Institutionalists) are often on the sidelines of contemporary mainstream economic theory. However the advent of the ‘New Economy’ has firmly shifted the spotlight back toward economic theory that explicitly incorporates intangible assets.

In contrast to the economics literature, management theory has steadfastly refused to ignore the importance of intangible assets. A study of the resulting literature reveals that solutions to managerial concerns are however mostly ad hoc and specific to time and place. Never-the-less this literature greatly increases our understanding of intangible assets.

Intangible assets change the characteristics of firms that employ such assets. The final section of this chapter examines how intangible assets affect the financial performance of a firm and how this change in performance is reflected in the financial accounts of the firm.

This survey of the treatment of intangible assets forms the background to applying hedonic pricing techniques to intangible assets; which is the subject of the following chapter.

### 2.2 The nature of intangible assets

If tangible and intangible assets were similar in all respects then the relative size of either would be of little interest. Economists, accountants, lawyers, and management theorists have recently begun to explain how these two groups of assets differ from each other. As Michael H. Armacost in the foreword to an influential work by Baruch Lev states:

‘While economists, business people, and policy analysts continue to
debate the question of what is “new” about the so-called “New Economy”, one important feature of modern economies in the early twenty-first century seems clear: intangible factors are playing an increasingly dominant role in wealth creation. A growing share of economic activity today consists of exchanges of ideas, information, expertise, and services. Corporate profitability is often driven more by organizational capabilities than by control over physical resources, and even the value of physical goods is often due to such intangibles as technical innovations embodied in the products, brand appeal, creative presentation, or artistic content.’ (Lev 2001, p.vii)

Rapid changes in technology over the last few decades have been one of the sources of structural change in modern economies. In order to analyse the New Economy measurements of the changes in the economy are necessary, however data has not been easily available. In his 1994 presidential address to the American Economic Association, Zvi Griliches, who has undertaken considerable work in an attempt to understand economic growth, states the matter thus:

‘I will concentrate primarily on the R&D component of this story - not because it can explain much of the productivity slowdown (it can not), . . . but because it illustrates rather well the major point I want to make here tonight: that our understanding of what is happening in our economy (and the world economy) is constrained by the extent and quality of the available data.’ (Griliches 1994, p.2)

The reason for this difficulty is not hard to find. Griliches points out that:

‘What is it about the recent situation that has made matters worse? The brief answer is that the economy has changed and that our data-collection efforts have not kept pace with it. “Real” national income
accounts were designed in an earlier era, when the economy was simpler and had a large agricultural sector and a growing manufacturing sector. ...

... By 1990, however, the fraction of the economy for which the productivity numbers are half reasonable had fallen to below one-third. ... Our ability to interpret changes in aggregate total factor productivity has declined, and major portions of actual technical change have eluded our measurement framework entirely.’ (Griliches 1994, p.10)

To reinforce the notion that the distinction between intangible assets and other forms of productive capacity is not trivial, consider the following summary of the proceedings of a conference on Research in Income and Wealth conducted by the National Bureau of Economic Research in 2002:

‘Not surprisingly, no overall consensus emerged from the conference. Because capital measurement issues are difficult and the debate is ongoing, this lack of consensus is consistent with the conference tradition. The statistical, research, and policy communities will be grappling with the difficult issues in measuring capital for some time to come - and the problems associated with defining and measuring intangible assets and measuring high-tech capital will be at or near the top of the list.’ (Corrado et al. 2005, p.8)

Most people have an informal notion of the characteristics of ‘intangible assets’. In general it is not difficult to correctly classify actual examples of assets as either tangible or intangible. However such notions are seldom complete and exhaustive, and there is no method for dealing with assets which contain characteristics of both groups. In order to model the effects of intangible assets, and subsequently to be able to value them, it is necessary to clearly identify intangible assets. This presents a possible philosophical dilemma, which is stated by Auguste Comte as follows:
Chapter 2. Research issues in the treatment of intangible assets

‘If it is true that every theory must be based upon observed facts, it is equally true that facts can not be observed without the guidance of some theory. Without such guidance, our facts would be desultory and fruitless; we could not retain them: for the most part we could not even perceive them.’ (Comte 2003, p.27)

The discussion of intangible assets (the ‘observed facts’ in the quotation by Comte) must be contained within some pre-existing theory or framework, however implicit that theory might be. It is not surprising that the various disciplines have defined intangible assets somewhat differently. These definitions are discussed in the context of the underlying theory in more detail below.

2.2.1 Law

Pre-eminent in the analysis of legal systems is the concept of property rights. Without the ability of individuals to hold property securely, enjoy the benefits of that property, and be able to transfer ownership to another, much of Western society would cease to exist. Intangible assets differ from other assets partly due to the extent that intangible assets have limitations with regard to security and transferability of ownership. A number of different forms of intangible asset are recognized explicitly within the legal system, the most important of these forms are:

**Patents.** A patent can be defined as:

> ‘an exclusive right of limited duration over a new, non-obvious invention capable of practical application. There are four categories of inventions protected by utility patents: processes, machines, manufactures, and compositions of matter. . . . new technologies seemingly distinct from these definitions have been rationalized into these four classifications. Software, for example, has been patented as either
virtual machines or processes.’ (Merrill 2004, p.143)

Patents have been used in Italy from as early as the mid-fifteenth century. Today patent laws are considered to be important enough that the European Commission conducted a study into the value of patents for the European economy (Ceccagnoli et al. 2005).

Copyright. Copyright and the authors right are designed to protect the rights of both literary and artistic works. Depending on the country in which protection is being sought, there are vastly differing traditions in the law of copyright (which is based on the common law in the UK and former colonies, and on civil law in the European continent and associated former colonies). The Berne Convention (1886) has resulted in homogeneous rules for most countries. The objective of copyright rules are clear:

‘... the purpose of copyright is to stimulate production of the widest possible variety of creative goods at the lowest possible price.’

(Goldstein 2001, p.3)

Trademarks. Trademarks and brands are some of the most valuable of all intangible assets held by firms today. The legal definition of these assets is very broad:

‘Technically speaking, a trademark is any word, design, slogan, sound, or symbol (including non-functional unique packaging) that serves to identify a specific product brand for instance, Xerox (a name for a brand of photocopiers), Just Do It (a slogan for a brand of sport shoes and sportswear), Apple’s rainbow apple with a bite missing (a symbol for a brand of computers), the name Coca-Cola in red cursive lettering (a logo for a brand of soft drink). ’ (Elias
Trade Secrets. There is no specific law that deals with trade secrets, but they are of great importance to many firms. A commonly accepted definition of Trade Secrets is:

‘any information (including a formula, pattern, compilation, program, device, method, technique, or process) that derives independent economic value, whether actual or potential, from not being known to the public or others and is the subject of reasonable efforts to maintain its secrecy.’ (Bouchoux 2001, p.194)

The objective of the legal system is to protect information that is valuable to the firm, or that has future potential value.

The legal classification of major groups of intangible assets has proven to be valuable to business firms in helping to protect these assets. These classifications emphasize the range of legal rights that ownership of the asset bestows upon the firm.

### 2.2.2 Accountancy

In order to analyse the performance of a single firm over time, as well as to compare firms to each other, financial reporting follows a uniform set of standards. Without such uniformity differences in reported performance might equally well be the result of changes in accounting treatment as of changes in the financial circumstances of the firm. Initially accounting treatments were largely a matter for individual firms to decide. The first reporting standards were to await the establishment of the Committee on Accounting Procedure of the AICPA (American Institute of Certified Public Accountants) in 1936. With the development of financial markets and the associated risks of fraud and deception, the setting of accounting standards became
increasingly important. The development of Generally Accepted Accounting Principles (GAAP) was an important step in the efficient operation of financial markets, however major economies each adopted a different standard. All standards however share the same objectives; to provide information that is reliable, verifiable, objective, consistent, and comparable.

One of the principles on which GAAP is based is that of ‘conservatism’. The implementation of this principle has had the effect of not recognizing intangible assets as an item on the balance sheet, except in the most unusual circumstances. The principle of conservatism is described by Watts (2003) thus:

‘Conservatism is defined as the differential verifiability required for recognition of profits versus losses. Its extreme form is the traditional conservatism adage: “anticipate no profit, but anticipate all losses.” Despite criticism, conservatism has survived in accounting for many centuries and appears to have increased in the last 30 years.’ (Watts 2003, p.207)

Since the expenditure on many forms of intangible assets cannot be directly linked to the production of income (the ‘Matching Principle’) the ‘Conservatism Principle’ requires that such cash outflows be expensed and not capitalized.

At the time of writing there is a concerted effort to harmonize all the major GAAP’s, driven both by the internationalization of firms and financial equity markets. Although the process is proceeding slowly, it would appear that it will eventually reach its goal (Hague et al. 2006).

The recognition of intangible assets in financial statements will however not be a simple matter. Watts (2003) sums up the problem as follows:

‘FASB attempts to ban conservatism in order to achieve “neutrality
of information” without understanding the reasons conservatism existed and prospered for so long are likely to fail and produce unintended consequences. Successful elimination of conservatism will change managerial behaviour and impose significant costs on investors and the economy in general. Similarly, researchers and regulators who propose the inclusion of capitalized unverifiable future cash flows in financial reports should consider the costs generated by their proposal’s effect on managerial behaviour.’ (Watts 2003, p.207)

International Accounting Standards (IASs) are the standards to be used in financial reporting as set out by the International Accounting Standards Board. The standard IAS38: Intangible Assets was issued in March 2004 and defines how intangible assets are to be treated in the financial records of a firm. Intangible assets are only recognized if the following criteria are met:

1. the asset is identifiable and controlled by the firm,

2. it is probable that future economic benefits that are attributable to the asset will flow to the firm, and

3. the cost of the asset can be measured reliably.

In the United States, the Financial Accounting Standards Board (FASB) sets standards for the accountancy profession. The Statement of Financial Accounting Standards (SFAS) No141 and 142 are relevant for the recognition of intangible assets. These statements recognize five categories of intangible assets:

1. **Market-related intangible assets**
   for example: trade marks, package design, internet domain names, non-competition agreements.

2. **Customer-related intangible assets**
for example: customer lists, customer contracts and relationships.

3. **Artistic-related intangible assets**

   for example: books, plays and other literary works, musical works, pictures and photographs, video material.

4. **Contract-based intangible assets**

   for example: licensing and royalty agreements, advertising, construction, service or supply contracts, lease agreements, use rights (such as drilling, water, air, mineral, timber cutting and route authorities).

5. **Technology-based intangible assets**

   for example: patented technology, computer software, databases, trade secrets, formulas, recipes.

Despite this recent recognition of intangible assets in financial statements, many firms find that major groups of intangible assets are not recognized by GAAP, and are fully expensed in the year of acquisition. The accounting definitions of intangible assets thus omit important categories of intangible assets are are not conducive to a study of asset pricing.

### 2.2.3 Economics

Within the economics literature the term ‘capital asset’ is more commonly used than the word ‘asset’. A ‘capital asset’ denotes a source of current and future outputs (or services); there is no presumption on the tangibility or otherwise of such an asset. However the concept of the measurement of capital in an economy is not without difficulty:

> ‘Outside of the hypothetical case where real capital consists of a single commodity, it is impossible to express the stock of capital goods as a
homogeneous physical entity. As a consequence of capital’s heterogeneous nature its measurement has become the source of many controversies in the history of economic thought’. (Hazeman 1999, p.345)

In general the intangibility or otherwise of an asset is of little consequence in economic theory per se, with only a few noticeable exceptions. One important exception is the study of ‘human capital’:

‘Human capital is the stock of skills and productive knowledge embodied in people. The yield or return on human capital investments lies in enhancing a person’s skills and earnings power, both within and without the market economy.’ (Rosen 1999, p.682)

The study of human capital as a discipline clearly lies outside the scope of this study as only intangible assets that are owned by firms are considered as part of the analysis. The theory of human capital, although of great importance to the general economy, is only considered in relationship to those aspects of human capital that relate to the efficient operation of the firm.

While the economic literature is not particularly useful in defining the differences between tangible and intangible assets, it is very powerful in analysing differences in transaction costs inherent in these two groups of assets. Almost all intangible assets differ radically from the ‘ideal form’ of economic goods traded in a perfectly competitive market. This is especially true in the case with regard to homogeneity and perfect and complete information. There is the further complication that merely by describing an intangible asset (such as the recipe for making ‘Coca Cola’) the entire value of the asset will be transferred before any payment has been received - if this was to occur on multiple occasions the entire value of the asset would be lost. This problem is an example of information asymmetry, and it has important implications for market efficiency (Akerlof & Maun 1970).
Chapter 2. Research issues in the treatment of intangible assets

Transaction costs may take various forms. The most well researched areas include:

- search and information costs
- bargaining costs
- policing and enforcement costs.

Wider ranging studies of transaction cost (Williamson 1995, for example) classify the determinants of transactions cost in relationship to:

- frequency
- specificity
- uncertainty
- limited rationality
- opportunistic behaviour.

Thus economic theory, while not providing a convenient definition of intangible assets, does provide a means of describing the characteristics of many such assets.

2.2.4 Summary of the characteristics of intangible assets

Given the various methods of defining intangible assets that are covered in this section, it is useful to summarize those characteristics that are most important to the question at hand; that of valuing intangible assets. These characteristics are:

- Intangible assets are not often traded on open markets - there are problems associated with imperfect property rights, information asymmetries, and other costs to trading intangible assets.
- The ‘cost of production’ of intangible assets often bears no relationship to the
value after completion. Many costly software systems are virtually abandoned after completion (The Standish Group International 1996); in contrast some brands and reputations are built at very low cost (others at great expense). Any ‘resource cost’ theory of intangible assets seems doomed to failure.

- Classification, measurement and valuation of intangible assets at the firm level is complicated by the manner in which intangible assets are ‘tightly bound’ to other aspects of firm performance.

- The use of an intangible asset by one customer does not necessarily exclude the simultaneous use by another. For example, airline seats can only be used by one passenger at a time, while the brand ‘Qantas’ can be sold to any number of passengers simultaneously without exhausting the available supply.

### 2.3 Importance of intangible assets in the economy

Having dealt with the problem of identifying intangible assets, the extent to which intangible assets pervade both the public and private sectors of the modern economy is discussed next.

Nakamura (2001) writing about the the annual rate of investment by US firms in intangible assets states that:

> ‘The rate of investment in intangibles, and its economic value, accelerated significantly beginning around 1980. Currently, I estimate that US private gross investment in intangibles is at least $1 trillion. ... An intangible investment rate of $1 trillion suggests that US businesses are investing nearly as much in intangibles as they are in plant and equipment. It also suggests that a third of the value of US corporate assets are intangibles.’ (Nakamura 2001, p.2)
The World Bank is charged with, amongst other objectives, facilitating economic development of countries. As part of this objective it has undertaken a study into the determinants of wealth of nations (The World Bank 2006). The findings may be somewhat surprising:

‘The wealth estimates suggest that the preponderant form of wealth worldwide is intangible capital - human capital and the quality of formal and informal institutions. Moreover, the share of produced assets in total wealth is virtually constant across income groups, with a moderate increase in produced capital intensiveness in middle-income countries. The share of natural capital in total wealth tends to fall with income, while the share of intangible capital rises. The latter point makes perfect sense - rich countries are largely rich because of the skills of their populations and the quality of the institutions supporting economic activity.’

(The World Bank 2006, p.XIV)

The estimates of the various categories of wealth are presented in Table 2.1.

The sheer size of intangible assets in today’s economy is not the only indicator of the importance of intangible assets. Petty & Guthrie (2000) argue that the tools that management must use in the New Economy are vastly different from those of the previous decade. There is not only a quantitative change, but an equally large qualitative change to consider. Similar views are advanced by Leif Edvinsson (Edvinsson 2002) who was the first Chief Knowledge Officer in the world when he served as Corporate Director for Intellectual Capital, Skandia AFS.

At a national level the design of policy to assist in the creation of intangible assets has recently been given prominence by a number of important policy and research groups. In 2002 the Conference on Research in Income and Wealth of the National Bureau of Economic Research (NBER) hosted a conference that focused on these
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<table>
<thead>
<tr>
<th>Income group</th>
<th>Natural capital</th>
<th>Produced capital</th>
<th>Intangible capital</th>
<th>Total wealth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-income countries</td>
<td>1,925</td>
<td>1,174</td>
<td>4,434</td>
<td>7,532</td>
</tr>
<tr>
<td>Middle-income countries</td>
<td>3,496</td>
<td>5,347</td>
<td>18,773</td>
<td>27,616</td>
</tr>
<tr>
<td>High-income OECD countries</td>
<td>9,531</td>
<td>76,193</td>
<td>353,339</td>
<td>439,063</td>
</tr>
<tr>
<td>World</td>
<td>4,011</td>
<td>16,850</td>
<td>74,998</td>
<td>95,860</td>
</tr>
</tbody>
</table>

Table 2.1: Total wealth by type of asset, 2000
US dollars per capita, at nominal exchange rates. Oil states are excluded.
The importance of intangible assets, even in low-income countries, far exceeds natural capital (natural resources) and produced capital.
OECD: Organisation for Economic Co-operation and Development.
Source: The World Bank (2006, p.4)

issues. In a collection of papers and discussions of this conference, the editors emphasize the importance of policy in the the following terms:

‘As the new economy has developed, intangible assets and high-technology investments are playing an increasingly important role. These developments have raised many important questions about measurement, including how to treat intangible assets in economic accounts and whether we are accurately measuring newer, high-technology capital. Economic researchers, data-providers, and policy analysts are interested in answering these questions because the answers can lead to better assessments of the economy’s long-run pace of economic growth and rate of technological advance, as well as to improved measures of national wealth.’ (Corrado et al. 2005, p.1)

The call to better account for the investment in intangible assets in the national accounting system is echoed by Nakamura (1999) and Moulton (2004), amongst
Chapter 2. Research issues in the treatment of intangible assets

others. Work on this problem had commenced earlier under the so-called ‘System of National Accounts 1993’, or SNA. This was an attempt at international cooperation in solving the difficulties in reporting new aspects of the national accounting under the auspices of the Inter-Secretariat Working Group on National Accounts (which consisted of the Statistical Office of the European Communities, the International Monetary Fund, the Organization of Economic Cooperation and Development, the Statistical Division and regional commissions of the United Nations Secretariat, and the World Bank).

However, the difficulties in implementation remain considerable, especially in regard to intangible assets. Moulton (2004) states the matter thus:

‘Because of the substantial data and measurement problems associated with intangible assets other than those already recognized by the SNA, it seems prudent at this point to encourage development of estimates as part of satellite accounts and not immediately add new intangible assets to the core SNA asset boundary. If analysis of data on certain types of intangible assets within the context of satellite accounts demonstrates that they are robust and useful, it may then be appropriate to propose adding them to the core accounts. Data on R&D and on worker training appear to be better developed than for other intangibles, and serious attention should be given to the research needed for evaluating them as potential fixed assets in the SNA.’ (Moulton 2004, p.271)

The importance of intangible assets to the modern economy is beyond doubt. Intangible assets exist in both the public and private sectors and are important elements in the growth and prosperity of the system.
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2.4 Economic theory and intangible assets

Assets, whether tangible or intangible, are a means to the production of goods and services. Assets are thus an important element of economic analysis. This section of the thesis examines how economists have dealt with intangible assets.

2.4.1 Macroeconomics

The Classical School of economics (usually defined as including the works of Adam Smith, David Ricardo, Thomas Malthus and John Stuart Mill) was concerned with economic growth and development at a time when Europe was undergoing a transformation from an agrarian economy to an industrialized one. There was great emphasis on the use of new technologies and production, but this was encumbered by a labour theory of value.

The incorporation of intangible assets into economic analysis initially came from macroeconomics. Macroeconomics is concerned with aggregate behaviour (the study of the sum of individual economic decisions). While the Neoclassical School refocused the lens of economic analysis at the micro level, the Austrian School and the Institutionalists retained a macro perspective.

The Austrians

The link between the capital stock of an economy, investment and economic growth was developed early in the economic literature. Many macroeconomic growth theories regarded capital as a homogeneous entity (Solow 1956), and only later were these theories extended to include various categories of capital; human capital and embodied technological change being the most popular adjustments (Romer 1996).

The assumption of the homogeneity of capital has however brought into question
by, amongst others, the Austrian School and especially by Ludwig M Lachmann. Lachmann (1956) held that:

‘It is hardly possible to discuss the causes and consequences of a change in a stock (of capital) without some knowledge of the nature and composition of this stock: or, it is only possible to do so if we are prepared to abstract from all those features of the situation which really matter.’ (Lachmann 1956, p. xiii)

Contemporary Austrian economists adopt economic subjectivism and methodological individualism as an important part of their analysis. This orientation can only further the treatment of intangible assets in contemporary economic analysis.

**The American Institutionalists**

Thorstein Veblen was especially influential amongst the earlier theorists in regard to intangible assets. Veblen was the first editor of The Journal of Political Economy and was influential amongst professional economists. Contemporaneously the Neoclassical School had grown in importance (partially as a result of the success of the ‘marginal approach’ that had been introduced by the Austrian School). Veblen attacked neoclassical economics as being too narrowly focused. Sowell (1999) states:

‘Veblen argued that the particular assumptions of neoclassical economics left out precisely what he considered most important to investigate - how and why economies continually evolve structurally rather than simply grow quantitatively.’ (Sowell 1999, p.800)

In August of 1908 Veblen published the first of two papers on the nature of capital (Veblen 1908). These papers contain much of the theory underlying the more well known of Veblen’s work, and Veblen’s treatment of ‘capital’ is clearly set out.
Veblen begins by critiquing the then current economic theory of production and distribution by rejecting methodological individualism. Since humans live and work in communities, Veblen postulates that each community will, over time, develop a body of ‘technical knowledge’ that will aid the members of the community in their everyday activities, both social and economic. To Veblen capitalism is a rather recent phase in the life of mankind, and in pre-capitalistic societies Veblen considers these intangible assets to be ‘far and away the most important and consequential category of the community’s assets or equipment’ (Veblen 1908, p.519). Furthermore, in pre-capitalistic economies these assets are held by the community and not by individuals.

However as the technology develops it becomes more and more embodied in physical goods which are needed to implement the technology, and thus use of the technology (which was previously loosely held by the community) becomes available only to those members of the community who are able to secure the use of these physical goods (capital assets). In the final phase of a capitalist economy, economies of scale have set in; and only those members of the economy with access to larger units of capital equipment are able to compete successfully. Thus Veblen states:

'It is not until a late period in the life-history of material civilization that ownership of the industrial equipment, in the narrower sense in which that phase is commonly employed, comes to be dominant and typical method of engrossing the immaterial equipment. . . . the unit of industrial equipment, as required by the new technological era, was larger than one man could compass by his own efforts with the free use of the commonplace knowledge of ways and means. And the growth of business enterprise progressively made the position of the small, old-fashioned producer more precarious.' (Veblen 1908, p.533)
Veblen’s view of the economic process, together with those of John R. Commons, and later Wesley Clair Mitchell and John M Clark constitute the school of thought that has become known as American Institutionalism. Among contemporary economists John Kenneth Galbraith is perhaps the leading exponent of the Institutionalist School. In order to appreciate the adaptations which are currently beginning to be made to the neoclassical models to re-incorporate intangible assets it is useful to stress the manner in which the Institutionalists differ from neoclassical economics. Samuels (1999) sums up the differences thus:

‘The fundamental institutionalist position is that it is not the market but the organizational structure of the larger economy which effectively allocates resources. To the extent, then, that institutional and neoclassical economists study the same questions, for example, resource allocation, the institutionalists generally encompass a broader or deeper set of explanatory variables: instead of having price, and resource allocation, be a function of demand and supply in a purely conceptual market, these latter are in turn related to the structure of power (wealth, institutions) which help form them. Power structure in turn is related to legal rights, thence to the use of government in forming legal rights of economic significance and thereby influencing the allocation of resources, level of income, and distribution of wealth.’ (Samuels 1999, p.865)

Intangible assets are thus perhaps the most important class of capital goods to economists of the Institutional School and their influence is beginning to show, especially in the modern management literature (which is discussed below).
Economic growth, technological progress and neoclassical economics

In response to the relative poverty of the less developed countries, policies to encourage economic growth rose to prominence in the earlier part of the last century (starting in the 1940’s with the establishment of the World Bank). During this period the Harrod-Domar type formulations (Harrod 1939, Domar 1946) held sway with both academics and policy makers. This approach posited a ‘golden-growth path’ at which an economy could grow while maintaining full employment. Maintaining an economy on the full-employment growth path was akin to balancing on a knife-edge, and there was no automatic mechanism that would correct any departure, however slight. Formally the system can be stated as follows:

\[ g^* = n = \frac{s}{v} \]  

(2.4.1)

where \( g^* \) is the rate of growth on the golden-growth path, which is equal to the growth of the population \( n \), and is simultaneously equal to the ratio of the savings generated by the economy, \( s \), and the capital/output ratio \( v \) (which is assumed to be fixed though time). The difficulty is that \( s \), \( v \) and \( n \) are determined independently, and there is no mechanism to bring them into alignment. Thus unemployment is a constant danger in such a system, Harrod stated the matter thus:

‘Trouble arises if the rate of growth which it warrants is greater than that which the increase of population and the increase in technical capacity render permanently possible. And the fundamental paradox is that the more ambitious the rate warranted is, the greater the probability that the actual output will from time to time, and even persistently fall below that which the productive capacity of the population would allow.’ (Harrod 1939, p.31)
In a much cited article, Solow (1956) attempted to resolve the problem of an unstable growth path by adapting the Harrod-Domar model to include a Cobb-Douglas production function and constant returns to scale. This modification effectively meant that through adjustments in savings and the capital-output ratio, the economy would always return to a full-employment growth path. While this was a restoration of a neoclassical approach to economic policy, it did de-emphasize the role of technical change as a policy instrument for many years. There has been much debate on the length of the time period needed to restore equilibrium, if the period is very long, as appears to be the case (Sato 1964), then the assumption of a fixed capital-labour ratio might be a justifiable working hypothesis for policy formation.

The theoretical implications were clear; there is only one dimension in the measurement of capital, its monetary value. Since economic growth requires capital, and more growth requires even more capital, woe betide any emerging economy that was not able to attract enough (homogeneous) capital to grow at a rate faster than the population growth rate.

In summary, the result of the resurgence of neoclassical economics has been that ‘capital’ was treated as a homogeneous commodity, and that the emphasis was laid on physical rather than intangible assets. Capital was also considered to be malleable and it was the quantum and not the composition of capital that was important. Technical progress was used to accommodate the increasing importance of intangible assets, but this formulation was not very successful. Neoclassical economic theory had little reason to distinguish between tangible and intangible assets.

**Theories for the ‘New Economy’**

A very wide ranging investigation into the study of the implications of the ‘New Economy’ was undertaken by the World Bank (The World Bank 2006). In an
attempt to identify future growth potential for the world’s economies and to reduce poverty, this study examines economic growth in 120 countries. Intangible assets were judged to be in the forefront of economic growth:

‘The wealth estimates suggest that the preponderant form of wealth worldwide is intangible capital, human capital, and the quality of formal and informal institutions.’ (The World Bank 2006, p.xiv)

The report portrays a notion of economic development as a process of ‘portfolio management’, and recommends that natural resources be managed so that future economic development, via technology, is financed by current earnings. Thus the report states:

‘There are no sustainable diamond mines, but there are sustainable diamond-mining countries. Behind this statement is an assumption that it is possible to transform one form of wealth - diamonds in the ground into other forms of wealth such as buildings, machines, and human capital.’ (The World Bank 2006, p.xv)

The implications of the report are clear, the ‘New Economy’ is an important model for understanding the economy of today.

However, not all economists are in agreement that there has been a structural change, and they argue that there is no so-called ‘New Economy’. Core et al. (2003) find only partial support for the hypothesis that the relationship between equity value and financial ratios changed significantly over this period: if a structural change had taken place then this relationship should have shown that far less physical capital was required per unit of output. In addition, any change might only have an impact for a limited period of time (Madsen & Davis 2006). The studies that are critical of the New Economy however only investigate the relationship between financial
variables, and ignore wider aspects of human, social and public capital formation.

2.4.2 Bridging the gap between microeconomics and macroeconomics

A work that bridges the gap between micro and macroeconomics was published by the Australian economist Elizabeth Webster (1999). Webster’s work investigates the importance of intangible assets, and provides a link between the economics of the firm and the macro-economy. The work is unique in that it draws from the approaches of what are usually disparate strands of economic thought, to provide a comprehensive framework for studying the effects of the growing importance of intangible assets for economic development.

One strand is a neo-Austrian emphasis of ‘process’ over static equilibrium in the study of competition between firms. Thus Webster argues that:

*‘Firms compete by investing in heterogeneous intangible capital which gives rise to endogenous market barriers, unless they are operating under a very short profit horizon. The larger capacity their capital, and thus sunk costs, the greater the incentive they have to invest in complementary control capital. The latter is created by difficult to emulate demand- and cost-side market advantages.’* (Webster 1999, p.52)

Webster also makes use of Kalecki’s theory of the economy to explore the implications of the dynamics of investments in intangible assets. The results are intriguing: Firstly, high levels of intangible assets have implications for capital structure. Since debt is relatively more costly when there are only intangible assets to act as security, firms with high levels of intangible assets might have to fund themselves by using instruments other than conventional debt. This is largely an empirical matter, which
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at the time of writing, has not been extensively researched.

Secondly, ‘given the natural heterogeneity of individuals’ (Webster 1999, p.102),
labour will be stratified into those groups in which investment is considered prof-
itable and those in which no investment at all will be made - leading to a strongly
segregated labour market, and concomitant repercussions for income distribution.

Websters work is important because it places intangible assets in the nexus between
the theory of the firm and macroeconomic performance.

2.4.3 The theory of the firm

The model of perfect competition allows firms to earn abnormal profits, but only in
the short-run. However there are firms which do not have natural monopolies and
yet which seem to be able to maintain positive levels of abnormal profits for lengthy
periods of time. Robinson (1933) and Chamberlin (1933) investigated imperfect
competition as a possible explanation for such abnormal profits in the 1930’s.

Abnormal profits could also occur if the returns to innovation exist for extended pe-
riods of time. The hypothesis is that investment in innovation leads to competitive
advantages, with the expectation that on average these advantages could be en-
trenched through the use of patent legislation. Surprisingly, investigation has failed
to find a consistent relationship between investment in innovation (often proxied by
R&D expenditure) and abnormal profits. Chan, Lakonishok and Sougiannis (Chan
et al. 2001) report that the performance of firms engaged in conducting R&D re-
search is not superior to firms in the aggregate. Hall (1993) reports similar findings.
However the emergence of ‘knowledge based’ firms, that possess little if any physical
capital, is a counter example to these criticisms.

The decision by a firm to invest additional capital is dependent on the forecast of
future net cash flows. Provided the risk-adjusted return is greater than the cost of financing the investment, such investments will increase the value of the firm. This is the well know ‘net present value rule’ of corporate finance (Brealey & Myers 2003, p.19).

If investment in R&D is not responsible for the abnormal profit of firms, is it possible that there was an unaccounted ‘factor of production’? The literature on management has often mentioned ‘organizational capital’ as an important factor of production. Lev & Radhakrishnan (2005) investigate the effect of organizational capital on firm performance. They begin by hypothesizing the usual Cobb-Douglas production function for the firms output:

\[
SALE_{it} = a_{0it}^PPE_{it}^{b_1} EMP_{it}^{b_2} RND_{it}^{b_3} e_{it}
\]  

(2.4.2)

where:

\(SALE_{it}\) is the firms output, measured in terms of the dollar value of sales

\(a_{0it}\) represents the organizational capital (the variable of interest)

\(PPE_{it}\) is the net value of plant, property and equipment

\(EMP_{it}\) is the number of employees

\(RND_{it}\) is the firms R&D capital

\(e_{it}\) is the stochastic error term

Each variable has both a firm (i) and a time (t) subscript and the parameters (the b’s) are estimated using panel data techniques.

In the form of the model given in equation 2.4.2 above, the variable \(a_{0it}\) is not directly
observable. Lev and Radhakrishnan suggest that the level of the firm’s organizational capital is related to the firm’s reported expenditure on ‘sales, general, and administrative expenses’ - usually abbreviated to SGA in the accounting literature. The specific relationship that the authors use is:

\[
\log(a_{it}) = b_{0t} + b_{0st}\log(SGA_{it})
\]  

(2.4.3)

where:

- \(b_{0t}\) is an ‘economy-wide’ level of organizational capital
- \(b_{0st}\) represents the firm specific level of organization capital

Combining equations 2.4.2 and 2.4.3 allows the parameters of the model to be estimated. A final adjustment is made to allow for the endogeniety of SGA. The authors report that the results of the estimation procedure are significant (that organizational capital can be measured) and useful. However, it seems that this approach is unlikely to yield greater insight into the problem of measuring the value of individual intangible assets.

### 2.4.4 Issues arising out of the treatment of intangible assets in economic theory

In summary, while economic theory has begun to recognise that capital assets are not homogeneous, much of the theoretical and empirical work has been in the macroeconomic sphere. The microeconomic literature has been mainly concerned with identifying the returns to investments in research and development. The broader issues of how to value intangible assets owned by firms has not been directly addressed,
perhaps because this problem traditionally forms part of managerial theory. The following section of this chapter evaluates the managerial literature and the valuation of intangible assets.

2.4.5 New Institutional Economics

Oliver Williamson (Williamson 1987, Williamson & Winter 1993) coined the term ‘New Institutional Economics’ to refer to situations where transaction costs and institutional arrangements played a decisive role in determining the economic outcome of a system. Other major contributors to this field are Ronald H Coase (Coase 1937), Douglass North (North 1981, 1961), Harold Demsetz (Demsetz 1967), and Avner Greif (Greif 2006).

Intangible assets are traded infrequently (or not at all), are hard to describe accurately, and are often not easily protected from appropriation by third parties. One party may have superior knowledge of the attributes of the asset (informational asymmetry) or their actions may be difficult to monitor (which leads to problems of agency). In such cases the value of the intangible asset is only able to be captured under specific firm structures. The New Institutional Economics has attempted to expand the explanations found in Neoclassical Economics to include political, historical, economic and social institutions.

Given the nature of many intangible assets, the New Institutional Economics has much to offer in the analysis of specific intangible assets. The current study is however concerned with the widest possible grouping of intangible assets and at this level of aggregation many of these issues fall away.
2.5 Managerial approaches to the valuation of intangible assets

2.5.1 Introduction

The management literature has tackled the problem of intangible assets extensively. While there is no comprehensive framework within which to classify these solutions, each bears on the fundamental tasks of management (i.e. to plan, organize and control the use of assets).

Andriessen (2001) is typical in his conception of intangible assets in this approach:

‘We were looking for a practical tool that can give managerial guidance in the field of managing intangible assets. We felt that the outcome of such a tool should be the strategic management agenda for intangible assets. We wanted to put the intangibles to the test. For this reason, we have drawn up a list of criteria which will help managers to determine the practical strength of each bundle of intangible assets, called a core competence.’ (Andriessen 2001, p.212)

The concept of ‘core competence’ has become important in the management literature (Hamel & Prahalad 1996), and is closely identified with intangible assets. A ‘core competence’ is an aspect of the business that:

1. adds values for customers
2. provides a competitive edge
3. encourages innovation and new products
4. is sustainable
5. is a permanent part of the firm.
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This section of the thesis firstly discusses the reasons why managers might want to value intangible assets, and then analyses specific solutions that have been developed in the literature. It is however difficult to generalize from this literature to find more generic models.

2.5.2 Reasons for valuing intangible assets

Since there is no universally accepted methodology for valuing intangible assets, the techniques adopted in any particular instance is based on the reason that the valuation is required. The following are the major reasons for valuing intangible assets:

Management of the firm. Management needs to measure the performance of each aspect of the business. Ignoring either the benefits or cost of intangible assets would lead to sub-optimal decision making. Activities such as investment in new productive capacity or formulating strategy are examples of such management activities.

Mergers and acquisitions. When entire business or stand-alone subsidiaries are bought or sold, the value of the intangible assets must be taken into account.

Reporting to stakeholders. Management’s responsibility to report to stakeholders often extends beyond the requirements of GAAP statements. It is common to report the impact of the firm on the environment and the community within which the firm operates. The impact of the firm on the human capital and health of both its employees and the local community is often considerable and it may be desirable to include these effects in the firm’s reporting objectives. The acquisition of productive intangible assets, whether through purchase or internal development, should be reported in a manner that is both transparent and reliable.
2.5.3 Monetary methodologies for valuing intangible assets

Following Luthy (1998) and Sveiby (1997) the following taxonomy can be used to discuss the various methods that can be used to measure intangible assets:

Market capitalization methods

These methods measure the difference between the market value of a firm and the accounting book-value of the firm. This difference represents the value of the intangible assets that the firm owns or controls. These methods are often useful in the analysis of merger and acquisition activity.

The most well known of such measures is Tobin’s q, which is defined as the ratio of the market value of a firm’s assets to their replacement cost. Tobin’s q was initially formulated as an aid to the analysis of investment in the macro economy, however the concept of Tobin’s q had great appeal to economists studying the behaviour of individual firms. Tobin’s q is one method of finding firms with high levels of intangible assets. It is not difficult to estimate Tobin’s q as the accounting data (used as a proxy for the replacement cost of capital assets) and market value of the firm are widely available. Using only basic accounting and financial data Chung & Pruitt (1994) find that they can use regression analysis to successfully estimate the theoretically correct value of Tobin’s q.

Using Tobin’s q as a measure of firm performance, Wernerfelt & Montgomery (1988) found that differences in efficiency between firms is partly attributable to the degree to which the firm focuses on its core competencies, and hence represents an argument against diversification for its own sake. These findings are reinforced by Lang & Stulz (1994) who compare Tobin’s q of diversified and specialized firms, and after controlling for industry effects, find no evidence to support the view that
diversification provides firms with additional valuable intangible assets.

However, in a later study Villalonga (2004), using Tobin’s q as a measure of the degree to which a firm’s assets are composed of intangible assets, finds that it is the intangible assets (and not the firm’s focus) that are responsible for sustaining the competitive advantage of the firm.

The Market-to-Book ratio, as used by Fama & French (1992) (see Section 3.4.5 for a detailed description) is closely related to Tobin’s q, and has been found to be a robustly significant variable in the value of equities (both in different time periods and differing national equity markets). However, in the Fama-French models this ratio is used as a proxy for risk and not for intangible assets.

**Return On Assets methods**

These methods calculate the difference between the rate of return on assets employed by a particular firm and the average rate of return for similar firms (usually within the same industry). This difference in returns is then used to calculate the ‘above average’ net income of the firms, which is in turn discounted to provide an estimate of the capital value of the intangible assets for that firm.

There are many variations of this method, some of them proprietary. The VAIC (Value Assessed Intellectual Coefficient), as described by Pulic (2004) is one of the more elaborate of these methods.

However, the use of a single ratio to measure the inherent complexity of possibly multiple categories of intangible assets makes this approach somewhat difficult. Coombs & Bierly (2006) find that a variety of individual accounting measures of performance, including ROA (return on assets employed), do not perform well as explanations of the technological capability or performance of firms. ROA ignores
risk and the time value of money, and can be influenced by the firm’s debt structure.

The development of EVA (Economic Value Added) (Stewart 1999, Stern et al. 2001) was a response to many of the short-comings of traditional accounting ratio analysis as a means of measuring firm performance. Changes in EVA might be indicative of changes in intangible assets. However the measurement of EVA is not beyond criticism (Salmi & Virtanen 2001, Palliam 2006).

**Direct intellectual capital methods**

These methods rely on separating a firm’s intangible assets into their constituent components. Once this is achieved, each component is valued separately, in a ‘divide and conquer’ approach. While some authors and consultants seem to view this as a general approach to valuing intangible assets, it appears to be most useful where a firm has a single very valuable intangible asset or a set of intangible assets that are technologically closely related (such as a brand name, music rights, or pharmaceutical registrations).

The literature for the measurement of ‘brand equity’ is discussed as an example of how this approach might be implemented:

> ‘Brand equity is defined as the marketing effects or outcomes that accrue to the product or service with its brand name as compared to the outcomes if that same product or service did not have the brand name.’
>
> (Ailawadi & Keller 2004, p.340)

Early studies of brand equity were based on the theory of marketing and usually measured brand equity with reference to consumer behaviour, basing the calibration on such factors as brand recognition and loyalty. This technique is:

> ‘...based on the brand name’s influence on customer evaluation.'
This technique typically employs surveys of preference, attitude, or intent to purchase.’ (Simon & Sullivan 1993, p.30)

Later studies of brand equity evaluated brand equity via the effect of brand equity on a financial performance of the firm. However this approach is not beyond reproach: Fernandez (2001) dismisses these methods and advocates identifying brand value drivers as a means of enhancing brand value. Event studies of announcements of the acquisition of brands shows that investors do seem to value brand equity as an asset (Kallapur & Kwan 2004), however the event study referred to uses only 33 firms and the results are not as robust as one would hope for.

In contrast Damodaran (2006) stresses the use of generic models in valuing brand equity. This involves identifying the cash flows that are the result of the brand equity.

‘We begin by looking at intangible assets that stand by themselves and generate cash flows commercially developed patents, copyrights, trademarks and licenses and argue that conventional discounted cash flow models do a more than adequate job in valuing them. We follow up by looking at intangible assets such as brand name and corporate reputation that generate cash flows collectively for the businesses that own them, but are more difficult to isolate and value independently. Nevertheless, we will argue that conventional discounted cash flow valuation models can capture their values and that adding a premium for them afterwards can result in double counting.’ (Damodaran 2006, p.3)

While this method is to be preferred on purely theoretical grounds, it seems that the ability to identify the relevant cash flows may make it less attractive to managers.

Much of this literature is concerned with managerial decision making, rather than
purely with matters of valuation. Brands are valuable as a barrier to entry (Mottamani & Shahrokhi 1998), especially if the brands are international brand names. The strategies for building brands differ by industry and sector; Ailawadi & Keller (2004) sets out a methodology for branding by retailers, while Roubi (2004) focuses on the hotel industry, with vastly differing advice.

There are many other industry specific studies of intangible assets. While the results of these studies are often very useful to participants in that industry or sector, they are not readily generalizable to firms outside of that industry or sector, nor are they helpful in the building of a theoretical model.

2.5.4 Non-monetary methods for valuing intangible assets

The popularity of ‘balanced scorecards’ as a method of formulating strategic plans has had a great impact on management practice. Starting with Kaplan & Norton (1992) and then Kaplan & Norton (1996), the concept of simultaneously addressing the factors that are most important to the future success of the firm has became widely adopted. Integral to the method is finding a balance for all aspects of strategy. In the traditional balanced scorecard approach these are the:

- financial perspective
- customer perspectives
- internal processes (business processes)
- learning and growth perspectives

The methodology does not rely on monetary measurement of these perspectives, but does emphasize the development and importance of many kinds of intangible assets.
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As an indication of the extent to which the method has become part of corporate culture, Kurtzman (1997) found that 64% of the large US companies surveyed measured their performance from a number of perspectives, in a manner similar to the balanced scorecard.

Score card methods for intangible assets

The concept of using a ‘scorecard’ has been applied more narrowly, and may be used exclusively for the strategic management of intangible assets. Software is one of the quintessential examples of an intangible asset. Within the world of software engineering Buglione & Abran (2002) have developed a scorecard method (called QUEST)

‘...to handle, simultaneously and concurrently, a three-dimensional perspective of performance:

- economic dimension – the perspective of managers
- social dimension – the perspective of users
- technical dimension – the perspective of developers.’

(Buglione & Abran 2002, p.1)

Both Edvinsson et al. (2005) and Green & Ryan (2005) have provided yet other scorecard methods for software. Liyanage & Kumar (2003) attempt a similar task for the effective management of operations and maintenance performance, using North Sea oil companies as a source of data.
2.5.5 Issues arising out of the managerial literature and the valuation of intangible assets

The macro studies that use Tobin’s q as an indicator of intangible assets yield estimates of the total value of ALL intangible assets that a firm holds, and can not be used to value individual assets (except in the unlikely case that the firm has a single intangible asset). In addition the measurement of Tobin’s q is susceptible to movements in factors that affect the market value of a firm other than changes in intangible assets.

The use of expected incremental cash flows that arise from employing an intangible assets avoids the problems associated with Tobin’s q but modelling the relevant cash flows and risk is difficult and this method has not proven to be popular amongst managers (and indeed might be impossible to apply). Industry and asset specific studies have proven to be more popular among managers, but there is little that can be generalized from these studies.

All of these methods are useful to managers who need to consider the strategic aspects of such assets, but they are often not suitable for valuing intangible assets.

2.6 Intangible assets and the financial characteristics of the firm

Accounting statements are prepared to inform interested parties of the firm’s past performance, the current state of the firm’s finances, and (to a limited extent) the future prospects for the firm. Intangible assets can affect all aspects of a firm’s performance.

This thesis investigates the feasibility of valuing intangible assets by reference to
the effect such assets have on the performance of the firm and the value that the equity market places on such performance improvements. It is thus necessary to investigate the extent to which intangible assets, the financial performance of the firm and the financial statements of the firm are related. These issues are examined in this section of the thesis.

DuPont ratios have traditionally been part of managerial accounting and are used to identify and control the various factors responsible for the profitability of the firm. DuPont ratios can be easily calculated from the published financial accounts of most listed companies. These ratios provide a novel means of decomposing the profitability of a firm into various characteristics. Thus firms with favourable DuPont ratios can be expected to outperform their peers.

Although this decomposition of the characteristics of the efficiency of firms is less fine-grained than other measures, these ratios are available for most firms listed on equity exchanges. The advantage of a plethora of data points across many industries is to make the model more generally applicable than would be the case of a more idiosyncratic performance measurement.

### 2.6.1 Accounting and reporting of intangible assets

There have been numerous studies that have investigated the relationship between the disclosure of intangible assets in the financial statements of firms and investor behaviour.

Financial analysts collect and analyse information, and are able to provide a useful service to investors. The question of the influence of intangible assets on the ability of the analysts to forecast future earnings is important in the present context, i.e. are firms with high levels of intangible assets more difficult to analyse than other types of firms? The null hypothesis would be that analysts forecasts are similar for
all firms, irrespective of the degree of intangible assets that they might own. Gu & Wang (2005) find that:

‘high information complexity of intangible assets increases the difficulty for analysts to assimilate information and increases analysts forecast error of intangibles-intensive firms.’ (Gu & Wang 2005, p.1673)

Barron et al. (2002) find similar results. However this result does not hold for firms in industries which traditionally have had high levels of intangible assets, especially biotech/pharmaceutical and medical equipment firms. Thus Gu & Wang (2005) finding’s might refer to the novelty aspect of intangibles assets, rather than to the assets themselves. A study by Amir et al. (2003) supports this conclusion.

**Value relevance of intangible asset reporting in accounting statements**

If investors do value the reported expenditure on intangible assets (as set out in the financial statements of the firm), then a positive correlation between such expenditure and the price of the equity of such firms would be expected, once all other influences on the share price had been adequately controlled for. In practice this relationship has proven to be difficult to substantiate.

Before the establishment of GAAP the SEC accounting practice allowed management a free hand in deciding which intangible assets to capitalize. Ely & Waymire (1999) find that when firms could freely choose the accounting treatment of intangibles, the capitalization of intangible assets by 146 industrial firms (listed on the New York Stock exchange) was not significantly related to the stock price of those firms. However this study was only able to investigate firms reporting for the financial year 1927, and the results may not be robust.

The introduction of GAAP resulted in most expenditure on intangible assets being
written off in the year in which the expenditure was incurred. It is often feasible to reconstruct a firm’s accounting records to treat expenditure on intangible assets in a more realistic manner by firstly capitalizing the expenditure on the assets and subsequently depreciating the asset over a realistic period of time; thus ‘correcting’ the accounting records. Financial analysts, who’s raison d’être is to understand the future earning potential of firms, can often obtain additional information directly from management and thus augment published financial accounts. This information would not be considered as ‘insider information’, but rather the result of applying the ‘mosaic theory’ of investment analysis:

‘The mosaic theory states that an analyst may use significant conclusions derived from the analysis of public and non-material, non-public information as the basis for investment recommendations and decisions. This is true even if those conclusions would have been material inside information had they been communicated directly to the analyst by the issuer. Under the mosaic theory, analysts are free to act on this collection, or mosaic, of information.’ (CFA 2004, p.9)

If financial reporting of intangible assets is incomplete, then analysts should be able to add more value in the analysis of firms with high levels of intangible assets. Indeed Barth et al. (2001) find that firms with higher levels of intangible assets do have higher analyst coverage, and that analysts spend greater effort in the analysis of these firms. However, the question of whether such coverage is of value to investors is not clear. Barron et al. (2002) find that there is a negative relationship between the consensus in analysts’ forecasts and the level of intangible assets, and that the relationship is strengthened in the case of internally generated intangible assets. It would therefore appear that individual analysts can indeed add value to investment decisions.
However Amir et al. (2003) point out that analysts are not able to completely rectify the gaps in the financial accounts, and that a change in GAAP is highly desirable. The authors report that:

‘We identify the most serious deficiencies of analysts’ information in (a) sectors with low-R&D intensity, and (b) among the sectors with high-R&D intensity, in the industrial machinery and computer equipment, electrical equipment and transportation sectors. Taken together, our evidence suggests the need for a continued concern and action of accounting policy-makers with intangibles-related information deficiencies. Sadly, as of this writing, such action has been negligible.’ (Amir et al. 2003, p.657)

In the Australian setting firms have comparatively wide discretion in deciding on whether or not to capitalize some forms of expenditure on intangibles. Matolcsy & Wyatt (2006) investigate the effect of this accounting decision on the ability of market to correctly price the equity of firms which report intangible assets in a more open manner. The results indicate that such firms have a larger number of analysts reporting on their results. The analysts forecasts for firms with higher levels of intangible assets also have lower dispersions and a higher forecast accuracy. However, as the authors indicate, this result may be due to the nature of the intangible assets (the reported intangible assets having a greater perceived degree of ‘certainty’ than intangible assets in general) rather than the reporting decision itself. This aspect is reinforced by a study by Gu & Wang (2005) who test the hypothesis that the ‘high information complexity’ of intangible assets leads to greater forecast errors by analysts. The findings indicate that there is a positive relationship between forecast errors and firms with diverse and innovative technologies. In contrast, where technologies are well established (for example in biotech/pharmaceutical and medical equipment firms) forecast errors are significantly smaller.
Analysts forecasts have been the subject of much scrutiny in the past few years. In an attempt to quantify the benefits of such forecasts Jegadeesh et al. (2004) analysed the recommendations of sell-side analysts and find that:

‘the quarterly change in consensus recommendations is a robust return predictor that appears to contain information orthogonal to a large range of other predictive variables.’ Jegadeesh et al. (2004, p.1083)

The reason suggested by the authors for this result is pertinent:

‘One interpretation of our findings is that recommendation changes capture qualitative aspects of a firm’s operations (e.g. managerial abilities, strategic alliances, intangible assets, or other growth opportunities) that do not appear in the quantitative signals we examine.’ Jegadeesh et al. (2004, p.1108)

2.6.2 Return on equity (ROE) and the DuPont ratios

The use of an hedonic model is predicated on the presence of measurable characteristics of the asset to be valued. The thesis that will be explored in the following chapters is that intangible assets have a tangible effect on the performance of the firms, and that this effect can be quantified and priced. This section introduces one method by which the effect of intangible assets on the firm’s financial performance can be gauged.

The aggregated balance sheet and income statements of publicly traded firms are publicly available. These financial statements have been one of the traditional sources of information for assessing the financial performance of firms. The use of the ratio of two items from these financial statements has been particularly popular. Ratios are used as part of financial statement analysis, and allow for comparisons
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between:

• companies,

• industries,

• different time periods of one company, and

• a company and the industry average.

One ratio that is often considered to be of importance is that of the return earned (or net income) to the average value of shareholders’ equity - termed ‘Return on Equity’ (ROE). ROE is a measure of the efficiency with which the firm generates profits from the capital provided by the shareholders.

The ROE can be used to compare firms in similar industries. Higher ROE generally equates to higher efficiency, and hence higher growth and profitability. However there are a number of important caveats in using ROE to compare firm productivity:

**If the firms are in different industries** ROE may not be a good measure to compare the performance of two firms; some industries have high ROE because they require little or few assets (for example consulting firms) while other industries require large infrastructures (for example firms that generate electrical energy).

**If there are no, or few, barriers to entry** firms with high ROE may find that the advantage of higher efficiency will be competed away within a relatively short period of time.

**Firms with high ROE do not necessarily earn higher returns for investors.**

Only if earnings are retained by the firm and are subject to a return greater than the cost of capital to the firm, will the value of the firm increase.

ROE can be analysed by breaking it down into smaller, constituent parts. This
methodology has come to be known as DuPont ratio analysis. DuPont ratios were originally used by the DuPont Corporation in 1918 to help analyse the profitability of General Motors (DuPont had by this date acquired 23% of the equity of General Motors). There have been minor changes to the form in which the ratios are calculated, but the original reason for the design of this method of analysis is still valid; the return on shareholders equity is an important indicator of corporate performance. The usual statement of the DuPont system is as follows:

\[
ROE = \frac{\text{NetIncome}}{\text{Equity}} = \frac{\text{NetIncome}}{\text{NetSales}} \times \frac{\text{NetSales}}{\text{TotalAssets}} \times \frac{\text{TotalAssets}}{\text{Equity}} \quad (2.6.1)
\]

where \(ROE\) = return on equity

The product of the three individual ratios given above is equal to the definition of ‘return on equity’ (i.e. net income/equity), since the common terms ‘cancel out’. The three ratios however each have a useful and independent interpretation:

\(\frac{\text{Net Income}}{\text{Net Sales}}\) is referred to as the ‘net profit margin’ and is a measure of the ability of the firm to either command relatively high prices for it’s products (for example: brand names) or the ability to keep operating costs low (for example: operating efficiencies)

\(\frac{\text{Net Sales}}{\text{Total Assets}}\) is referred to as ‘asset turnover’ and is a measure of the productivity of the assets employed. Total Assets includes both Fixed Assets and Current Assets. Each of these categories of assets may be directly influenced by the existence of intangible assets.

\(\frac{\text{Total Assets}}{\text{Equity}}\) is referred to as ‘financial leverage’ and is a measure of the amount of debt employed by the firm. Return on equity can be increased by increasing borrowing, however this will increase the risk to the holders of equity. This ratio is not expected to be greatly influenced by the mixture of
tangible and intangible assets that the firm employs.

The individual ratio used in DuPont Analysis may in turn be decomposed into further components. One such decomposition that has been widely used in the managerial accounting literature is described by Reilly & Brown (2000):

‘Beyond the original DuPont System, some analysts have suggested using an extended DuPont System, which provides additional insights into the effect of financial leverage on the firm and also pinpoints the effect of income taxes on the firm’s ROE. Because both financial leverage and tax rates have changed dramatically over the past decade, these additional insights are important.’

(Reilly & Brown 2000, p.401)

Many other variations of this system are possible. Thus Bodie et al. (2005, p.663) use the following (and some what simpler) specification to achieve the same objective:

\[
ROE = \frac{\text{NetIncome}}{\text{pretaxProfits}} \times \frac{\text{pretaxProfits}}{\text{EBIT}} \times \frac{\text{EBIT}}{\text{Sales}} \times \frac{\text{Sales}}{\text{Assets}} \times \frac{\text{Assets}}{\text{Equity}}
\]

(2.6.2)

The effect of intangible assets on the efficiency of the firm forms the basis for the use of hedonic models. DuPont ratios are a well known method of measuring firm efficiency and are easily calculated from the published financial accounts of listed firms. As discussed above, these ratios can also be directly related to the employment of both tangible and intangible assets. The problems involved in constructing and interpreting these ratios is discussed in the following section.
2.6.3 Problems in the application of DuPont Analysis

A large number of factors other than the quantity of intangible assets will affect ROE and its component ratios. Many of these factors are industry specific, and for this reason firms are usually compared to their respective industry norms when using ratio analysis. Even this procedure may lead to difficulties since there is evidence that some ratios are sensitive to firm size:

‘The results of the study presented here indicate that there are significant differences between many of the industry average ratios for small private and large public firms across a large number of well-defined industry groups. These differences are apparent for all leverage ratios and for many of the profitability and activity ratios examined. These findings suggest that financial analysts, lenders and small firm managers should be sure to identify an appropriate industry average ratio for comparison purposes when examining these ratios.’

(Osteryoung et al. 1992, p.45)

The possibility that ratios may be manipulated by management to deceive investors can not be ruled out. If this practice is common, the application of ratio analysis may be of little use. Certainly management projections of future estimates of accounting variables is questionable (Lev et al. 2005), however the safeguards built into GAAP provide enough assurance that, in aggregate, published ratios of past performance are not overly distorted.

There has been surprisingly little application of the DuPont ratios to studies of the effects of intangible assets on corporate performance. Dehning & Stratopoulos (2002) have studied the question of whether, given that a firm has acquired a competitive advantage from an investment in Information Technology (IT), that advantage can be further decomposed into efficiency gains and profitability gains. A
matched-pair research design (comparing companies with a successful IT investment to a direct competitor that enjoyed other comparative advantages) was employed. Using a restricted form of DuPont analysis (only the Return on Assets is considered), the authors were able to show that:

‘the IT-enabled competitive advantage shows up in superior returns on assets (ROA), due to a combination of profitability and efficiency, while a competitive advantage not due to IT shows up in superior ROA due only to increased profitability.’

(Dehning & Stratopoulos 2002, p.166)

2.6.4  Issues arising in the applicability of DuPont analysis to the measurement of the characteristics pertinent to intangible assets

Although any number of other financial ratios could be considered, the traditional DuPont ratios have the following desirable characteristics:

• only three ratios need to be computed, thus saving on the number of degrees of freedom that will be lost in OLS regression estimation when the number of data points may well be near the lower end of the required range

• they cover those areas of activity that are most likely to be affected by the use of intangible assets

• the ratios are independent of each other (by construction) and the likelihood of multicollinearity is therefore known
Other measures of corporate performance have been suggested (for example Stern et al. (2001) uses EVA), many of which are superior to ROE both from the perspective of management (Peterson & Peterson 1996), and for the construction of incentive schemes (Stewart 1999). These claims may be true, but are not relevant in this context. The objective is not to manage or reward productivity but rather to measure the extent to which the market rewards firms for employing assets some of which are not represented in the financial statements of that firm.

2.7 Conclusion

This chapter discussed the most important characteristics of intangible assets, and how they are defined in the legal, accountancy and economic literatures. The importance of intangible assets in both the public and private sectors of the economy was then documented.

After establishing the nature and importance of intangible assets, the chapter then examined how the various schools of economic thought have dealt with intangible assets. The Austrian School, the American Institutionalists, and neoclassical growth models all examined intangible assets from the perspective of the macro-economy, there have been however some important work at the level of the firm.

Managerial literature also deals with intangible assets. This literature, as well as the importance of the valuation of intangible assets for the efficient management of a firm, was discussed. These studies, although useful to managers and possibly appropriate for sectoral studies of the economy, fail to yield a general method for valuing intangible assets.

The effect of intangible assets on the efficiency of the firm forms the basis for the use of hedonic pricing models. The chapter therefore discussed how intangible assets
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affect the financial reports of a firm and the influence of these accounting statements have on the market value of the firm. The DuPont system of analysis was suggested as a method whereby the influence of intangible assets owned by a firm can be consistently observed. Finally a critical discussion of the use of DuPont system as a means of measuring the characteristics of intangible assets was presented.

The next chapter will introduce hedonic pricing models and demonstrate how such models can be used to extend the framework to allow for the analysis of intangible assets without the limitations of the existing approaches that were discussed in this chapter.
Chapter 3

Research issues in hedonic pricing theory and the valuation of financial assets

3.1 Introduction

The previous chapter examined the nature and importance of intangible assets, how the economic and managerial literatures have incorporated intangible assets, and how intangible assets affect the characteristics of firms that own such assets. This chapter investigates the suitability of hedonic pricing models as a method of valuing the many different types of assets held by firms.

Neoclassical economic theory currently forms the basis for the valuation of all financial assets, including intangible assets. This chapter begins by briefly reviewing how the value of financial assets are determined within the neoclassical paradigm.

The hedonic pricing model is then introduced as a generalization of the neoclassical model. The nature of intangible assets is such that an empirical application of the neoclassical model is difficult. At the same time these very characteristics make the hedonic approach seem very attractive, although the model has seldom been used
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for these purposes.

If the hedonic model is to be used as the major tool for the valuation of intangible assets, it is important that it is shown to be conformable with existing methods of valuing assets in general. The third section of this chapter demonstrates how both the Capital Asset Pricing Model (CAPM) as well as the multi-factor models are consistent with, and are deducible from, the hedonic pricing model.

Finally the advantages of employing the hedonic framework are evaluated.

3.2 The neoclassical foundations of the theory of choice

The hedonic model is key to the analysis that follows, and is chosen on the basis that it is superior to the neoclassical pricing model for the purposes of valuing intangible assets held by firms. In order to support these contentions, the neoclassical theory of pricing is presented in sufficient detail that this claim can be justified. The hedonic model is shown to contain the neoclassical pricing model as a special case (where each ‘good’ consists of only one ‘characteristic’).

3.2.1 Consumer behaviour

Since the consumer is assumed to have limited means and insatiable wants, economic theory needs to explain how the demand for any particular good is determined. The neoclassical theory of choice is the result of a long process of continual refinement that has culminated in the formulation commonly known as the Slutsky-Hicks analysis (Hicks 1946, Slutsky 1952). This aspect of microeconomics now forms a core segment of the standard economic syllabus (Varian 2006, Lipsey et al. 2004, Samuelson & Nordhaus 1992) and is therefore only briefly discussed.

In this approach a consumer’s preference for each good is expressed in terms of
a utility function. The numerical magnitude of utility is of no importance as the function is used only to order bundles of goods. Any monotonic transformation of the utility function will preserve the ordering of such bundles, and will therefore suffice. The consumer’s income limits the total amount that may be consumed. Income is assumed to be constant over the period of analysis.

In algebraic terms the problem may be stated thus:

\[
\begin{align*}
\text{Max. } U(x) \\
\text{s.t. } m = px
\end{align*}
\]  

where:

- \(U(x)\) is the utility function of the consumer
- \(x\) is the vector of goods from which the consumer may choose
- \(p\) is a vector of prices (which are invariant to the consumer’s decisions)
- \(m\) is the income constraint (the monetary expenditure by the consumer)

The result of the optimization is that the marginal rate of substitution for each good (with respect to any other good) will be equal to the ratio of the prices for those goods.

Graphical representation of problems of choice have become traditional in the microeconomic literature. The usual manner in which the problem of choice is framed is to compare one good against a basket of all other available goods (sometimes referred to in the literature as the ‘Hicksian composite good’).

In Figure 3.1 the consumer maximizes utility by consuming the bundle of goods \((x_1, x_2)\) that reaches the highest indifference curve possible, given the budget constraint.
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3.2.1 Indifference curves

A consumer will maximize his/her utility by choosing the bundle of goods $x_1, x_2$ where his/her indifference curve is tangent to the budget constraint.

Source: Constructed by author.

There have been attempts to extend this analysis to incorporate additional factors (Becker 1965, for example, incorporates time as an additional constraint), however the basic model remains unchanged.

3.2.2 Financial assets

The valuation of financial assets is based firmly on a neoclassical microeconomic framework. However there are two important characteristics of financial assets which are absent from most other consumer goods; the effect of time on the value of the asset, and the riskiness of the outcomes (i.e. the variability of the asset returns).
Financial assets are required both to enable consumers to defer consumption to future periods (hence the demand for such assets), as well as to allow investors to finance the current use of capital assets (the supply of financial assets). The study of financial asset markets assumes a general equilibrium framework, where the demand and supply of financial assets (also referred to as ‘loanable funds’ in parts of the literature) jointly determine the price of such assets (i.e. the interest rate structure of the economy).

This section contains a very brief summary the current state of the theory of the demand for financial assets as set out in the literature (Ross et al. 2005, Titman & Martin 2008, Damodaran 1996, Elton & Gruber 1995).

**In a world with no risk**

In a world in which there is no uncertainty the equilibrium prices of financial assets are easily determined. Prices of all assets (both capital goods and financial assets) will be such that:

- the (certain) return on all assets is equal, and
- the supply and demand for loanable funds is equal.

In order to illustrate this proposition, firstly consider a single individual facing only two periods, traditionally termed ‘now’ and ‘the future’. The choice facing the consumer is to maximize his/her utility by choosing the appropriate amount to consume in each of the two periods. Any saving in the first period is rewarded by an increase in consumption in the second period (savings plus interest earned). Similarly, any borrowing in the first period has to be paid for in the second period, plus interest.
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The consumer’s ‘opportunity set’ is given by the function:

\[ C_2 = I_2 + (I_1 - C_1)(1 + r) \]  

(3.2.3)

where:

- \( C_t \) is consumption in period \( t, t = 1, 2 \)
- \( I_t \) is income in period \( t, t = 1, 2 \)
- \( r \) is the interest rate at which the consumer can borrow or lend at time \( t = 1 \)

Stated in words: consumption in Period 2 is equal to income for that period plus (minus) any savings (borrowing) from the previous period, adjusted for the rate of interest. The ‘opportunity set’ is linear, this is an important difference to the case in the hedonic pricing model, which is discussed in the following section of this chapter.

The slope of the opportunity set is the ‘cost’ of Period 2 consumption in terms of Period 1 consumption: every dollar consumed in Period 1 reduces consumption in Period 2 by \((1+r)\) dollars. The actual bundle that is chosen by a consumer depends on his/her idiosyncratic utility function, about which the economics profession has been loath to pass comment (Stigler & Becker 1977). However, given the form of the utility function, it may be represented by a set of ‘indifferences curves’ with the usual properties. Figure 3.2 illustrates the case for an individual who decides to save some income in Period 1.

General equilibrium in the market for financial assets requires that all consumers’ savings and borrowing plans can be met simultaneously. If the aggregated planned borrowing in Period 1 exceeds the planned lending the market will not clear and the ‘price’ of funds will adjust upwards until equilibrium is reached (some borrowers will be discouraged at the higher interest rates, and some savers will increase their
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Figure 3.2: Utility maximization for a single consumer, 2 period analysis
A consumer with income of $I_1$ in Period 1 and $I_2$ in period 2, will choose to locate at point D; thus saving part of Period 1 income which is to be spent in Period 2. Source: Constructed by author.

savings). In equilibrium there will be a unique rate of interest, which in this simple world of no uncertainty, determines the price of all financial assets - so that the rate of return on each asset is equal to the single equilibrium rate of interest. If this condition does not hold borrowers would try to sell the cheaper asset (lower cost of borrowing) and lenders would only want to hold the asset with the higher return. Thus, without uncertainty there could only be a single interest rate in the economy (and by analogy there could only be one rate for each time period in a multi-period analysis).
Introducing risk

It is useful to draw a distinction between risk and uncertainty. Following the work by Frank Knight (Knight 1921), the term ‘uncertainty’ is reserved for occasions when it is not possible to assign probabilities to events; ‘risk’ is used if the outcomes can be thought of in terms of a probability distribution.

In the asset market financial securities are subject to differing types of risk. The major sources of risk can be categorized as follows:

- unanticipated inflation
- credit risk/default risk
- interest rate risk
- market liquidity and depth.

The investor can choose from a range of assets to transfer consumption from one period to another. If the ‘risk-free’ asset is chosen, then the rate of interest that is either paid or earned is determined by the demand and supply for that particular asset. However there are close substitutes to the risk-free asset (assets with similar characteristics and differing degrees of risk) that will perform a very similar function. The ‘prices’ of each of these assets are formed by the interaction of the aggregated demand and supply for each of these assets.

In the neoclassical model assets have only two characteristics that determine their value; risk and return. However, there is empirical evidence (see Section 3.4.5) that other characteristics may be at play. Hedonic pricing models are the perfect mechanism with which to investigate this phenomena.
3.3 Hedonic pricing models

3.3.1 Introduction

The neoclassical model, although elegant, is not always useful when applied to the empirical estimation of the demand for actual consumer goods. The development of the hedonic model is an attempt to deliver better empirical results.

There is an interesting debate concerning the first use of hedonic pricing models. Goodman (1998) states that:

‘...the pioneering work, and apparently the coining of the term ‘hedonic’, dates back to a 1939 article by Andrew Court. Court’s work generally receives, at best, a perfunctory citation in most articles. It deserves better. By many standards of contemporary hedonic price analysis, Court’s work stands up quite well.’ (Goodman 1998, p.291)

Court was interested in the pricing of passenger vehicles. It appears that there was even earlier work in this area by Haas:

‘G. C. Haas produced a hedonic study more than 15 years prior to A. T. Court who first published the term hedonics. Haas’s application was to agricultural land prices with a particular focus on distance to the city centre and city size. Thus, Haas’s work has much of the flavour of contemporary urban economics. A re-estimation of Haas’s model reveals that he did a respectable job in an age before computational machinery was available.’ (Colwell & Dilmore 1999, p.620)

While these works are important in their own right, it was left to Lancaster (Lancaster 1966) to develop an entire model of consumer behaviour in terms of hedonic characteristics. Lancaster’s ‘new approach’ to consumer theory was formulated to
remedy a specific shortcoming in the traditional neoclassical theory of consumer choice. The introduction of a variation of an existing good could not easily be incorporated into existing empirical analysis. Variations of existing goods were becoming commonplace - consider for example the annual introduction of variations in passenger motor vehicles. Neoclassical theory could be made to deal with these variations in one of two ways:

**Regard the variant as an entirely new good** and thus disregard any information concerning the previous model (for example price and income elasticities), or

**Ignore any changes in the new variant** and treat it as exactly the same good as the previous model (ignoring any improvements in, for example, technology or safety).

Neither of these two solutions is attractive, nor do they produce good empirical results.

Lancaster’s attempt to rescue the neoclassical model is to consider the ‘characteristics’ of the goods rather than the goods themselves. In the example of motor vehicles, consumers do not choose between models of cars but between ‘bundles of characteristics’ (for example: speed, luxury, size, reliability, and so forth). This approach is perfectly general and is not specific to a single group of goods - indeed the traditional neoclassical theory of consumer demand is found to be a special case of the hedonic pricing model.

The discussion of the hedonic pricing model that follows is developed in the most general terms, and only then applied specifically to assets that are owned by firms. This approach is prompted by the characteristics of the model itself and the important facility of partitioning goods into non-overlapping sets.
3.3.2 Characteristics of goods

In the hedonic pricing model goods are demanded for the properties/services that they provide to households. Households are conceived of as production units that combine goods to produce utility for the household. In this aspect the approach is similar to that of Gary Becker (Becker 1965) who modelled households that combined ‘goods’ and ‘time’ to produce utility.

Each good can have a large number of properties. For example, most physical goods will have properties related to size, shape, colour, chemical composition and so forth. At first glance the sheer number of properties would seem to be so overwhelming as to preclude this approach from empirical estimation. However not all properties are relevant for the consumer to choose between goods. Those properties which are relevant are referred to as ‘characteristics’ and the number of characteristics that might be relevant to any choice is an empirical matter. Experience has shown that in many cases the number of characteristics is often smaller than the number of varieties of the good being considered. As a naive example consider the number of characteristics that might be relevant to a consumer choosing a brand of honey (colour, origin, package size, perceived quality, price, ...) as against the number of brands that might be offered for consideration on the shelf. In the case of financial assets it appears that the number of characteristics are relatively few in comparison to the number of assets available.

Modern portfolio theory specifies only two characteristics of financial assets; ‘risk’ and ‘expected return’ (see Section 3.4.3). Whether there are additional characteristics remains an open question, but the empirical studies of Fama and French suggest that this might be so (Section 3.4.5 discusses these results in more detail). For the purposes of the argument in this study, it is assumed financial assets, and more specifically equities, may have additional characteristics. The nature of these
characteristics is at present left unspecified and is the subject of later analysis.

### 3.3.3 Assumptions of the hedonic model

In addition to the usual assumptions of the neoclassical model, the hedonic pricing model is mostly easily developed if a number of additional assumptions are made. It is possible to relax some of these assumptions, however it is not possible to remove them entirely.

The additional assumptions required are:

1. goods possess objective and measurable characteristics - there is no dispute about these characteristics and all consumers would agree on their existence, although not necessarily on their desirability, see (2) below.

2. individual consumers value characteristics differently - thus, for example, the characteristics ‘top speed’ in relationship to a motor vehicle may be valued differently by a teenage driver and his/her parent.

3. the relationship between goods and characteristics is both linear and additive - doubling the quantity of a good will result in double the quantity of the characteristics, and purchasing more than one good with the same characteristic will simply result in the consumer having the sum of each characteristic, regardless of which good it originated from.

Unless the reader is convinced that Milton Friedman was absolutely correct in the statement that:

> ‘Truly important and significant hypotheses will be found to have “assumptions” that are wildly inaccurate descriptive representations of...’
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*realistic the assumptions (in this sense).*’ (Friedman 1966, p.14)

it might be best to examine these assumptions in the context of financial assets and especially the market for equities.

The first assumption is clearly not problematic; financial assets sold on recognised exchanges are probably the most widely documented of all goods that are traded in the economy. This aspect is strengthened by the harsh penalties for false statements about the financial position of the firm by the officers of that firm, and the regulations surrounding ‘insider trading’.

The second assumption is in no way problematic.

The third assumption may be troubling in many instances, but not in the case of financial assets. Certainly ‘return’ is both linear and additive, and ‘risk’ can be transformed into a linear and additive quantum by using ‘beta’ as a measure of risk. These assertions are discussed in Section 3.4.4 which reviews the literature surrounding ‘beta’ and the Capital Asset Pricing Model. Any additional characteristics of financial assets that might be introduced would need to be evaluated in terms of this assumption.

3.3.4 An algebraic specification of the hedonic model

Consider a consumer with limited income who can select from a small set of consumption goods. Let \( z = [z_i] \) be a vector of characteristics of the goods the consumer is contemplating purchasing. Let the goods themselves be denoted by the vector \( x = [x_j] \). Finally let \( B = [b_{ij}] \) be the matrix of coefficients relating goods and characteristics (called the ‘consumption technology matrix’ in the literature, since it relates the technological conditions under which goods are transformed into
characteristics). Then:

\[ z = Bx \]  

(3.3.1)

Equation 3.3.1 states how the vector of possible goods are converted into the vector of characteristics that the consumer desires. There is no *a priori* restriction on the the number of goods in relationship to the number of characteristics, thus the rank of \( B \) is not known, and \( B \) can not be assumed to be either square or invertible.

We can restate the additional assumptions required for the hedonic model in terms of the variables in equation 3.3.1:

\[ z_i = b_{ij}x_j \]  

(3.3.2)

i.e. the characteristics are linear with respect to the quantity of the good consumed, and

\[ z_i = b_{ij}x_j + b_{ik}x_k \]  

(3.3.3)

i.e. characteristics are additive, so the total quantity of the i’th characteristic is simply the sum of that characteristic present in all the goods consumed.

Each consumer acts so as to maximize his/her utility given the vector of prices \( (p) \), his/her income \( (k) \), and the particular shape of his/her utility function. The solution is given by the following system of equations:

Max. \( U(z) \)  

(3.3.4)

\[ s.t. \ z = Bx \]  

(3.3.5)

\[ x \geq 0 \]  

(3.3.6)

\[ px \leq k \]  

(3.3.7)
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There is a choice to be made about which space (characteristic space or goods space) to perform the maximization. Mathematically the solution will be the same. However, if we choose to maximize utility in characteristic space the set of indifference curves (for any particular given utility function) will be invariant to changes in the vector of goods \((x)\). This is a key feature in the hedonic model, since it will allow new goods to enter into the analysis with the same set of indifference curves, thus allowing comparisons between new goods and existing goods without having to recalibrate the indifference curves.

Choosing to maximize in characteristic space however involves mapping the budget constraint into characteristic space. The difficulty of this operation is somewhat ameliorated by the following conditions:

1. The budget constraint for individual consumers \((px \leq k)\) will differ only by the level of income, \(k\).
2. Since \(z = Bx\), the relationship between goods and characteristics is the same for all consumers.
3. \(z = Bx\) is linear, so the feasible sets for each consumer are simply related by a scalar expansion (contraction) in proportion to the ratio of their incomes.

The same mapping of the budget constraint will thus suffice for all consumers facing the same market conditions. The indifference curves will however be unique for each consumer.

3.3.5 A numeric example

Since graphical analysis is so embedded in the analysis of financial asset selection, it is perhaps not inappropriate to illustrate the hedonic pricing model using a simple numeric example. The initial example is based on consumer goods; partly to
demonstrate the general applicability of this approach. The transition to financial
assets is made at the end of this section. [This numeric example is based on one
given by Lancaster (Lancaster 1966, p.28-32).]

Consider 3 types of food: milk, eggs, and steak that an imaginary consumer may
choose amongst. In the traditional neoclassical model of consumer choice, it would
be assumed that the consumer had some prior preference function based on a liking
for each of these goods, and would choose that combination that resulted in the
marginal utility per unit of expenditure be equal over all goods. In the hedonic
pricing model the consumer’s utility function is expressed in terms of the utility of
each of the characteristics of the goods - to keep the analysis as simple as possible
assume that there are only two characteristics to consider; calories and protein
(Obviously our ‘consumer’ is a bit of a health nut!).

The relationship between goods and characteristics is given by equation 3.3.1, which
is repeated below:

\[ z = Bx \]

Assume the following values for \( B \):

\[
\begin{bmatrix}
2 & 1.8 & 1 \\
1 & 1.8 & 2
\end{bmatrix}
\]

Further, to keep the arithmetic simple, but without loss of generality, let the price
of each good and the consumer’s income equal unity. Firstly, consider the problem
in the conventional neoclassical setting. The budget set in goods-space which is
given the tetrahedron bounded by the co-ordinate planes and the budget constraint
\((x_1 + x_2 + x_3 = 1)\), as illustrated in Figure 3.3.

The extreme points represent a position in which the entire budget is spent on only
one of the goods. Normally we would expect a consumer to locate at some point on
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Figure 3.3: Budget constraint in goods space
The consumer can choose any combination of the three goods \((x_1, x_2, x_3)\) given by shaded plane. The actual choice will be determined by the shape of the utility function which is assumed to be different for each consumer.
Source: Constructed by author.

the budget set, where his/her indifference curve is tangent to the plane. The three extreme points are:

\[
x^1 = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}; \quad x^2 = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}; \quad x^3 = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}
\]

The importance of the hedonic pricing model becomes apparent if we now consider the budget set in Characteristic-space.

Since:

\[
z = \begin{bmatrix} 2 & 1.8 & 1 \\ 1 & 1.8 & 2 \end{bmatrix} x
\]
the image of each of the extreme points in the budget set in Characteristic-space occurs when the entire budget is spent on only one of the goods. The budget set in Characteristic-space is depicted in Figure 3.4, where each of the extreme points (labelled $z^1, z^2, z^3$) is in a one-to-one correspondence with the extreme points of Figure 3.3 (which are labelled $x^1, x^2, x^3$ respectively).

![Budget constraint in Characteristic space](image)

**Figure 3.4: Budget constraint in Characteristic space**

*The consumer can choose any combination of the two characteristics $(z_1, z_2)$ by a suitable selection of goods. The actual choice will be determined by the shape of the utility function which is assumed to be different for each consumer. Note that the opportunity set is no longer linear. Source: Constructed by author.*

Each consumer will choose that combination of goods which give him/her the highest utility. This combination is represented by the highest indifference curve which is obtainable (either tangent to a facet on the the budget set, or at one of the apexes).

[The magnitude of the variables used in this example are those of an equilibrium]
solution. Note that different initial values might require adjustments in prices before an equilibrium is reached.]

**Deriving aggregate demand functions**

Given that individual consumers have each chosen the optimal bundle of goods, the aggregate demand for each good can be determined. However the concept of a representative consumer no longer applies (since consumers may chose different facets of the budget constraint they will react differently, or not at all, to relative price changes). The empirical estimation of the demand functions for particular goods therefore needs to take into account the distribution of preferences among consumers.

This is most easily accomplished by constructing a ‘representative efficiency frontier’ under the assumption that there is a linear consumption technology (which implies that consumers with differing incomes will face the same shaped efficiency frontier). An alternative solution is to consider the distribution of consumers with similar preferences.

This task is less onerous than it might first appear, especially when the number of characteristics is likely to be small relative to the number of goods available. In this regard assets in general prove to be eminently suitable for analysis using hedonic pricing models. A discussion of the characteristics of financial assets forms the subject of a later section of this chapter.

**3.3.6 Empirical studies using hedonic models**

This study applies the hedonic model to intangible assets. It is encouraging to note that there have been other successful implementations of the hedonic model.
While early studies of hedonic models met with limited success, this lead to a raft of papers that explained the poor results and offered improved techniques in the application of the model. This section reviews some of the areas (other than finance) where hedonic models have proven to be useful. The hedonic model has proven to be especially useful in two main areas; the explanation of housing prices, and the construction of price indices.

In each of the studies that use hedonic models, the distinguishing factor is that a price (or value) of a characteristic that is not directly observable must be estimated. The usual reason that the price is not observable is that no market exists for that characteristic. By finding a relationship between the observable price for goods that contain that characteristic and the characteristic, the characteristic itself can be priced. The following studies illustrate how this is achieved in very differing circumstances.

When the variables that are used to measure the characteristics of the good change very slowly over time (for example, the number of rooms in a house) they are not able to capture much of the variance of the relatively more rapid changes in the price of the goods. This is more significant where there is a large stock of such goods that changes only slowly over time (for example; housing, or public amenities). In contrast the measured profitability and the DuPont ratios of firms display great variability over very short periods of time (which is partially the reason for the popularity of DuPont ratios in management theory). In addition the frequency of the data used to construct DuPont ratios is at the very least annual, and the frequency of data availability is steadily increasing. Quarterly financial statements of US listed firms are usual, and the increasing use of XBRL (see Section 4.3.3 Deriving the value of intangible assets from the hedonic model of equity valuation) offers the promise of even more frequent updates on measurements of financial performance.
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House price studies

In the case of residential houses the purchase price of a property is observed when a house is sold in a competitive market. The house confers a bundle of benefits (characteristics) on the owner/occupier: shelter, comfort, proximity to amenities, etc. The very large number of domestic property transactions has enabled the price of each characteristic of such properties to be estimated. Once these values have been determined they can be used to value a property that has not been previously sold (or which might not even exist at present), by simply summing the value (price times quantity) of each of the characteristics.

Recent house price studies have been very successful. The authors of a recent Australian study state that they:

‘...are able to construct consistent temporal and spatial house price indexes for 128 postcodes in Sydney over a three year period.’ (Hill & Melser 2005, p.23)

As is perhaps expected, spacial disaggregation appears to be especially important in housing studies (Goodman & Thibodeau 2003). There are however many other characteristics to consider: local crime rates (Gibbons 2004), security of tenure (Kim 2004), and potential natural hazards (Maani & Kask 1991) for example.

Hedonic price indices

The construction of price indices is a matter of public importance. Many longer term contracts now employ the official price indices to adjust payments between parties over time. Since many of the constituents of the index may undergo changes in quality, it may not be sufficient to equate one unit of a product today with the same unit a few years previously. Pharmaceutical products, information technology...
products, and products from other areas of rapid technological advance are all susceptible to rapid improvements in quality. The IMF has prepared a working paper that discusses the alternative ways in which hedonic pricing models might be used to compile such indices (Silver & Heravi 2006).

Other applications of hedonic models

Hedonic models are becoming more popular in the economic literature, and have been applied to a very wide range of issues with varying degrees of success.

Hedonic pricing techniques have been used to price public goods. Since no overt market exists for these goods, some estimate of the benefits to consumers is needed if resources are to be efficiently allocated. This application of the model is far removed from the type of goods with which we are concerned. A good survey of these models is provided by Brookshire et al. (1982), and a current example is provided by Van Praag & Baarsma (2005) who investigated the cost of airport noise on the surrounding community.

There is a long tradition of using hedonic models to value environmental assets (Decker et al. 2005). There is considerable data available for environmental attributes that surround housing; Getz & Huang (1978) estimate benefits of urban amenities using hedonic prices, while Decker et al. (2005) investigate the effect of industrial chemical releases on the value of nearby residential properties. The demand for sporting events is affected not only by the event itself, but also by the physical environment within which the event takes place. Hightower et al. (2002) use an hedonic model to investigate the value of such amenities (called the ‘servicescape’ by the authors) to attendees.

Requena-Silvente & Walker (2006) control for over 100 characteristics in new cars
sold in the UK, but the ‘quality adjusted prices’ thus obtained are far from satisfactory. However, when applied to hotel investments, hedonic pricing models seems to perform very well indeed (Roubi 2004).

Some applications of hedonic pricing models seem esoteric; rating PhD programs in Economics (Ehrenberg & Hurst 1998) and the ‘price’ of husbands in terms of dowry payments (Rao 1993) are just two examples.

### 3.4 Pricing assets

#### 3.4.1 Introduction

The intangible assets considered in this thesis are owned by firms, and are thus a subset of all the intangible assets in the economy. This thesis tests if the value of such intangible assets may be derived from the value of the firm itself; therefore that value of the firm is directly relevant to this thesis.

This section of the chapter examines how, in general, equities of quoted firms are valued. The concept of ‘risk’, while present in almost all economic problems, is given special emphasis in finance. Equities, along with other financial assets, can be viewed as streams of future income, subject to risk.

Before the advent of Modern Portfolio Theory (MPT), the risk of equity investments was dealt with by examining the ‘quality’ of the investment. The attributes of intangible assets are such that they may quickly lose value in some circumstances - the result was that tangible assets were deemed to be of higher quality than their intangible counterparts.

Modern Portfolio Theory, following the lead from neoclassical economics, found no advantage in differentiating between tangible and intangible assets. What mattered
was the volatility and quantity of the resulting income stream, not the composition of the assets of a firm. After all, in the absence of any agency problems, managers could be relied upon to select that set of assets that would maximize the expected income, irrespective of the tangibility or otherwise of the assets. In MPT intangible assets \textit{per se} are not of great interest.

However, the failure of MPT to generate useful empirical models has lead to the recent emphasis on multi-factor models. Multi-factor models yield better empirical results, but rely on the same theoretical underpinnings of MPT.

The use of hedonic pricing methods promises to overcome some of the theoretical problems of the multi-factor models, and to re-introduce the distinction between tangible and intangible assets (as well as other factors which lead to differential performance of firms).

There are many different reasons for valuing the equity of a firm. The finance literature is concerned with explanations in terms of the risk and return trade-off of assets, with equities as one of many classes of assets. In contrast, the accounting-based literature attempts to relate the price of a firm’s equity to the accounting statements of the firm. This has led to a large body of literature that is concerned with the usefulness of accounting literature to investors. The major works in this field include Ohlson (Ohlson 1995, 2007), Penman & Zhang (1999) and Chambers & Penman (2008) as well as Penman (2001). Only the partial effects of the presence of intangible assets on the value of equity are considered in this study and the equity valuation model is specified in terms that are general enough to include most valuation models from both the accounting and finance literatures.
3.4.2 Benjamin Graham and value investing

*Security Analysis* (Graham & Dodd 2004) which was first published in 1934, and is still used as a text at Columbia University, stresses the fundamental analysis of firms as the prime method of selecting equity investments. Equity in firms which are ‘defensive’ (in the sense that the price at which the stock is purchased should not be much above the tangible book value of the firm) are recommended for further analysis. This strategy came to be known as ‘value investing’ and has undergone much refinement and reinterpretation since the 1930’s. Value investing has proven to be a viable and successful strategy over an extended period of time. Numerous studies have shown that value stocks have outperformed ‘growth stocks’ and the market as a whole (Fama & French 1992, Barber & Lyon 1997).

There have been many adherents of value investing. Possibly one of the best known of these advocates is Warren Buffet, who often claims to be merely applying the methods of his teacher Benjamin Graham, as in this statement in his annual letter to shareholders:

> ‘Some people may look at this table and view it as a list of stocks to be bought and sold based upon chart patterns, brokers opinions, or estimates of near-term earnings. Charlie and I ignore such distractions and instead view our holdings as fractional ownerships in businesses. This is an important distinction. Indeed, this thinking has been the cornerstone of my investment behaviour since I was 19. At that time I read Ben Graham’s The Intelligent Investor, and the scales fell from my eyes. (Previously, I had been entranced by the stock market, but didn’t have a clue about how to invest.)’ (Buffett 2004, p.16) [Buffet is referring to a table of equities in the Berkshire Hathaway portfolio of equities that he manages. Berkshire Hathaway is a listed company on the New York
The search for value can take many forms, and may incorporate the value of intangible assets that a firm possess. However, the process of value investing is often idiosyncratic and the inclusion of intangible assets is not systematic.

3.4.3 Markowitz and Modern Portfolio Theory

Markowitz (1952) was the first to formulate a mathematical model of portfolio risk. Over time Markowitz’s method of exposition has been refined and formalised so that it is now a standard part of the theory of finance (Ross et al. 2005, Joshi 2003, Elton & Gruber 1995, Brealey et al. 2006).

The expected return of a portfolio of risky assets is simply the weighted average of the expected return of each asset. However, the risk of the portfolio is not a linear function of the risk of each asset, since the risk of one asset may be offset to some extent by the risk of another asset. These characteristics of portfolios of financial assets can be expressed by the following set of equations:

\[
R_p = \sum_{i=1}^{n} X_i R_i \tag{3.4.1}
\]

\[
\sigma_p^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} X_i X_j \sigma_i \sigma_j \rho_{ij} \tag{3.4.2}
\]

where a bar over a variable is used to indicate the ‘expected value’ of the variable

\( p \) refers to the portfolio

\( i, j \) refer to individual assets within the portfolio

\( \sigma^2 \) refers to the variance of the portfolio

\( \rho_{i,j} \) refers to the correlation coefficient between assets \( i \) and \( j \).
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It is not the risk of an individual asset which is important in this model, but rather the effect of the individual assets on the risk of the entire portfolio (via the covariance terms) that determines desirability of that asset.

Since investors are assumed to be rational, of all the possible portfolios that can be constructed only the ‘efficient’ set of portfolios needs to be considered. A portfolio is ‘efficient’ if there is no other portfolio with the same risk and a higher return (or equivalently, if there is no portfolio with the same return but a lower risk). The set of efficient portfolios is illustrated in Figure 3.5 and is the solid line that is labelled ABC (Efficient Frontier).

Figure 3.5: Efficient frontier of risky assets
Investors can choose any combination of risk and return that is included in the shaded ellipse. Only portfolios along the arc ABC are efficient. The choice of efficient portfolio is determined by the individual investors preference function, expressed in terms of the utility curves. The particular investor specified in this diagram will choose the portfolio represented by point B.
Source: Constructed by author.
Given this set of portfolios the investor will decide on the most preferred portfolio by reference to his/her utility function. Only portfolios on the efficient frontier need be considered, and the optimal choice will be where the marginal rates of substitution between risk and return are equal to the marginal rate of transformation given by the efficient frontier - algebraically equivalent to the point at which the consumer’s indifference curve is tangent to the efficient frontier.

Risk is considered to be a ‘bad’ (in contradistinction to a ‘good’) since increasing the amount of risk reduces the investor’s utility. The set of indifference curves in risk:return space thus take an unusual shape. The set of indifference curves displayed in Figure 3.5 indicates that the consumer will maximize his/her utility by choosing the portfolio that has the characteristics of the point labelled B.

Markowitz’s formulation of portfolio risk has been identified as the beginning of what is now know as ‘Modern Portfolio Theory’ (Rubinstein 2002b, p.1041).

However, the restriction that the investor must choose only among a set of risky assets is artificial. The investor can always substitute the risk-free asset for one of the risky assets, and the opportunity set facing the consumer is greatly enhanced. The more realistic choice facing the investor is depicted in Figure 3.6, where the risk-free asset earns a rate of return of \( r \).

If the investor was previously constrained to choose portfolios along segment AMC in Figure 3.6, he is now able to choose along the ray \( rM \), which in all but one case (the point labelled ‘M’) dominate the segment AMC.

The significance of the portfolio at point ‘M’ is clear - irrespective of risk tolerance, every consumer will hold a combination of the risk-free asset and the portfolio labelled ‘M’. This particular portfolio is so important in the literature that it is given the label of the ‘Market Portfolio’. The portfolio M contains every asset that is
Figure 3.6: **Efficient Frontier with the risk-free asset**

Combining the efficient frontier of risky assets, represented by the arc AMC with a risk free asset, represented by the point r, changes the opportunity set from which an investor can choose. In this diagram the opportunity set is the ray rM. Individual investors choose a particular risk and return combination from the opportunity set according to their individual preferences; the investor in this case has chosen the risk and return combination represented by the point D.

Source: Constructed by author.

Individual differences in risk aversion on the part of investors is accounted for by the different weights of the risk-free asset and the market portfolio in the investors holding of financial assets. If investors are able to borrow at the risk-free rate (i.e. have negative amounts of the risk-free asset) then any position along the ray rM is feasible.
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3.4.4 The Capital Asset Pricing Model

In MPT all financial assets are reduced to only two characteristics; return and risk. The fact that one asset may be the equity of a firm that employs a relatively large proportion of intangible assets is of no consequence.

The empirical application of the model proved to be problematic. The model was adapted to better explain the market valuation of equities, but these empirically stronger results were at the expense of the rigorous theoretical underpinnings of the earlier (and simpler) approach. However these models are important and are discussed in some detail in this section; firstly, they remain the mainstream approach to the valuation of equities, and secondly the hedonic pricing model which is developed in the next chapter is based on a similar foundations (it is in fact a superset of these models).

If equilibrium prevails in the asset market, it is possible to determine the rate at which the future cash flows of any assets should be discounted, and the resulting amount will be the value (i.e. equilibrium price) of that asset. This extension to the Markowitz model is due to four authors, each of whom developed the theory independently, namely Treynor (1961); Sharpe (1964); Lintner (1965); and Mossin (1966). Initially, in order to make the problem tractable, the model was developed under the following set of limiting assumptions:

1. investors have rational expectations
2. investors are risk averse
3. capital markets are perfectly competitive
4. there are no arbitrage opportunities
5. asset returns are normally distributed
6. investors can borrow and lend any amount at the risk-free rate

7. there are no transaction costs or taxes

8. investors have a single planning horizon.

However, later work has shown that relaxing these assumptions usually leaves the results intact. An important result, known as the ‘Capital Asset Pricing Model’ (CAPM) states that the expected return on any asset is given by the following relationship:

\[ E(r_i) = C + \beta[E(r_m) - r_f] \]  \hspace{1cm} (3.4.3)

where:
- \( E(r_i) \) is the expected return on the asset of interest, \( i \)
- \( r_f \) is the risk-free rate of interest
- \( E(r_m) \) is the expected return of the market portfolio, and
- \( \beta \) is a measure of the sensitivity of the asset returns to market returns, measured by \( Cov(r_i, r_m)/Var(r_m) \).

CAPM has been widely adopted by the financial sector. It is used in portfolio management as a means of rating portfolio managers (using a reward-to-variability ratio relative to the capital market line); in corporate finance (to find the required return on capital investments); in legal claims the courts have generally accepted discount rates for valuing future claims that are based on CAPM; and regulatory bodies routinely use CAPM to calculate the cost of capital for regulated industries and firms. However, empirical tests of the CAPM have been less than encouraging.

The earliest tests (Lintner 1965, for example) found a positive and significant intercept term (whereas CAPM predicted a linear function that passed through the
origin), and a market risk premium that was significantly less than that which was observed. However, the statistical methods used in these tests were subject to criticism and much debate about the correct form of test ensued.

Roll (1977) raised a more important and fundamental objection to the empirical tests of CAPM. All empirical tests of CAPM test a joint hypothesis; that the ‘market portfolio’ is mean-variance efficient and that the proxy for the ‘market portfolio’ is accurate. The theoretical ‘market portfolio’ consist of all assets available to an investor, and includes assets such as housing, human capital (e.g. education) and other non-market assets. Roll was able to demonstrate that even a highly diversified portfolio consisting of all the current market assets does not necessarily provide a good proxy for the theoretical market portfolio (Roll & Ross 1994). Kandel & Stambaugh (1995) show that even using generalized least squares it is not possible to estimate the model correctly if the extent to which the proxy for the market portfolio differs form the theoretical market portfolio is not known.

Although the CAPM model has been extended in many different directions, these developments of the model are not pertinent to the current argument and are not pursued further.

### 3.4.5 Multi-factor Models

Partly as a response to the poor empirical qualities of the single-factor CAPM, multi-factor CAPM models were proposed. These models require the risk factors to be specified prior to the testing of the model against the available data. The risk factors should be derived from some theoretical model, or these attempts are open to the criticism of ‘data dredging’.

The most successful empirical form of the multi-factor model was developed by Fama & French (1992). This model has undergone much testing and some elaboration
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(Fama & French 1996, 2004). The generic model tests the hypothesis that there are three factors which determine the return on industrial equities; firm size, the book-to-market ratio, and the market index. The rationale for including these three factors is that each represents a different (and orthogonal) form of systematic risk. The first two factors were recognized in prior literature as factors which affect equity returns, but Fama and French were the first to test all three factors simultaneously.

The empirical test of the model consists of sorting firms into groups, based on their characteristics. Each year firms are sorted by size into small (S) and large (B) firms. The same data is then sorted on the ‘value’ characteristic of each firm (i.e. the book-to-market ratio) into low (L) medium (M) and high (H) value firms. Based on these characteristics, six portfolios are formed, as is illustrated in Table 3.2.

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>S/L</td>
<td>S/M</td>
<td>S/H</td>
</tr>
<tr>
<td>Big</td>
<td>B/L</td>
<td>B/M</td>
<td>B/H</td>
</tr>
</tbody>
</table>

Table 3.1: Fama and French portfolios

The entire set of equities is divided into six equally sized portfolios based on Size (Small, Big) and Value (Low, Medium, High).

Source: Constructed by author.

The monthly returns of each of these portfolios is calculated from the returns of the constituent equities. The differences in returns between small (S) and big (B) firms is calculated for an equally weighted (by the value characteristic) portfolio for each month:

$$SMB = \frac{1}{3}(S/L + S/M + S/H) - \frac{1}{3}(B/L + B/M + B/H)$$ (3.4.4)

Thus $SMB$ ['Small minus Big’ portfolio return] is the excess return due only to size for a portfolio of no capital cost. The same procedure is used to calculate the value
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premium:

\[
HML = \frac{1}{2}(S/H + B/H) - \frac{1}{2}(S/L + B/L) \tag{3.4.5}
\]

where \( HML \) is termed the ‘High minus Low value’ portfolio return.

The returns on the market portfolio are calculated in the usual manner (i.e. the returns on the value weighted index of all shares). The model that is estimated is thus:

\[
r_{ij} = \alpha_i + \beta_{iM}R_{Mt} + \beta_{iSMB}SMB_t + \beta_{iHML}HML_t + e_{it} \tag{3.4.6}
\]

This model provides statistically significant results over most time periods and in many differing markets, and is one of the major achievements of modern finance. There have however been criticisms of the model that relate to the extent to which the factors are truly measures of economic risk. Daniel et al. (2001) find that the factors are characteristic-based rather than risk-based factors. This research finds that:

‘…the expected returns of assets are directly related to their characteristics for reasons, such as behavioural biases or liquidity, which have nothing to do with the covariance structure of returns.’ (Daniel et al. 2001, p.744)

However the issue remains unresolved, with Vassalou (2003) arguing that the factors contain news related to future GDP growth.

The approach of Fama and French is an important advance in the theory of finance. Their models attempts to explain the value of equities in terms of the characteristics
of the firm, and are therefore based on hedonic pricing models. There is however an important difference between the Fama and French models and the model developed in this thesis: Fama and French model the value of a firm’s equity while this thesis attempts to model the value of the intangible assets that the firm owns (which may only be a small proportion of the overall value of the firm itself). [The model to be tested is fully described in the following chapter.]

3.4.6 Conclusion

Financial theory has emphasised risk and return as the determining factors in the valuation of assets. Empirical research in the equity markets has however been disappointing. As a result there have been attempts to enhance the theoretical models.

The most promising results have however been on the empirical estimation of the returns on equities (especially the Fama-French results). These empirical models do not easily relate to the theoretical framework, nor do they explicitly allow for the influence of the effect of intangible assets on the value of equities.

3.5 Valuing assets using an hedonic pricing model

3.5.1 Introduction

Assets are a natural area for the application of hedonic pricing models, and the previous descriptions of the work of both Markovitz and the CAPM are replete with descriptions of ‘risk’ and ‘return’ as characteristics of financial assets. Later studies of market inefficiencies introduced additional characteristics, such as ‘value’ and ‘growth’. In a tribute to William Moore Gorman, whose work included the theoretical implications of examining product characteristics, Honohan & Neary
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(2003) state:

‘Yet the characteristics model has assumed an empirical life of its own: far from egg or tomato markets, this insight now underpins the most widely used asset-pricing models in modern finance theory. After all, most financial assets are closely substitutable, and investors choices between them are largely driven by their potential to deliver a relatively small number of yield characteristics. Whereas Markowitz (1959) asserted that investors were seeking to balance portfolio risk and return, measured by mean and variance, modern theories allow the goals of investors to be unmeasured characteristics of the stream of future returns. Market-clearing prices of the various assets must, in these theories, be adapted to the shadow prices of these characteristics in the market just as Gorman saw. Thus, such price processes are estimated by factor-analysis type methods (Campbell et al. 1997). Even the famous option pricing model of Black & Scholes (1973) and Merton (1973) appeals to precisely the same arbitrage logic so lucidly presented by Gorman more than fifteen years earlier.’ (Honohan & Neary 2003, p.204)

3.5.2 Style investing

‘Style investing’ has been popular amongst practitioners of portfolio management since at least the early 1980’s. Although not often mentioned in the theoretical literature, this form of portfolio enhancement is well established in the industry, with most equity portfolio managers identifying themselves as either ‘value’ or ‘growth’ managers. Style investing is an application of hedonic pricing models, usually with an additional time series component. In an attempt to define ‘style investing’ Bernstein (1995) offers the following:
'A simple definition, therefore, of equity segments might be groups of stock with similar characteristics that tend to perform as a group over several economic and market cycles. Anomalies are market segments that cannot be explained by traditional risk models. Style investing is that done in an attempt to exploit market anomalies.' (Bernstein 1995, p.3)

There has been some empirical support for style investing. In the UK the ‘small versus large’ portfolio combined with a rotation strategy (where the portfolio manager switches between growth and value stocks based on the state of the economic cycle) has proven to be a profitable strategy over a thirty years window period; however a static ‘value versus growth’ portfolio has not outperformed the market (Levis & Liodakis 1999). Some support for momentum strategies is found by Barberis & Shleifer (2000). However, there is little general support to be found in the empirical studies of style investing (Pomorski 2004).

Financial assets are thus easily incorporated into the hedonic model. Modern Portfolio Theory can be interpreted so as to imply that there are only two characteristics that are of any significance; ‘risk’ and ‘return’. Both these attributes conform to the additional assumptions that are required for the hedonic pricing model (see Section 3.3.3).

Since ‘risk’ is a ‘bad’ (in contradistinction to a ‘good’ in economic parlance) the direction of the preference mapping is reversed; ‘less’ is better than ‘more’ in this case. To preserve the graphical model of the previous section, it is only necessary to introduce the complement of ‘risk’ (for example, a measure of how ‘certain’ an income stream might be). Under these conditions, and using a transformation of ‘beta’ that represents ‘certainty’, Figure 3.4 could then equally well represent the choice facing investors where there are only two characteristics of concern.
Chapter 3. Research issues in hedonic pricing theory and the valuation of financial assets

The following important propositions follow immediately from formulating the choice of financial assets in this manner:

**The shape of the choice set.** The shape of the choice set depends only on the available set of assets and the ‘technology matrix’ that transforms each asset into the set of characteristics. The shape of the choice set is the same for all investors and changes only slowly over time. The shape of the choice set will change as the equity of new firms enter the market, and the ability of firms to produce the desirable characteristics changes. This latter aspect may be due, for example, to advances in financial engineering which reduce the riskiness of the resultant income stream.

Since goods other than financial assets do not produce the characteristics of financial assets, changes in the price or quantity of these goods will have no effect on the choice set that is of interest in the current study. This is a general characteristic of the hedonic model; the ability to partition goods into sets which have no influence on unrelated sets. [In the neoclassical model all goods affect all others, since the marginal utility per unit of expenditure must be the same for all goods.]

**Aggregate demand for characteristics.** Each investor will choose that combination of assets which give him/her the highest possible utility. This combination is represented by the highest indifference curve which is obtainable (either tangent to a facet on the the budget set, or at one of the apexes). The aggregate demand by all investors is simply the sum of the demand by individual investors (as in the neoclassical model).

**Asset prices reflect aggregate.** In equilibrium the price of each asset reflects the sum of the value of each of the characteristics with which it endows the holder of that asset. In order to illustrate this, consider a simple situation when this
does not apply. Reconsider the previous arithmetic example and replace the items that the consumer chooses amongst with assets rather than consumer goods. Consider the case where the price of asset $x_2$ is so high that if the entire budget was spent on that asset, the bundle of characteristics $(z_1, z_2)$ would be given by the point $z^4$ in Figure 3.7; all other conditions in the previous example remain unchanged.

![Budget constraint in Characteristic-space, with Asset $x_2$ mispriced](image)

**Figure 3.7: Budget constraint in Characteristic-space, with Asset $x_2$ mispriced**

*In this example the price of Asset $x_2$ is too high. If only this asset is held the bundle of characteristics is inferior, and the investor will do better by purchasing a combination of the other two assets. The price of Assets $x_2$ will fall until $z^4$ is on the efficiency frontier.*

*Source: Constructed by author.*

Since all assets contain the characteristics $z_1$ and $z_2$, investors can obtain the combination of $z_1$ and $z_2$ that is given by the asset $x_2$ at less cost by purchasing a suitable combination of assets $x_1$ and $x_3$. With demand for $x_2$ depressed,
the price of the asset falls; which has the effect of moving the point \( z^4 \) along the ray \( 0A \) in Figure 3.7 until, at the very least, \( z^4 \) lies on the boundary of the efficient set. There is however no reason for the price to fall so that the efficient set once again resembles that of Figure 3.4.

In equilibrium the prices of assets reflect the value of their characteristics.

Once equilibrium has been reached, the price of each asset is composed of the quantity and value of each of its characteristics. The ‘prices’ of the characteristics however are not directly observable; and are therefore referred to as ‘shadow prices’. The crucial result is that given the prices of the financial assets and the characteristics of these assets, it is possible to discover the ‘shadow prices’ of the characteristics.

### 3.6 Conclusion

This chapter discussed the neoclassical foundations for the pricing of goods in general and of assets as an extension of the general neoclassical model. The hedonic pricing model incorporates the neoclassical model as a special case and this model was discussed in detail. Examples of the application of the hedonic model were discussed and the lack of the explicit application of this model to financial assets was noted.

The methods of estimating the prices of assets has undergone significant change over the last 60 years. The contributions of Benjamin Graham and Harry Markowitz were discussed, as well as the evolution of modern portfolio theory and the capital pricing model. The importance of multi-factor models and the practical importance of the Fama-French studies was then discussed in detail.

Finally this chapter discussed how the modern models of equity valuation can be placed in the form of an hedonic model. It was argued that this is not only a cosmetic
change, but that this reformulation allows the full strength of hedonic models to be explicitly evoked. The following chapter does precisely this, by investigating the use of hedonic models to price the intangible assets that are held by publicly listed firms.
Chapter 4

Methodology

4.1 Introduction

Previous chapters have discussed the nature of intangible assets and the hedonic pricing model. This chapter critically examines the various methods that could be used to value intangible assets held by firms, and argues that the hedonic pricing model is in general superior to the alternative methods.

Almost all methods of valuing financial assets are based on comparison of the asset to be valued with other similar assets for which a value is already known. The concept of ‘market value’ is thus the basis for all other forms of valuation and is discussed in detail in this chapter. The use of ‘relative valuation’ models, discounted cash flow models, and contingent claims models are then examined. Each of the valuation models is discussed in relation to intangible assets and the difficulty of applying each model in this context is examined.

In the previous chapter the hedonic pricing model was shown to encompass most other valuation models, and this chapter proceeds to examine how the hedonic model can be applied to value intangible assets. Figure 4.1 illustrates the relationship between the differing techniques for the valuation of various types of assets.
Homogeneous assets that are traded in active markets are valued by reference to the current market price; this can be reformulated as a restricted hedonic model where each asset has only one characteristic.

Hedonic pricing models were developed to overcome the problem of pricing differentiated goods (as discussed in Section 3.3). Hedonic pricing models examine the characteristics of the goods, which are often the same across groups of goods, rather than the physical goods themselves.

The proposition that ALL assets share common characteristics is very common in the field of finance - the usual characteristics of interest are the ‘net cash flow’ and the variability of that cash flow (‘riskiness’) generated by the asset. It is commonly assumed that any asset can be valued in this manner, provided that the cash flows and their risk can be identified. However where the cash flows of a specific asset cannot be separated from those of other assets of the firm, other methods of measuring the contribution of that asset to the profitability of the firm are often feasible; the problem is to identify and price such characteristics.

It is important to note that the characteristics of interest are those of the FIRM, and only indirectly those of the asset itself. These characteristics relate to the ability of the firm to create profits. The existence of the particular asset enhances the firm’s profitability, and the profitability of the firm is reflected in the price of that firm’s equity. Thus it is not necessary to find the characteristics of the asset itself, but the characteristics of the firm which are changed by the presence of the asset. This implies that all assets may be valued in this manner, although the basis for valuation will differ with the circumstances, and alternative methods may be more efficient in deriving a value (Section 4.2 Evaluation of alternative approaches to estimating the value of financial assets discusses these issues in detail).

Differentiated assets are similar to each other in that they have varying bundles
of the same characteristics. Assets of this class are best valued using an hedonic model if the characteristics can be readily measured. As an example, the discounted cash-flow valuation techniques used to value firms are simple hedonic models with two characteristics; free cash flow and risk.

<table>
<thead>
<tr>
<th>Type of asset</th>
<th>Example</th>
<th>Comparison / characteristic</th>
<th>Model</th>
<th>Valuation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homogeneous asset, active market</td>
<td>gold</td>
<td>not required</td>
<td>Supply = Demand</td>
<td>current market price</td>
<td>neoclassical pricing model</td>
</tr>
<tr>
<td>Differentiated asset, active market</td>
<td>diamonds</td>
<td>size, clarity, purity, ...</td>
<td>Hedonic, n characteristics</td>
<td>$V = \sum x_i p_i$</td>
<td>Prices derived from actual sales.</td>
</tr>
<tr>
<td></td>
<td>houses</td>
<td>location, size, finishes, amenities</td>
<td>ditto</td>
<td>ditto</td>
<td>Stale prices, measurement of some characteristics difficult</td>
</tr>
<tr>
<td></td>
<td>firms</td>
<td>expected cash flow, risk</td>
<td>Hedonic, 2 characteristics</td>
<td>$V=\text{DCF}$</td>
<td>CAPM to price risk</td>
</tr>
<tr>
<td>Intangible asset, non tradable</td>
<td>core competence</td>
<td>enhanced performance of the firm</td>
<td>Hedonic, n characteristics (measured by financial ratios)</td>
<td>$V=\Delta \text{value of the firm}$</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.1: **Relationship between valuation models and asset types**

The relationship between the proposed model to value intangible assets and other valuation models is illustrated in this figure. Each class of asset requires a different valuation technique; however each technique is shown to be a restricted form of the hedonic pricing model.

Source: Analysis by author.

For intangible assets the application of hedonic pricing models follows directly from the above models, save only that the characteristics of intangible assets are not directly observable. It is suggested that the relevant characteristics can be estimated by the increase in the financial performance of the firm that employs such assets. The value of the intangible asset would then be the increase in the value of the firm that is due to enhanced performance.
If the hedonic model is to be implemented, the problem of specifying the characteristics of firms must be resolved; especially with regard to the intangible assets employed by firms. The evolving Extensible Business Reporting Language (XBRL) implementation is discussed in Section 4.3.3.2, and the possibility that this standard will make the specification of the characteristics of firm a central feature of equity finance is investigated. The use of DuPont ratios is suggested as an initial method for measuring the characteristics of firm performance that are related to the presence of intangible assets.

The objective of the thesis is to investigate the suitability of using an hedonic pricing model as a means of valuing intangible assets held by firms. This requires the formulation of a model that relates the value of such assets to the characteristics of the firm, and the specification of a set of hypotheses that can be used to empirically test the existence of such relationships. The final section of this chapter develops a structural model that is compatible with both the financial literature as well as hedonic pricing theory and specifies a set of hypotheses that can be used to test the empirical validity of the model.

### 4.2 Evaluation of alternative approaches to estimating the value of assets

#### 4.2.1 Introduction

Each of the various methods for valuing assets will be optimal in some circumstances; and inappropriate in others. The skill of the valuator is to choose the best technique, given the idiosyncrasies of the asset to be valued. In practice more than one approach can be used, and the various estimates provide the bounds to the final valuation.
Chapter 4. Methodology

The most appropriate method for a particular asset depends on the information available at the time of the valuation and the characteristics of the asset itself. Damodaran (1996) warns that:

‘At the risk of stating the obvious, the model used in valuation should be tailored to match the characteristics of the asset being valued. The unfortunate truth is that the reverse is often true. Time and resources are wasted trying to make assets fit a prescribed valuation model, either because it is considered to be the “best” model or because not enough thought goes into the process of model choice. There is no one “best” model. The appropriate model to use in a particular setting will depend upon a number of the characteristics of the asset or firm being valued.’

(Damodaran 1996, p.502)

This section of the study critically examines the various methods for valuing assets.

4.2.2 Market valuation


The term ‘market value’ has a technical meaning in the financial literature. The International Valuation Standards Committee (2005) defines market value as:

‘The estimated amount for which a property should exchange on the date of valuation between a willing buyer and a willing seller in an arm’s-length transaction after proper marketing wherein the parties had each acted knowledgeably, prudently, and without compulsion’. (International Valuation Standards Committee 2005, p.27)
The other definitions of the term are operationally very similar. For example the US Financial Accounting Standards Board (FASB) has an equivalent (but much longer) definition of market value. The Internal Revenue Services of the US use the following wording:

‘The price at which the property would change hands between a willing buyer and a willing seller, when the former is not under any compulsion to buy and the latter is not under any compulsion to sell, both parties having reasonable knowledge of relevant facts. The buyer and seller are assumed to be able, as well as willing, to trade and to be well informed about the property and matters concerning the market for such property.’

Based on the definition used by the Internal Revenue Services (United States of America) ruling 50-60, Section2

These definitions of market value presuppose the existence of a well functioning market. In such a market the Law of One Price will hold; this states that at any given point in time and under a set of ideal conditions, all units of a homogeneous good will sell for the same price.

The Law of One Price is one of the fundamental principals on which much of the theory of finance is built. All methods of valuation rely upon this condition. Each method of valuation compares the asset to be valued to a similar asset (or combination of assets) which has been priced in an efficient market.

Empirical studies of consumer markets reveal that prices for many supposedly homogeneous products (e.g. petrol, books, compact disks and sugar, to name a few) showed remarkable variations in price for almost identical goods. Baye et al. (forthcoming) concludes that:

‘The empirical evidence suggests that price dispersion in both on-line
and offline markets is sizeable, pervasive, and persistent - and does not purely stem from subtle differences in firms’ products or services.’ (Baye et al. forthcoming)

These observations reinforce the earlier suppositions of Stigler (1961) and Varian (1980), who attribute price variations to the presence of information costs.

In the major financial markets however the Law of One Price is largely empirically valid. There have been consistent policy formulations amongst market participants and regulators to reduce information costs wherever possible. These endeavours have been very successful, and are one of the major reasons for the rapid growth in financial markets over the last few decades. Current practice:

‘regulates the listing, selling, and buying of shares in publicly traded companies and monitors the trading practices of investors, brokers, dealers, and exchanges.’ (NASDAQ 2006, p.1)

Such regulations include prohibitions on ‘insider trading’. Proposed new regulations by the US Securities and Exchange Commission (Securities and Exchange Commission 2004) will further enhance information flows. Amongst the recommendations are plans for:

‘. . . disseminating market information to the public that, among other things, would modify the formulas for allocating Plan net income to reward markets for more broadly based contributions to public price discovery. . . . Under the current formulas, the allocation of Plan net income is based on the number or share volume of an SROs reported trades. Although quotes are disseminated by the Networks, these current trade-based formulas do not reward those market centers that generate quotes with the best prices and the largest sizes that are an important source
of public price discovery.’ (Securities and Exchange Commission 2004, p.11126)

While financial markets do not display the same price dispersions as markets for consumer goods, the question of designing the most efficient market structures is complex and ongoing (Madhavan 2000).

The market price (if available) may be the best indicator of the value of a financial asset, for example; the markets for foreign exchange, the bullion market, and the gilts markets. These markets approach the theoretical ideals of a competitive market; there are a large number of well-informed buyers and sellers and the product is homogeneous, divisible and can be stored at (relatively) low cost. The nexus between the market price and the intrinsic value of an asset is ensured by the presence of arbitrage. These markets are also highly liquid, although in times of crisis this liquidity may disappear.

Under this approach the asset to be valued is compared to a similar asset for which a market price is readily available. For example, the value of the coupon payments of a Treasury Note could be separated from the Note (in a process known as ‘stripping’ (Elton & Gruber 1995, p.495)), that produces a new financial asset. The value of the new asset is easily estimated by using the treasury yield curve; even if there is no asset which is traded that exactly matches the new asset’s cash flow and risk.

Even under these ideal circumstances it is possible to construct models where the market price may deviate significantly from the intrinsic value of the asset for significant periods of time. The relatively recent models of behavioural finance emphasize mis-pricing, non-rational decision making, and return anomalies; DeBondt & Thaler (1989), Tversky & Thaler (1990) and Shleifer (1999).
**Application of market valuation models to intangible assets**

In almost all circumstances, intangible assets do not lend themselves to valuation via this approach. Intangible assets can not normally be described as homogeneous, nor is perfect and complete knowledge of these assets a reasonable assumption. Markets for intangible assets often do not exist in any meaningful sense.

### 4.2.3 Relative valuation models

Where assets share many similar features, yet remain different in a few important respects, the concept of ‘market valuation’ can be adapted to calculate the value of such assets. This approach is common where the sale of identical assets are rare, but sales of similar assets occur frequently. These models are referred to in the literature as relative valuation models.

Sets of similar assets can be conceived of as forming a separate market. The value of each asset is then thought of as comprising two elements:

1. the mean value of the group,
2. an adjustment for the difference between the specific asset and the group.

**An example**

In its simplest form this technique ‘standardizes’ a group of assets on a single criteria. As a naive example consider valuing a firm which is not listed on the stock market. Firstly, a group of firms which are listed on the stock market is chosen by selecting all firms with the same industry classification as the firm to be valued. Next, assume that the best method of comparing the firms is to use the price/earnings ratio. If the price/earnings ratio for the group is (say) 27, this is assumed to be the ‘correct’
value for this ratio (it is the mean value for all the firms in the industry group). The firm to be valued should then also have a price/earnings ratio of 27. If the firm to be valued has expected earnings of $0.5 mill., the value of that firm would equal the price which yields a price/earnings ratio of 27:

\[ \frac{\text{price}}{\text{earnings}} = \frac{\text{price}}{0.5 \text{mill}} = 27 \]

\[ \Rightarrow \text{price} = 54 \text{mill.} \]

This simplistic example is in fact a common choice amongst equity analysts for valuing firms, but is subject to numerous shortcomings:

The results are sensitive to the choice of assets in the comparable group.

There is no \textit{a priori} method of selecting this group, and the skill of the analyst is an important factor in the reliability of the results.

Bias in the composition of the comparable group. For example; one firm might be the subject of a hostile takeover attempt. The observed values might thus be far from the true mean.

Results are sensitive to changes in market sentiment. If the market has received a ‘shock’ shortly before the valuation occurs the resulting value will be unduly influenced by these recent events and not be an unbiased measure of the value of the firm under consideration.

It is possible to adjust the relative valuation method to deal with many of these difficulties. Multiple regression analysis can be used to identify the gross impact of accounting variables on the chosen multiple, and the firms then placed in rank-order. Firms which lie close to each other are then used to form the comparable group. Bhojraj & Lee (2002) conducted such a study and found useful results. Cohen (2005) has suggested an alternative method of overcoming these limitations by using the
entire market as the comparable group:

‘The method is based on a coordinate transformation or mapping, which enables one to weigh the index against the aggregated earnings and GDP. This, therefore, gives rise to the notion of relative valuation between the index, the earnings and the GDP.’ (Cohen 2005, p.99)

Relative valuation models are often used in practice to value firms whose shares are not listed on an equity market. Examples include IPO’s and new firms that result from merger and acquisition activity. The term ‘multiples analysis’ is occasionally used in the literature to describe this type of valuation. Similar methods are also used to value buildings and land, and even works of art.

Relative valuation models can then yield useful measures of value, although Courteau et al. (2006) find that the direct valuation of a firm (using some form of discounted cash flow, which is discussed below) yields more accurate results than the relative value techniques. The authors conclude both methods (direct valuation and relative valuation) are important:

‘a simple combination of the two approaches yields intrinsic value estimates that outperform either method used in isolation’ (Courteau et al. 2006, p.573)

Application of relative valuation models to intangible assets

The use of comparables to value assets depends crucially on the existence of a group of similar assets for which market determined prices are available. This is unlikely in the case of intangible assets in general.

Intangible assets are often not easily traded; they may be bundled with and inseparable from other tangible assets (for example; customer loyalty and IT infrastructure).
Even if the intangible asset is separable from other assets, it may prove difficult to market since, for example, disclosure of the information of the asset may lead to its replication, with concomitant loss in value (for example; business strategy). The lack of market prices in general and the difficulty of forming a reasonable group for comparison precludes the general use of this method for intangible asset valuation.

There are however rare occasions when a form of comparable valuation is possible for intangible assets. If two similar firms, both of which are listed on an equity exchange, differ only in respect to the possession of one major intangible asset, then the value of the asset may be determined by the premium that the firm with the intangible asset is able to earn on its equity. Choi et al. (2000) use a set of ‘matched pairs’ of firms (i.e. similar in terms of total assets, book value of equity, earnings, and SIC code) but differing in the level of intangible assets reported in the financial accounts (one set of firms with high intangible assets, the other with zero reported intangible assets). The authors are interested in the effect of reporting intangible assets and the valuation of the firm’s equity, and find that:

‘The results indicate that the financial market positively values reported intangible assets. Furthermore, consistent with theoretical predictions, the market’s valuation of a dollar of intangible assets is lower than its valuation of other reported assets. . . . These results support the current requirement that intangible assets be reported in firms’ balance sheets. (Choi et al. 2000, p.35)

While this is an important result, it is concerned with the reporting of intangible assets rather than the valuation of these assets. Nor can this methodology readily be used to value individual intangible assets, since the explanatory variable is the value of all intangible assets as reported in the firm’s published financial statements. While not providing a measure of value, the study does however suggest that an
efficient equity market recognizes that intangible assets add value to the firm (and in a similar manner that tangible assets add value).

### 4.2.4 Discounted cash flow models

The Discounted Cash Flow (DCF) technique utilizes a different method to compare similar assets. Instead of finding assets which are similar in appearance or structure (i.e. firms in the same industry), the DCF techniques compares assets with similar cash flows and risks.

This technique is commonly used to value the equity of firms. The approach is not new, Rubinstein (2002a) observes that:

> ‘John Burr Williams (1899 - 1989), the author of the insufficiently appreciated classic The Theory of Investment Value (1938), was one of the first economists to interpret stock prices as determined by “intrinsic value” (that is, discounted dividends).’ (Rubinstein 2002a, p.6)

When this technique is applied to the valuation of firms, differing definitions of cash flow (and their associated risk) may be used in the valuation. The most general approach is to value the Free Cash Flow (FCF) to the firm, discounted by a risk-adjusted rate of interest, where the risk is given by Weighted Average Cost of Capital (WACC). Thus the value of the firm would be calculated as:

\[
NPV = \sum_{t=0}^{\infty} \frac{FCF_t}{(1 + WACC)^t}
\]  

(4.2.3)

where:

- \(NPV\) is the Net Present Value of the firm, and thus its value
- \(t\) is the time period
- \(FCF\) is the free cash flow to the firm
WACC is the weighted average cost of capital for the firm.

The following difficulties arise in the application of the generic DCF model:

**The difficulty in predicting future cash flows.** Given the limited knowledge of future events, this is an onerous task. In practice detailed cash flows are forecast for the next five years or so, and then a (constant) growth rate is used to forecast over the remaining period. A volatile business environment increases the difficulty of these forecasts; and it is usual to use conditional forecasts in scenarios of this kind.

**The relationship between the growth rate and the discount rate is non-linear.** If the discount rate is less than or equal to the implied growth rate of the cash flows, the equation 4.2.3 is undefined. When the growth rate is very close to the discount rate, the NPV is very sensitive to small variations in either of these variables. Since these values are subject to estimation error, the resulting valuation may have a large variance.

**The discount rate is subject to error.** While it is essential to use a discount rate to incorporate future cash flows, the estimation of the discount rate is subject to a large degree of subjectivity. Penman (2006) is very critical about this aspect of valuation:

‘*All valuation models incorporate a discount rate ... and a desired valuation can also be justified by the choice of discount rates. Despite considerable effort to develop so called “asset pricing models,” we really do not know how to quantify discount rates. The premier model, the Capital Asset Pricing Model (CAPM), is another formula, among many, that encourages playing with mirrors; the due diligence team and valuation expert know well that changes*’
in beta estimates or in the market risk premium (which is essentially a guess) have a significant effect on the discount rate and the value calculated.’ (Penman 2006, p.49)

Valuations can be easily manipulated. The sheer number of variables that are needed in this approach to valuation allow the final valuation to be adjusted to suit the requirements of the person conducting the valuation:

‘The concept of future prospects and particularly of continued growth in the future invites the application of formulas out of higher mathematics to establish the present value of the favored issue. But the combination of precise formulas with highly imprecise assumptions can be used to establish, or rather justify, practically any value one wishes, however high, for a really outstanding issue.’ (Graham 1973, p.315)

Despite these difficulties, the technique continues to be the most popular method of valuing firms in the academic literature (Damodaran 1996, Koller et al. 2005). There have also been significant improvements in dealing with the underlying problems of the approach (Penman 2006).

Application of discounted cash flow models to intangible assets

It is possible to use the DCF technique to value certain classes of intangible assets. If the asset is well defined, the cash flows associated with that asset are able to be clearly defined and predicted, and the risk of those cash flows can be estimated then the method is easily applied. Applying the DCF technique to value intangible assets is however often problematic. Firstly the marginal cash flows that accrue to the intangible asset may be even more difficult to predict than for the firm as a
whole. Secondly, the assessment of the risk that the intangible asset adds to the enterprise is not easily quantified.

4.2.5 Contingent valuation techniques

At times an asset may yield not only an income stream, but also a considerable degree of flexibility in the manner in which it is used in the future. This flexibility is valuable to the firm, although the value does not appear in the discounted income stream. In such cases the investment contains what have been called ‘real options’ (in contradistinction to ‘financial options’). At the time of the valuation full knowledge of future events is not possible; this is thus a case of true uncertainty rather than risk. Under these circumstances conventional probability techniques (which rely on being able to specify the outcome space) are not helpful.

Real options may confer a mixture of the following benefits on the firm:

- the option to defer a commitment until more is known,
- the option to expand the scale of operations,
- the option to divest or reduce operations.

These options are valued using a variety of techniques. Originally Black-Scholes techniques (Black & Scholes 1973) (Merton 1973) were used, but the assumptions of normally distributed asset returns, constant volatility and fixed interest rates are not ideal. Monte Carlo techniques have proven to be popular but are difficult to use for American type options (which most real options are) (Glasserman 2004). The binomial lattice approach is the most flexible and has the advantage of being easily understood by management (Cox et al. 1979). However, it is not the technique as much as the lack of suitable data that make these valuations difficult.
Chapter 4. Methodology

Application of contingent valuation techniques to intangible assets

Intangible assets have many option-like qualities, making these techniques of valuation an attractive choice. For example, a large part of the value of a well trained and educated workforce is the ability to change course quickly in a volatile environment (or at least more quickly than the competition).

However, of all the techniques, contingent valuation requires the most idiosyncratic data and information. If a critically important asset has significant optionality then this method of valuation is paramount. The level of detailed knowledge required to undertake such a valuation however makes each valuation procedure unique, and therefore this technique is not suitable for intangible assets in general.

4.3 Using hedonic pricing models to value intangible assets

4.3.1 Introduction

The various approaches to the valuation of assets that were discussed in the previous section all have shortcomings when applied to the valuation of intangible assets. In some circumstances one of these methods might be the optimal approach, because of the idiosyncratic characteristics of the asset, but none are suitable as a generic solution.

Hedonic models may seem to be a strange approach to valuation, however much of the investment literature uses the language of the hedonic approach to describe financial assets, and this is especially the case in equities and equity portfolios. The contention of this thesis is that the hedonic model is a suitable generic method for valuing intangible assets. The argument is developed as follows; firstly the current
conventional theory of equity valuation is shown to be fully consistent with the
hedonic approach, the quantification of the characteristics of intangible assets is
then considered, and a structural form of the model is specified. Once the model is
specified a number of hypotheses that may be used to verify the model flow from
the model specification itself. Since the model derives from the theory of hedonic
pricing, so do the hypotheses. The empirical testing of the hypotheses is the subject
of the following chapter.

4.3.2 Equity valuation and hedonic models

This section discusses how the hedonic approach to valuation can be seen as a
super set of the conventional techniques currently used to value equities. This adds
credence to the use of the hedonic model to value the intangible assets held by firms.

There is little direct reference to hedonic models in the literature that is concerned
with the valuation of equities. This seems odd, since the language of investment
analysis is peppered with allusions to the characteristics of financial assets.

In order to compare the return of various equities the concept of Total Shareholder
Return (TSR) is normally used:

\[
TSR = \frac{P_1 - P_0 + D}{P_0}
\]  

(4.3.1)

where:

*TSR* is the return to the shareholder over a given period of time,

*P_t* is the price of the equity at time *t*, *t = 0* signifies the beginning of the period and

*P_t* = 1 the end of the period,

*D* are the dividends (if any) paid during the period.

TSR provides an appropriate basis for the comparison of different equities, and a
higher expected return per unit of investment (which is what TSR measures) is more desirable, ceteris paribus. Much of the investment literature uses the concept of TSR (rather than the price of the equity) as the variable to be explained. Since TSR is not known with certainty at the beginning of the period, it is usual to explain the expected return, denoted by \( E[R_i] \), which is read as “the expected return of equity \( i \) over the period”.

There has been much research on the factors that determine the return on equities, since a superior model holds the promise of profitable trading opportunities in equity markets. This section of the study re-states the well-known models of equity valuation in terms of an hedonic approach.

**The Single Index Model.** In the neoclassical model the only characteristics of financial assets are risk and expected return. In a well diversified portfolio the effect of idiosyncratic risk would be eliminated, leaving only systematic risk. The relationship can be specified as follows:

\[
E[R_i] = f(Risk_i)
\]  

(4.3.2)

where \( E \) is the usual expectation operator. Re-stated in words; the expected return on an equity is a function only of the riskiness of the income stream of that equity.

This approach is made more specific by introducing the assumptions of the Capital Asset Pricing Model (CAPM); these assumptions were fully discussed in Section 3.4.4. Under these conditions the following empirical relationship can be expected to hold:

\[
E[R_i] = R_f + \beta_{i,M}(R_M - R_f)
\]  

(4.3.3)
where:

\[ E[R_i] \] is the expected return on equity \( i \),
\[ R_f \] is the return on the risk-free asset,
\[ \beta_{i,M} \] is the correlation coefficient of the returns of equity \( i \) and the return of the market,
\[ R_M \] is the return on the market.

**The Multi-factor Model.** There are various problems in the application of the CAPM model (these were discussed in Section 3.4.4.) While there have been different attempts to overcome these difficulties, the most influential of these is the approach of Fama & French (1992, 1996). Fama & French extend the model by introducing additional characteristics that represent differing forms of risk (as discussed in detail in Section 3.4.5.) The form of the model used can be expressed as follows:

\[
E[R_i] = f(Risk_i) \quad (4.3.4)
\]

\[
Risk_i = g(MRP, SMB, HML) \quad (4.3.5)
\]

where:

- \( MRP \) is the market risk premium
- \( SMB \) is the excess return of small capitalization equities over large capitalization equities
- \( HML \) is the excess return of high book/price equities over low book/price equities.
Chapter 4. Methodology

The equations 4.3.4 and 4.3.5 are estimated by assuming that the system takes the following structural form:

$$R_i = R_f + \beta_i,M[R_M - R_f] + \beta_i,S SMB + \beta_i,V HML$$  \hspace{1cm} (4.3.6)

where:

$\beta$'s are the sensitivities of the equity to each of the factors.

This formulation of the model has been successfully applied to many different economies, and over many differing periods of time. There is however little theoretical basis for the importance of these particular variables (this was more fully discussed in Section 3.4.5).

**A general hedonic model of equity returns.** In the most general terms an hedonic model of equity returns can be specified as:

$$E[R_i] = f(Risk_i, C_{1...m})$$  \hspace{1cm} (4.3.7)

$$Risk = g(C_{(n+1)...n})$$  \hspace{1cm} (4.3.8)

where:

$C_j$ represents the $j$’th characteristic.

The discovery of the characteristics other than risk is really a matter of empirical investigation. This formulation is general enough to provide a model of the return to equity, but imparts no knowledge of which explanatory variables to use. Any of the generally accepted models of equity valuation are readily seen to be restricted
forms of this model.

The application of an hedonic model to explain equity returns is an important topic, and further investigation into its use is a valid research project. To be useful as an empirical model of equity valuation all the possible characteristics that are important to different groups of investors would need to be incorporated into the analysis. Whilst this is possible it is not necessary to fulfil the objectives of this thesis; rather a partial model will suffice. It is only necessary to consider those characteristics of the firm that are affected by the presence (or absence) of intangible assets in order to value these assets. This forms the subject of the following section of this chapter.

4.3.3 Deriving the value of intangible assets from the hedonic model of equity valuation

If the valuation of the equity can be explained in terms of an hedonic model, can the intangible assets that are owned by the firm be valued using this model? In general the answer must be in the affirmative if intangible assets provide an observable set of characteristics that can serve as inputs into the hedonic model.

To this end, it is useful to conceive of the value of intangible assets in terms of the contribution that they make to the profitability of a firm. For example, the value of a brand name is often associated with lower costs of market penetration, and higher margins. Likewise, a skilled and contented workforce (undoubtedly an asset, and intangible) results in more efficient production, fewer defects, etc. It is possible to describe most intangible assets employed by firms in terms of their contribution to the profitability of the firm. This approach forms the basis for the valuation of intangible assets in this study.
Quantifying firm characteristics that pertain to intangible assets.

Intangible assets are treated differently to tangible assets in the published financial reports of a firm’s performance. If it were not for this difference, there would be less interest in studying intangible assets. Investors would simply treat intangible and tangible assets as similar when deciding on the future performance (and hence value) of the firm. Managers of firms, who are able to evaluate alternative investments in greater detail, do not usually base investment strategies on a preference (or otherwise) for intangible assets over tangible assets. It is true that the cost of financing an intangible asset may be greater than that of a tangible asset, but this difference is subsumed in the rate at which the future cash flows are discounted. This point has been eloquently made by Webster:

‘Once it is accepted that investment comprises any present outlay which promises to reap a future reward - the field naturally opens to include all varieties of intangible capital such as the acquisition of knowledge, and the ability to control the firm’s internal and external environment by changing the organization, industrial relations systems, labour skills and by enhancing market access and protective rent-producing barriers. Intangible investment activities should not be limited to research and development and commercially successful innovations.’

(Webster 1999, p.20)

Once the investment decision has been taken, the effect on the financial reports will depend very much on the intangibility of the assets that are to be acquired. Given this asymmetry, the effect of (unreported) intangible assets can be expected to appear as improvements in the operational efficiency of the firm over time. Typically, a single investment in a large intangible asset would initially increase operating expenses (and reduce profitability), and later appear as an increase in profitability.
(with no matching expenditure).

One method that investors adopt to deal with this problem is to ‘rework’ the financial accounts of the firm, writing up the expenditure on intangible assets, and then depreciating them over the appropriate period of time. While the methodology is sound, the information needed to reconstruct the financial reports is very onerous, and often not available.

An alternative method of dealing with intangible assets is to examine the effect of such intangible assets on the reported results of the firm. Firms that employ larger quantities of intangible assets will have different reported characteristics to firms that do not. This section of the study investigates which characteristics of the firm should be observed in order to discover the effects of intangible assets.

Consider a firm that is about to make a new investment. Since the management of the firm is assumed to act rationally, the investment will add to the value of the firm (the new investment will yield a non-negative discounted net cash flow). The value of the firm’s equity will rise as a consequence; it is now more desirable than before the investment.

If there are objective measures of this increase in the firm’s efficiency and if these measures can be readily discerned, then there is every reason to suppose that the market for equities would ‘price’ these characteristics of individual firms. An hedonic model would then be the appropriate method to retrieve such ‘shadow prices’, and these prices could be used in the valuation of any proposed asset (tangible or intangible). Occam’s razor would suggest that other methods of valuation are more appropriate for most tangible assets, but that this might be the most efficient approach for intangible assets.
Extensible Business Reporting Language and firm characteristics

Observations of the performance of a firm derive mainly from the financial reports of the firm. Other sources of information (news releases, interviews with directors, etc.) are important adjuncts, but are not usually sufficient to form an accurate assessment. The timely and accurate availability of financial reporting information is thus of great importance.

It is common for the financial reports of many large firms to be collated and entered into financial databases. These databases are one of the core resources used in the analysis of firms performance, and in the selection of relative weights for firms in investment portfolios. There are two major difficulties with the current process. Firstly, the procedure is prone to errors in the collection, aggregation and entering of the actual numbers. Secondly, and perhaps more importantly, the differences in the use and interpretation of GAAP may lead to very different treatments of the reported quantities, both between firms and in the same firm over time. A pertinent example is the quantification of ‘Research and Development’ expenditures, which may appear as entirely expenditure, partly capitalized (at cost, or by some other means) or fully capitalized.

The advent of computerization of the financial records of firms has led in turn to the low cost of the dissemination of detailed financial results. The Extensible Business Reporting Language (XBRL) has been developed in order to provide a mechanism that ensures that important information about how accounting quantities were derived is not lost in the reporting process. This is accomplished by using a variant of the mark-up language XML (Extensible Mark-up Language). Although the implementation of XBRL is somewhat technical (and still incomplete in minor areas), the concept is simple. Each item of data is ‘tagged’ to identify the manner in which it was computed, with reference back to the actual GAAP treatment where necessary.
The result is that:

‘Computers can treat XBRL data “intelligently”: they can recognise the information in a XBRL document, select it, analyse it, store it, exchange it with other computers and present it automatically in a variety of ways for users. XBRL greatly increases the speed of handling of financial data, reduces the chance of error and permits automatic checking of information.’

source: http://www.xbrl.org/WhatIsXBRL/

The use of XBRL seems assured. In 2005 the Federal Financial Institutions Examination Council (FFIEC) in the US implemented a new reporting system for the banking sector:

‘The new system, known as the Central Data Repository (CDR), is the first in the U.S. to employ XBRL on a large scale and represents the largest use of the standard worldwide. The CDR uses XBRL to improve the transparency and accuracy of the financial reporting process by adding descriptive tags to each data element. The overall result has been that high-quality data collected from the approximately 8,200 U.S. banks required to file Call Reports is available faster, and the collection and validation process is more efficient.’

(Wisnieski & Deaton 2006, p.5)

The results appear to have met the expectations of all the parties involved.

In order to assess the XBRL project, the U.S. Securities and Exchange Commission started a voluntary program that allowed firms to provide XBRL data directly to the EDGAR filing system (such filings are mandatory under the Securities Exchange Act of 1934 and the Investment Company Act of 1940, but may be made in conventional
format). The trial program began with the 2004 calendar year-end reporting season (Securities and Exchange Commission 2005). The trial is an undoubted success. Table 4.1 lists the largest companies participating in the trial.

<table>
<thead>
<tr>
<th>Firm</th>
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<tbody>
<tr>
<td>Adobe Systems Inc.</td>
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<tr>
<td>Allegiant Advantage Fund</td>
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<tr>
<td>Altria Group Inc.</td>
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<td>Automatic Data Processing Inc.</td>
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<tr>
<td>Bowne &amp; Co. Inc.</td>
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<tr>
<td>Bristol Myers Squibb Co.</td>
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<tr>
<td>Business Objects S.A.</td>
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<tr>
<td>Crystal International Travel Group, Inc.</td>
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<tr>
<td>EDGAR Online Inc.</td>
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<td>EMC Corp.</td>
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<tr>
<td>Hitachi Ltd.</td>
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<tr>
<td>InfoSys Technologies LTD</td>
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<tr>
<td>International Securities Exchange Inc.</td>
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<tr>
<td>Microsoft Corp.</td>
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<tr>
<td>Pepsico Inc.</td>
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<tr>
<td>RR Donnelley &amp; Sons Co.</td>
</tr>
<tr>
<td>Satyam Computer Services Ltd.</td>
</tr>
<tr>
<td>United Technologies Corp.</td>
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<tr>
<td>Xerox Corp.</td>
</tr>
</tbody>
</table>

Table 4.1: **Large firms participating in the EDGAR XBRL trail**  
These firms are participating in EDGAR XBRL trial. Participation is voluntary and began in 2004. If the trial is judged to be successful XBRL is expected to become the mandatory method of filing reports to EDGAR.  
*Source: US Securities and Exchange Commission*

At present there is very little actual data available in XBRL format to be used in research which requires times series data. Commercial data aggregators are at present re-capturing historic financial information, but this is an ongoing process which will not produce usable data in the immediate future. It is the opinion of the author that because of the richness of meaning in XBRL data, that XBRL data will be the main input to future financial research projects.
DuPont ratios as an approximation for the effect of intangible assets on firm performance

The current lack of suitable XBRL data necessitates the use of alternative means of quantifying the effect of intangible assets on firm performance. DuPont ratios can be calculated for most listed firms. Section 2.6.2 discussed the interpretation as well as the difficulties in using these ratios as a means of estimating the effect of intangible assets on the financial performance of a firm. The definition and description of the ratios as discussed in Section 2.6.2 and summarized here are:

\[ ROE = \frac{NetIncome}{Equity} = \frac{NetIncome}{NetSales} \times \frac{NetSales}{TotalAssets} \times \frac{TotalAssets}{Equity} \] (4.3.9)

where \( ROE = \) return on equity

The product of the three individual ratios given above is equal to the definition of ‘return on equity’ (i.e. net income/equity), since the common terms ‘cancel out’.

The three ratios each have a useful and independent interpretation:

\( \frac{Net\ Income}{Net\ Sales} \) is referred to as the ‘net profit margin’ and is a measure of the ability of the firm to either command relatively high prices for its products (for example: brand names) or the ability to keep operating costs low (for example: operating efficiencies).

\( \frac{Net\ Sales}{Total\ Assets} \) is referred to as ‘asset turnover’ and is a measure of the productivity of the assets employed. Total Assets includes both Fixed Assets and Current Assets. Each of these categories of assets may be directly influenced by the existence of intangible assets. For example: a firm with a valuable brand name will have a higher Net Sales / Total Asset ratio than
competitors without a similar asset (since the brand name increases sales but is not reflected in the recorded assets of the firm). Any intangible asset which increases sales or improves the effectiveness of tangible assets will have similar effects.

\[(\text{Total Assets} / \text{Equity})\] is referred to as ‘financial leverage’ and is a measure of the amount of debt employed by the firm. Return on equity can be increased by increasing borrowing, however this will increase the risk to the holders of equity. This ratio is not expected to be greatly influenced by the mixture of tangible and intangible assets that the firm employs.

### 4.3.4 Specifying an hedonic model that incorporates the characteristics of intangible assets

In order to specify the functional form of a model that may be subjected to empirical test, it is necessary to related the theoretical model to the data that is available.

Fortunately there is an abundant set of data that relates to DuPont ratios and equity returns. This data is available in the form of both cross-section data (observations of firms at a fixed point in time) and time-series data (observations of the same firm over time). Data sets with both cross-section and time-series components are referred to as TSCS (time-series cross-sectional) data, or more commonly as ‘panel data’ (Baltagi 2001, Matyas & Sevestre 1996).

The collection of panel data has yielded a better understanding of many phenomena. The largest collections of panel data are household surveys; Baltagi (2001) lists the following large (and ongoing) surveys:

- US Panel Study on Income Dynamics,
- German Socio-Economic Panel,
• British Household Panel Survey,

• Household, Income and Labour Dynamics in Australia Survey.

Following Matyas & Sevestre (1996), the most general form of the hedonic model of the return on equity, as given by the set of equations 4.3.7 and 4.3.8 above, translates into the following form if panel data is available to estimate the parameters:

\[ R_{it} = \beta_{1it} C_{1it} + \cdots + \beta_{kit} C_{kit} + u_{it} = C_{it}'\beta_{it} + u_{it} \]  

(4.3.10)

where:

- \( i \) is the index for equities, and \( t \) is the index for time periods
- \( R_{it} \) is the return on equity \( i \) in period \( t \)
- \( \beta_{kit} \) is the (unknown) responsiveness of the return on equity \( i \) to the \( k \)'th characteristic at time \( i \)
- \( C_{kit} \) is the (known) value of the \( k \)'th characteristic of the \( i \)'th equity at time \( t \)
- \( \beta_{it} \) is a \((K \times 1)\) column vector
- \( C_{it}' \) is a \((1 \times K)\) row vector of the characteristics
- \( u_{it} \) are the errors terms, not explained by the model.

While Equation 4.3.10 correctly specifies the hypothesised relationships, the parameters cannot be estimated since the number of parameters exceeds the number of observations. The solution is to impose some structure on the model. Restrictive assumptions can be made about any of the following:

1. the selection and properties of the explanatory variables, \( C_{kit} \)

2. the properties of the residual terms
3. the statistical relationship between the residual terms and the explanatory variables.

These assumptions should be formulated so as to conform to the theoretical model that is to be investigated (Matyas & Sevestre 1996, p.28). In the case at hand the following restrictions are reasonably placed on the model:

1. The explanatory variables are comprised of the characteristics that investors seek in forming a portfolio of equities, and in addition that the usual assumptions of the hedonic model apply. Thus investors care about the mixture of characteristics of the overall portfolio, but not which particular equities these characteristics reside in. This implies that:

   \[ \beta_{kit} = \beta_{kt} \ \forall \ i \]  

(4.3.11)

If may be further assumed that investors preferences change only slowly (or not at all) over the period examined, then the time period will have no influence either; in which case:

   \[ \beta_{kt} = \beta_{k} \ \forall \ t \]  

(4.3.12)

The full list of characteristics is however not known.

2. The residuals are assumed to be distributed independently of the explanatory variables, to be serially independent, and normally distributed:

   \[ u_{it} \sim \text{i.i.d.}(0, \sigma^2) \]  

(4.3.13)

This restriction can be modified in many circumstances, but in an initial investigation this rather strong assumption of the structure of the error terms
may be justified.

Under these assumptions the model can be re-written as:

\[ R_i = \beta_1 C_{1i} + \cdots + \beta_K C_{Ki} + u_i \] (4.3.14)

If these assumptions did not include the restriction that the characteristics were not known, then estimation of the model would be straight forward. All the observations could be pooled, and the parameters estimated by ordinary least squares methods. However there is no theoretical reason to specify the characteristics \textit{a priori}, and if the full set of characteristics is not found then the estimates of the parameters will be subject to the ‘omitted variable bias’. Nor would it be possible to correct for this bias without investigating all the possible characteristics that determine the return on equities.

Fortunately it is possible to circumvent the problem of omitted variables in this particular case. Since financial markets have proven to be mostly efficient, it is reasonable to assume that equity returns are unbiased estimates of actual returns. Under these conditions, following Fama & MacBeth (1973), it is reasonable to construct a set of portfolios that differ only in respect to one characteristic and to compare the returns of each portfolio. If the portfolios are sufficiently large and diversified there should be no difference between the returns of these portfolios UNLESS the characteristics that distinguishes them is, in fact, a valid determinant of equity value.

We have identified three possible characteristics that are related to the presence of intangible assets. In order to test if the equity market places any value on these characteristics, given the assumptions that were made above, the following hypotheses will be tested:
1. \( H_0^1 \): The characteristic of the firm measured by the ratio of Net Sales to Total Assets (i.e. the asset turnover) is not a determinant of the return of the firm’s equity.

2. \( H_0^2 \): The characteristic of the firm measured by the ratio of Net Income to Net Sales (i.e. the net profit margin) is not a determinant of the return of the firm’s equity.

3. \( H_0^3 \): The characteristic of the firm measured by the ratio of Total Assets to Equity (i.e. the financial leverage of the firm) is not a determinant of the return of the firm’s equity.

The form of the model

The model specified in equation 4.3.14 has been derived from the most general of models for the return on equity (as specified in the set of equations 4.3.7 and 4.3.8). This means that the model incorporates most of the conventional financial and accounting models, which are all restricted forms of this general model. In addition we are only concerned with the effect of intangible assets on the value of the equity of the firm and not the value of the equity itself. Thus it is only the partial differentials of the value of the firm with respect to the characteristics of performance which need to be estimated, and the effect of other variables on the value of the equity can be ignored in the present study.

Ancillary assumptions

The following assumptions are ancillary to the model, but are important if any confidence is to be placed in the results of the empirical estimation. These assumptions accord with those normally made in financial modelling or in hedonic price models.
Chapter 4. Methodology

Variations in these assumptions might prove to be a source for further study.

Investor behaviour

It is assumed that investor behaviour can be modelled using an hedonic approach. This implies that:

1. The result of employing such intangible assets result in measurable changes to the firms performance, and that these changes in performance can be measured in an objective manner. These changes in performance form the set of characteristics that arise from employing intangible assets. This aspect is the subject of the empirical analysis of the following chapter.

2. Individual investors may value these changes to the firms performance differently. For example, some may be ‘value investors’ whilst other may be ‘growth investors’. This seems not to be contentious, and is a possible benefit of using the hedonic model as conventional models in finance often rely on the existence of a single representative investor.

3. The relationship between a unit of equity and the characteristics of the firm are both linear and additive. This implies that doubling the number of equities will result in double the quantity of the characteristics, and purchasing differing equities with the same characteristic will simply result in the investment portfolio having the sum of each characteristic, regardless of which equity it originated from. This does not present any difficulty except in relationship to the risk of an equity. Since Markowitz (1952) it is clear that the risk of a portfolio is not linear or additive if risk is measured by the covariance of the returns on the equities in a portfolio. However, once portfolios are diversified and only systematic risk remains, the risk measures do conform to this condition (Elton & Gruber 1995, Joshi 2003). Thus, for example, equity betas are
both linear and additive.

**Market efficiency**

If markets are not efficient then the returns on equity will be unreliable indicators of the value of the firm, and any analysis of those returns would be equally unreliable. It is a basic tenet of financial modelling that equity markets are largely efficient (Damodaran 1996, Elton & Gruber 1995, Brealey et al. 2006).

### 4.3.5 From shadow prices to valuations

Given that a relationship between a characteristic (such as the adjusted Sales/Asset ratio) and the return on equity is found to exist, it is possible to derive the ‘shadow price’ of this characteristic. The shadow price reflects the increase in return that the equity market pays for an additional unit of the characteristic.

Under these conditions the value of the asset may be determined. As an example consider the case where an intangible asset exists and where:

- the asset is expected to increase the Sales/Asset ratio of the firm by 10%,
- the shadow price of the characteristic is 5% (i.e. a one percent change in the Sales/Asset ratio is expected to increase the market return on the firms equity by 5%),
- the market capitalization of the firm is currently $1million, and
- there are no other effects.

Then the value of the intangible asset will be:

\[ 5 \times 0.10 \times 1,000,000 = 500,000 \]
The assets is thus worth $500,000 to the firm.

The estimation of the financial performance effects of intangible assets (which are referred to as characteristics in this study) are likely to be far less onerous than estimating net cash flows and risks of such assets, although in a world of complete information both methods would yield the same valuation. This is because both methods of valuation derive from the same core theory; expected cash flows and risk are simply another set of characteristics.

Once shadow prices have been estimated, there is no need to differentiate between firms that have equity that is traded on financial exchanges (listed firms) and private firms. In the same manner in which the risk free rate and the market risk premium are used to value both listed and unlisted firms, the shadow prices of the characteristics of intangible assets can be used to value such assets irrespective of which type of firm owns the asset.

4.4 Conclusion

This chapter examined the various methods that are used to value assets, and assessed the application of these techniques to intangible assets. Each valuation model can be derived as a restricted form of the hedonic pricing model, and the most general form of the hedonic model was proposed to value intangible assets.

The characteristics of intangible assets are however not directly observable. It was suggested that the relevant characteristics of intangible assets can be estimated by the increase in the financial performance of the firm that employs such assets. In order to analyse the financial performance of firms the XBRL specification delivers great promise but there is as yet insufficient data available. The use of DuPont ratios was suggested as an interim method for measuring the characteristics of firm
performance that are related to the presence of intangible assets.

A structural form of the hedonic model was then proposed and a set of null hypotheses that can be used to test the efficacy of the model were developed. Finally the method by which shadow prices can be used to value assets was illustrated. The next chapter will investigate if there is sufficient empirical support for using models of this type.
Chapter 5

Analysis and Empirical Results

5.1 Introduction

The previous chapter specified the model and the null hypotheses that will be used to test if intangible assets that are owned by firms can be valued using an hedonic pricing model.

This chapter examines the data, statistical methods, and tools that are used to test the methodology developed in Chapter 4. While this chapter discusses the results of the statistical analysis, the implications of these results are the subject of the following chapter.

Firstly, the sources of the data that are used to assess the firm’s financial performance as well as the holding period return are described. Descriptive statistics of the major variables are discussed and the variables that constitute the characteristics to be evaluated are constructed. Assets are sorted into portfolios based on these characteristics, and the return on each portfolio is examined in order to test the hypotheses that were developed in the previous chapter.

The computer code that is used to analyse the data is contained in Appendix A.
This provides the tools for a similar analysis to be undertaken in data sets from other time frames or locales.

## 5.2 Statistical and software tools

### 5.2.1 S-plus language

All statistical analysis is carried out using the S-plus language, as implemented in language variant named ‘R’ (R Development Core Team 2006). The scripts that are used for data manipulation and the statistical analysis of the model are provided in Appendix A [page 212]. These scripts allow the empirical section of this study to be replicated as new data becomes available, or to analyse data from other markets.

### 5.2.2 Ancillary software

The following utilities are used to expedite the processing of the data. These utilities are ancillary and the analysis can be conducted without their use.

**Tinn-R - GUI/editor for R language** - a utility to prepare scripts for use by the S-plus language interpreter (Faria et al. 2006).

**MySQL** - a database to store intermediate results. No queries or analysis was performed in this application. [MySQL 5.0 Community Server].

**Microsoft Excel** - a spreadsheet application. Data was downloaded in this format. Excel is used to rename variables and format the data before it is saved as a common-delimited file. Excel is also used to visually inspect the data at various stages in the processing. No analysis was performed in this application. [Microsoft Excel 2007 beta release].
Chapter 5. Analysis and Empirical Results

5.3 Data sources and description

Access to commercial financial databases was not available. Consequently all data was gathered from publicly available sources. The equity markets in the United States of America are among the largest and most efficient in the world; comprehensive data for both listed firms and equity prices are also freely available. As this study is exploratory in nature and no similar study has been undertaken previously it is preferable to use the largest data set available; therefore data from the American economy was chosen to test the proposed methodology.

5.3.1 Corporate financial data

Data source

Damodaran (2006) has collected and made available data that is collated from the financial reports of American listed securities. The original sources for the data are:

- Value Line Database [http://www.valueline.com/]
- Morningstar [http://www.morningstar.com/]
- Compustat [http://www.standardandpoors.com]

Damodaran splices the data from the various data vendors and calculates the usual financial ratios. The data is published as an Excel spreadsheet. Annual data for approximately 7100 entities (not all of them are firms) are available for the years 2000 until 2007. At the time of writing the data set was last updated in January 2007.
Quality of data and transformation of variables

A number of problems were encountered when the raw data was examined. It is unlikely that any of these problems (singularly or collectively) will have a significant effect on the estimation of the model. Each problem that was encountered is discussed below, as well as any action that was taken to ameliorate the concern:

1. **Re-use of ticker symbols.**

   If a firm discontinues it’s listing on an exchange the ticker symbol may be re-issued to another firm. The ticker symbol uniquely identifies the equity price of a firm on the exchange. If a firm is de-listed past price information will refer to an entirely different firm rather than to the firm that currently has the ticker symbol assigned to it. This occurred in a number of cases, and the older firm was removed from the database entirely. This will introduce a distortion similar to the ‘survival bias’, but the number of instances is too small (14 firms) to meaningfully affect the results.

   **Action taken:** The firms that have been removed from the data set are listed in Table 5.1. The code segment that was used to implement this adjustment is contained in Appendix A.1 page 213.

2. **Missing data - ‘Country of registration’ and ‘Exchange’.*

   The variables for the ‘country of registration’ of the firm and the ‘exchange’ on which shares are listed are not collected for the years 2000 and 2001.

   **Action taken:** The values for the year 2002 are used for the missing values in 2000 and 2001. If the firm existed in 2000 or 2001 but is not in the data set for 2003 then that firm is dropped from the data set.

3. **Missing data - accounting variables.**
## Chapter 5. Analysis and Empirical Results

<table>
<thead>
<tr>
<th>Firm</th>
<th>Ticker</th>
<th>Years for which data removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sears Roebuck</td>
<td>S</td>
<td>2004 - 2000</td>
</tr>
<tr>
<td>Crosswalk.com Inc</td>
<td>AMEN</td>
<td>2001 - 2000</td>
</tr>
<tr>
<td>Biosepra Inc</td>
<td>BSMD</td>
<td>2001 - 2000</td>
</tr>
<tr>
<td>Medical Advisory Systems Inc</td>
<td>DOC</td>
<td>2001 - 2000</td>
</tr>
<tr>
<td>ElPaso Corp</td>
<td>EPG</td>
<td>2001 - 2000</td>
</tr>
<tr>
<td>Polymer Group</td>
<td>PGI</td>
<td>2001 - 2000</td>
</tr>
<tr>
<td>Prize Energy Group</td>
<td>PRZ</td>
<td>2001 - 2000</td>
</tr>
<tr>
<td>Sulzer Medica Ltd</td>
<td>SM</td>
<td>2001 - 2000</td>
</tr>
<tr>
<td>Willamette Industries</td>
<td>WLL</td>
<td>2001 - 2000</td>
</tr>
<tr>
<td>Alliance Gaming Corp</td>
<td>AGI</td>
<td>2000</td>
</tr>
<tr>
<td>Apache Medical Sys Inc</td>
<td>AMSI</td>
<td>2000</td>
</tr>
<tr>
<td>Armbro Enterprises Inc</td>
<td>ARE.TO</td>
<td>2000</td>
</tr>
<tr>
<td>Brindley Weston</td>
<td>BDY</td>
<td>2000</td>
</tr>
<tr>
<td>Waterlink Inc</td>
<td>WLK</td>
<td>2000</td>
</tr>
</tbody>
</table>

Table 5.1: Firms removed from analysis; change in Ticker Symbol  
The Ticker Symbol for these firms has been re-used for newer firms, and share price data for these firms is no longer available. These firms have been removed from further analysis.  
Source: Analysis of data by author

Some basic accounting variables are not explicitly reported in the data set. This is presumably a restriction by the primary originators of the data, who are all commercial organizations which earn income from the sale of such data.

**Action taken:** It is possible to reconstitute all the required variables from the ratios and other variables that are provided in the data set. The following transformations were used (all the variables on the right hand side of the following equations are available directly from the data set):

**Book value of Debt** = \((BookDebt/Capital) \times (InvestedCapital + Cash)\)

**Book value of equity** = \(InvestedCapital + Cash - BVofDebt\)

**Sales** = \((EV/Sales)^{-1} \times EnterpriseValue\) [for the year 2000 only, data available for all other years]

**Equity** = \(InvestedCapital + Cash - BVofDebt\)
Income = EBIT(1 − t) [as other forms of income are only reported spasmodically in the data set]

4. Removal of firms and entities - not appropriate to this study

Some of the entities for which data is collected are not suitable for analysis in this study. The entities removed are indices, ADR’s (American Deposit Receipts) and firms in the financial sector. These observations are removed before any further processing of the data.

Action taken: The SIC codes are used to remove unsuitable items. Table 5.2 contains details of the items removed in this manner.

<table>
<thead>
<tr>
<th>SIC code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(no SIC code)</td>
<td>These entries represent financial indices</td>
</tr>
<tr>
<td>6000 - 6999</td>
<td>The financial sector</td>
</tr>
<tr>
<td>greater than 8800</td>
<td>ADR’s and other financial instruments</td>
</tr>
</tbody>
</table>

Table 5.2: Entities removed from the data set - SIC codes
Some of the entries in the source tables contain information about entities which are not suitable for analysis in this study. These entities are removed from the data set before any analysis is undertaken.

Source: Analysis of data by author

5. Removal of firms - critical accounting variables not available

There is insufficient data for some firms (missing values), or the data value is so small that the firm would not normally be considered for listing on an exchange (usually such firms are remnants or shells of previously active firms).

Action taken: These firms are removed from the data set before any analysis is undertaken. Table 5.3 contains details of the items removed in this manner.

These actions are taken to ensure that the data that is to be analysed is free of entries that do not represent the phenomena being investigated, or which are not complete.
Table 5.3: Entities removed from the data set - Accounting variables

<table>
<thead>
<tr>
<th>Accounting variable</th>
<th>Condition under which an observation is removed from the data set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>not available, or less that $1mill.</td>
</tr>
<tr>
<td>Total assets</td>
<td>not available, or less that $1mill.</td>
</tr>
<tr>
<td>Book value of equity</td>
<td>not available, or less that $1mill.</td>
</tr>
</tbody>
</table>

There is insufficient data for some firms (missing values), or the data value is so small that the firm would not usually be listed on the exchange. These firms are removed from the data set before any analysis is undertaken.

Source: Analysis of data by author

5.3.2 Descriptive statistics - firms

After the removal of the entries specified above, the final data set of firms has the following characteristics:

Firm size

The size of the firm is measured by its market capitalization. Since a few large firms dominate the American economy, the distribution of firm size is best analysed in terms of the logarithm of market capitalization. Figure 5.1 displays the distribution of the size of firms for each year of the study. There is nothing unexpected in these distributions; it is interesting to note the growth in larger firms over time and the possible consequences for competitiveness in the US economy. Table B.1 (in Appendix B) contains the same information in tabular form.

Firm type by Standard Industrial Classification code

Standard Industrial Classification codes (SIC codes) are used to allocate firms to specific industry groups. These four-digit codes are used by the U.S. Securities and Exchange Commission (SEC) and appear in the company’s EDGAR filings to indicate the company’s main type of business.
Figure 5.1: Log of Market Capitalisation of firms

This figure displays the distribution of firm size in each for each of the years in the data set. Firm size is measured as the log of market capitalisation.

Source: Analysis of data by author

There are some disadvantages of using this classification. The classification codes were established in the 1930’s and a more recent six-digit system (the North American Industry Classification System) was introduced in 1997. The new system has a finer granularity but is not available for many companies in the current study. The major economic activity determines the company’s SIC code, and diversified firms are not adequately described using a single code. In addition, both FASB and the IASB have implemented compulsory segment reporting for firms; In 1997 FASB issued SFAS 131, revising SFAS 14 standards for reporting information about operating segments. These reporting requirements provide a much richer set of information about the operations of the firms. The increasing use of XBRL will make these classifications more reliable indicators in further studies.

In this study firms are analysed under 87 different SIC codes and over seven years. The number of firms per SIC code for each year is reported in Appendix B Table
B.2. A brief description for each SIC code is given in Appendix B Table B.3.

5.3.3 Returns

Data sources

Yahoo provides a listing of prices for the equity of American firms that are quoted on the major markets. In all cases the daily ‘adjusted close’ price was collected for each firm in the data set. Because of the very large number of data points (approximately 300,000 prices), the actual physical collection was broken down into five sessions. This procedure has no effect on the quality of the data, but does allow a more efficient recovery in the event of communication interruptions with the Yahoo database. In addition, because of the size of the data set, the price data set is stored in a MySQL database and is ‘called’ into the S-plus system as required.

The script that was used to collect this data set is contained in Appendix A.4.

The data that is collected is the price of the equity on a particular day. The return over a discrete period is given by:

\[
y_t = \frac{P_{t+1} - P_t}{P_t} = \frac{P_{t+1}}{P_t} - 1
\]  

(5.3.1)

where:

\( y \) is the periodic compounding rate,

\( P \) is the price, and

\( t \) refers to the time period.

As prices are available on a daily basis \( y_t \) can be approximated by:

\[
y_t = \ln \left( \frac{P_{t+1}}{P_t} \right) = \ln P_{t+1} - \ln P_t
\]

(5.3.2)
where:

\[ \ln \] denotes log to the base \( e \).

**Data quality**

The database of firms that is obtained from Damodaran includes firms which, although public companies, are not listed on an exchange but are traded ‘over the counter’. Unfortunately it is not possible to collect prices for these firms from Yahoo. In addition some firms are listed only on minor or regional exchanges; the price estimates for such firms could be distorted by the illiquidity of these regional markets. Only firms which are listed on:

- National Association of Securities Dealers Automated Quotations (NASDAQ)
- New York Stock Exchange (NSE)
- American Stock Exchange (AMEX)

are considered in the remainder of the study.

If a particular price was not available from the Yahoo database, that observation is captured as ‘NA’, which in the S-plus system implies that that the observation is ‘missing’. There are many reasons why this may occur; for example trading in a firm might be suspended pending a material announcement, the Exchange might simply have not recorded a price, or the firm began to trade after the start of the data collection period. In such cases the price from the nearest previous period is used, except when the firm had not traded previously (in which case the price is treated as ‘missing’).
Descriptive statistics

Monthly returns for 3779 firms over 84 months are used in this study. The distribution of monthly returns over this period is illustrated in Figure 5.2, where the returns for all firms for the month of June of each year is displayed.

As is expected, the returns cluster in the neighbourhood around zero. These distributions differ from the normal measures of market volatility in that they represent...
an equally weighted index of returns. The distributions show a tendency to reduce in variance over time, and the returns for June of 2006 are remarkable in both the small magnitude of the variance and the negative mean (which accords with the negative performance of the American markets in that year).

Figure 5.2 only contains information for returns for the month of June. A comprehensive description that covers each of the 84 months of the time interval under investigation is provide in Appendix B as Table B.4. There is nothing unexpected in these values.

### 5.4 Estimation of model parameters

The model developed in Section 4.3.4 to describe the relationships between the market return and the characteristics of an equity is reproduced by Equation 5.4.1 below:

\[
R_i = \beta_1 C_{1i} + \cdots + \beta_K C_{Ki} + u_i
\]  

(5.4.1)

In this form the model does not specify which of the very many potential characteristics will be important in determining the return on equities. The hypothesis to be tested is that a particular set of characteristics, which are derived from the DuPont ratio analysis, are statistically significant in the empirical estimation of the model. In order to examine the effect of these characteristics the effect of other potential factors needs to be controlled. There are a number of ways in which this might be achieved; the method adopted in this study follows Fama & MacBeth (1973) as the most general method and which accords best with empirical models used in modern finance.
5.4.1 Empirical measurement of firm characteristics

The characteristics of the firm that are to be investigated are based on the DuPont system of analysis. Section 4.3.3.3 specified three specific ratios (Income/Sales, Sales/Assets and Assets/Equity) as well as the difficulties in interpreting the meaning of such measurements. A direct comparison of the net profit margins of firms in two different industries is often meaningless. However, the comparison of the net profit margin between similar firms is often enlightening. Consequently the following procedure is used to estimate each of the three ratios:

1. for each year, the relevant ratio is calculated for each firm

2. for each year, the average ratio for each industry (defined by the SIC code) is calculated

3. for each year, the difference between each firm’s ratio and the average for its industry is calculated.

In symbolic notation the construction of the variables is given by the following set of equations:

\[
ISD_{it} = \frac{Income_{it}}{Sales_{it}} - \frac{\sum_{i=1}^{n} \left( \frac{Income_{it}}{Sales_{it}} \right)}{n}
\]  

(5.4.2)

\[
SAD_{it} = \frac{Sales_{it}}{Assets_{it}} - \frac{\sum_{i=1}^{n} \left( \frac{Sales_{it}}{Assets_{it}} \right)}{n}
\]  

(5.4.3)

\[
AED_{it} = \frac{Assets_{it}}{Equity_{it}} - \frac{\sum_{i=1}^{n} \left( \frac{Assets_{it}}{Equity_{it}} \right)}{n}
\]  

(5.4.4)

where:

*Income*\(_{it}\) is the income for firm *i* at time *t*

*Sales*\(_{it}\) are the sales for firm *i* at time *t*
Chapter 5. Analysis and Empirical Results

Assets\(_{it}\) are the assets for firm \(i\) at time \(t\)

Equity\(_{it}\) is the equity of firm \(i\) at time \(t\)

for each of the SIC sectors.

\(ISD_{it}\) is thus the difference between the net profit margin for firm \(i\), within a particular SIC code at time \(t\) and the mean net profit margin for all firms in that sector at time \(t\). \(SAD_{it}\) and \(AED_{it}\) have similar interpretations.

The scripts used to perform these calculations can be found in Appendix A.5 and A.6.

The distribution of the variables ISD, SAD, and AED is shown in Table 5.4. All the distributions are extremely leptokurtic. These distributions can be made to approximate the Normal by use of a Box-Cox transformation, however since the variables will be used to allocate firms to portfolios (and not directly in any statistical tests) this transformation will not be necessary as the ordering of the firms will not be changed by the transformation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Min.</th>
<th>1st Qu.</th>
<th>Median</th>
<th>Mean</th>
<th>3rd Qu.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISD</td>
<td>-99.84000</td>
<td>-0.11110</td>
<td>-0.02566</td>
<td>-0.30700</td>
<td>0.02670</td>
<td>4.28900</td>
</tr>
<tr>
<td>SAD</td>
<td>-2.8690</td>
<td>-0.2466</td>
<td>0.0453</td>
<td>0.1935</td>
<td>0.4555</td>
<td>24.5600</td>
</tr>
<tr>
<td>AED</td>
<td>-6.4390</td>
<td>-0.8584</td>
<td>-0.3879</td>
<td>0.4685</td>
<td>0.2740</td>
<td>812.0000</td>
</tr>
</tbody>
</table>

Table 5.4: Distribution of characteristic measures

\(ISD\) is the difference between the net profit margin (Income/Sales) for a firm and the average for the industry; \(SAD\) is the same measure for the Sales/Asset ratio and \(AED\) for the Asset/Equity ratio.

Source: Analysis of data by author

Examination of outlying observations

The extreme values of the variables might be a cause for concern and are investigated individually. For each variable, the twenty most extreme outliers in each tail of the
distribution are examined. The details of each observation are listed in Appendix B, Tables B.5, B.6, B.7, B.8, B.9 and B.10.

In the case of the firms which display particularly low Income/Sales ratios, it is apparent that in each case the firm has incurred very heavy expenses in the initial years of operation (in anticipation of future income). The amounts of both Income and Sales are reasonable, and all observations are retained. There are numerous reasons why firms might display high Incomes/Sales ratios. These included the recognition of capital gains on fixed property and the sale of assets (tangible as well as intangible). Inspection of these observations does not provide any reason to exclude these firms.

The Sales/Asset ratio is partially the result of the financial leverage that the firm has employed in structuring its balance sheet. An examination of the extreme observations does not suggest that there is a need to exclude any of the outlying firms from the data set.

Finally, although very low ratios of assets to equity is a possible sign of financial distress, there is no reason to exclude observations from the data set simply because the firm finds itself in difficult circumstances.

In summary, an examination of each of the observations that fall furthest from the mean does not reveal any reason to exclude any of these observations from further analysis.

5.4.2 Portfolio formation

Diversification of idiosyncratic risk by combining firms into portfolios is a cornerstone of financial theory. Empirical studies have shown that portfolios with as few as 20 equities have almost zero idiosyncratic risk, provided the equities are randomly
selected (Gruber 1977, Statman 1987, Demir et al. 2004).

In this study firms are placed in one of five equally sized portfolios, in accordance with the measurement of a single characteristic of interest. Differences between the return on each of these five portfolios is then analysed. Since each portfolio consists of more than 750 firms selected solely on the basis of one characteristic it is reasonable to expect that each portfolio is well diversified. This process is repeated three times, once for each characteristic of interest.

The process used is illustrated in Figure 5.3 and consists of the following steps:

1. Firstly, one of the three characteristics (ISD, SAD or EAD) is selected for analysis.

2. Firms are then allocated to one of five portfolios based on the magnitude of the chosen characteristic; those firms with the smallest measure of the characteristic are placed in the first portfolio, the second quintile in the next portfolio, and so on. The last portfolio will consist of firms with the largest measure of the characteristic. Portfolios are formed for each month of the year (starting in May and ending in April) and while the equities in each of the twelve monthly portfolios will be constant over the year, the return of the portfolio will vary from month to month.

In May of each year the portfolios are rebalanced. A firm may move to any of the other 4 portfolios or remain in the current portfolio. As financial data of the firms performance is only available on an annual basis, portfolios can not be rebalanced more frequently.

3. The return on each portfolio is calculated for each month. As there are 7 years of data there are 84 monthly returns that are computed for each of the five portfolios.
Choose portfolio characteristic
• ISD
• SAD
• AED

Form 5 equally sized portfolios
• Rebalance annually

Calculate monthly returns for each portfolio
• Equally weighted monthly returns

Compare the returns on each portfolio
• Over the 6 year period

Figure 5.3: Portfolio formation

The major steps in the formation of portfolio that are used to test the effect of the characteristics of firms in the data set. This procedure results in five portfolios, each of which differs only in respect of the characteristic of interest (the ISD, SAD or AED variables). The returns of each portfolio can then be compared to establish if that particular characteristic has a discernible effect on returns.

Source: Analysis by author
Returns are calculated as an equally weighted average of the returns of each firm in that portfolio.

4. The returns of each of the five portfolios is compared. Any differences in the pattern of returns is likely to be caused by the characteristic used to form the portfolios because diversification should have removed the influence of all other factors.

5. The same process is repeated for the remaining characteristics.

The S-plus code that is used to perform these calculations can be found in Appendix A.7.

5.5 Analysis of portfolio returns and characteristics

Once the method of portfolio construction has been established it is possible to examine the three null hypotheses that were posited in Section 4.3.4 in the light of the empirical evidence available. This is accomplished by examining the relationship between the portfolio return and each of the characteristics in turn.

5.5.1 Portfolio returns and the Sales/Asset ratio

The ratio of Income/Sales is a measure of the firm’s operational efficiency, derived from the DuPont ratio analysis. This ratio is also known as the firm’s ‘operating profit margin’, and is more fully discussed in Section 2.6.2. In order to compare the operational efficiency of firms in differing industries, the difference between the Income/Sales ratio of a particular firm and the average for similar firms (as defined by the firm’s SIC classification) is used. This statistic is referred to as ‘ISD’ (Income/Sales Difference from the mean) and is calculated for all firms in the data set for which the relevant information is available.
Firms with intangible assets are expected to display a higher ratio of Sales/Assets compared to other firms in the same industry. The Sales/Assets ratio is a measure of how efficiently the firm is able to use the physical capital (which is what the term ‘Assets’ measures) to generate sales. Intangible assets such as brand names, relationships with customers, or core competencies in designing and producing products are only a few of the intangible assets that would result in a higher than usual Sales/Asset ratio.

In order to test the hypothesis:

\[ H_0^1: \text{The characteristic of the firm measured by the ratio of Net Sales to Total Assets (i.e. the asset turnover) is not a determinant of the return of the firm’s equity} \]

the relationship between the returns of portfolios formed on the basis of selecting firms with similar Sales/Asset ratios is examined.

Figure 5.4 displays the relationship between the portfolio returns when portfolios are formed on the basis of the Income/Sales ratio. The anticipated relationship between the presence of intangible assets and returns is clearly evident.

In order to preclude the fact that the differences in portfolio return might be due to differences in the risk of each portfolio, Figure 5.4 also displays the risk of each portfolio (as measured by the portfolio beta). It is clear that the portfolios with higher risk have lower returns, thus eliminating risk as an explanation for the differences in return of each of the five portfolios. This accords with the findings in Fama & French (2004, 1992) and the criticisms of the empirical estimation of beta as a measure of risk (Roll & Ross 1994, Kandel & Stambaugh 1995).
Figure 5.4: Returns for portfolios based on Sales/Asset ratios
Firms are divided into 5 equally sized portfolios, based on the magnitude of the Sales/Asset ratio.
Portfolio 1 contains firms with the lowest Sales/Asset ratio (referred to as ‘very-low’ in the text),
Portfolio 2 contains the next lowest (‘low’),
Portfolio 3 contains firms that are centred around the mean (‘mean’),
Portfolio 4 contains firms with higher ratios (‘high’), and
Portfolio 5 those with the highest ratios (‘very-high’).
The mean return for each portfolio (left-hand axis) and the beta (right-hand axis) is shown in the graph. Returns are expressed in percentage points (e.g. 0.1 is equal to 0.1% pa)
The return increases monotonically. The risk of the portfolio (beta) does not explain the differences in the portfolio returns.
Source: Analysis of data by author
Analysis of variance

It is possible to test the assertion that the difference in the returns of each of the portfolios is not due to chance alone.

The simplest test that can be used to test for the differences in means fall under the heading of ‘analysis of variance’ (ANOVA). Since there are five means that are compared, there are four degrees of freedom. The value of the F statistic is 22.48; which implies that the probability that the differences between the portfolio returns are due to chance is very low indeed. The formal results of the ANOVA procedure for the portfolios grouped by Sales/Asset ratios is presented in Table B.11 in Appendix B.

The ANOVA procedure is however based on a number of restrictive assumptions, especially that the distribution of the returns which form the portfolios is Normal and that the variance of the returns in each group is the same. There is some debate in the literature as to how robust the ANOVA procedures are to these assumptions (Ferguson & Takane 2005, Lindman 1974). In order to gain insight into the distributions of the returns Figure B.1 in Appendix B graphs each of the distributions. All the distributions appear to be fairly symmetrical and approximately normal. It is possible to test for normality. The Jarque-Bera test is an efficient joint test for normality, homoscedasticity and serial independence (Bera & Jarque 1980). Table 5.5 shows the results of this test; the p-values indicate that at the 5% confidence level the null hypothesis that the returns are drawn from a Normal population can not be rejected for any of the portfolios and the ANOVA analysis is thus valid.

Non-parametric tests are less powerful than parametric tests but they do not rely on assumptions about the underlying distributions. As the distributions of the returns of the portfolios labelled ‘Mean’ and ‘Very high’ have p-values of only 0.09866 and 0.09485 respectively it is considered prudent to use non-parametric measures to
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<table>
<thead>
<tr>
<th>Portfolio</th>
<th>X-squared</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>2.13</td>
<td>2</td>
<td>0.3447</td>
</tr>
<tr>
<td>Low</td>
<td>2.13</td>
<td>2</td>
<td>0.2130</td>
</tr>
<tr>
<td>Mean</td>
<td>4.6322</td>
<td>2</td>
<td>0.09866</td>
</tr>
<tr>
<td>High</td>
<td>4.0895</td>
<td>2</td>
<td>0.1294</td>
</tr>
<tr>
<td>Very high</td>
<td>4.7109</td>
<td>2</td>
<td>0.09485</td>
</tr>
</tbody>
</table>

Table 5.5: Robust Jarque Bera Test - Portfolio formed on Sales/Asset ratios

There are five equally sized portfolios, formed on the basis of the Sales/Asset ratio. The Jarque Bera statistic tests the probability that the returns of each portfolio is drawn from a Gaussian distribution. At the 5% level of significance there is no evidence to reject the hypothesis that each of the five distributions is drawn from a Gaussian distribution.

Source: Analysis of data by author.

---

test if the differences in the mean returns are still evident under a less severe set of assumptions. The Kruskal-Wallis rank sum test assumes neither normality or homoscedasticity. The results of this test are given in Table 5.6. Even under these assumptions the mean return of at least some of the portfolios are significantly different.

<table>
<thead>
<tr>
<th>Kruskal-Wallis</th>
<th>chi-squared</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAratio</td>
<td>69.1236</td>
<td>4</td>
<td>3.475e-14</td>
</tr>
</tbody>
</table>

Table 5.6: Kruskal-Wallis rank sum test - Portfolio means based on Sales/Asset ratios

There are five equally sized portfolios, based on the Sales/Asset ratio. The Kruskal-Wallis tests the probability that at least one of the portfolios has a return that is statistically different from the others. This test is non-parametric and does not assume that the underlying distributions are either Normal or homoscedastic.

Source: Analysis of data by author.

Since the portfolios are in rank order, and the use of a simple t-test of differences between the means will overestimate the probability that they are different when in fact they are not. The Tukey multiple comparison of means test, also called the ‘Tukey honestly significant difference (HSD) test’ (Yandell 1997) allows each pair of means to be tested for statistical difference. This procedure requires that the each portfolio has the same number of equities; this requirement is satisfied in the design
Chapter 5. Analysis and Empirical Results

of the portfolios. The results of the Tukey HSD test are given in Figure 5.5 and Table B.12 (in Appendix B) contains the values used to construct Figure 5.5.

Figure 5.5: Tukey HSD test of mean returns for portfolio based on Sales/Asset ratios

Firms are divided into 5 equally sized portfolios, based on the magnitude of the Sales/Asset ratio.

Portfolio 1 contains firms with the lowest Sales/Asset ratio (referred to as ‘very-low’),

Portfolio 2 contains the next lowest (‘low’),

Portfolio 3 contains firms that are centred around the mean (‘mean’),

Portfolio 4 contains firms with higher ratios (‘high’), and

Portfolio 5 those with the highest ratios (‘very-high’).

The Tukey honestly significant difference (HSD) test is used to test for differences in the mean of pairs of portfolios.

The means of four of the ten pairs of portfolios are not statistically different from each other.

Source: Analysis of data by author

On the basis of the Tukey HSD test four of the ten pairs of portfolio mean returns are not statistically different from one another. This indicates that grouping the equities into fewer portfolios would result in greater statistical significance. However, since the means appear to increase monotonically there is a distinct possibility that as
additional data becomes available (with the effluxion of time) that the variances of each portfolio will be reduced sufficiently that all ten pairs of returns become statistically different to each other.

**Inference of results for portfolios formed on the basis of Sales/Asset ratios**

It is clear in the empirical tests that have been conducted that there is sufficient evidence that the hypothesis

\[ H_0^1: \text{The characteristic of the firm measured by the ratio of Net Sales to Total Assets (i.e. the asset turnover) is not a determinant of the return of the firm’s equity} \]

can be rejected. The evidence supports the contention that higher holdings of intangible assets (as represented by higher Sales/Asset ratios) lead to greater return on equities.

### 5.5.2 Portfolio returns and the Income/Sales ratio

The ratio of Income/Sales is referred to as the ‘net profit margin’ and is a measure of the ability of the firm to either command relatively high prices for its products (for example: brand names) or the ability to keep operating costs low (for example: operating efficiencies).

In order to test the hypothesis:

\[ H_0^2: \text{The characteristic of the firm measured by the ratio of Net Income to Net Sales (i.e. the net profit margin) is not a determinant of the return of the firm’s equity} \]

the same methods are used as those to test the previous hypothesis. As these
methods were fully discussed in Section 5.5.1 only the results of the analysis are discussed here.

Figure 5.6 shows the relationship between the five portfolios that are formed by grouping firms with similar Income/Sales ratios. The relationship does not appear to be as strong as for portfolios formed on the basis of Sales/Asset ratios.

**Analysis of variance**

The distribution of the returns for each portfolio formed on the basis of Income/Sales ratios appears to be mostly symmetrical, although the variance of the portfolio contains firms with the lowest ratio is significantly higher than the other portfolios (Diagram B.2 in Appendix B). This suspicion is confirmed by the Jarque Bera test, shown in Table 5.7 which confirms that 2 of the 5 portfolios can not be assumed to be drawn from a Gaussian distribution.

<table>
<thead>
<tr>
<th>Portfolio</th>
<th>X-squared</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>1.5071</td>
<td>2</td>
<td>0.4707</td>
</tr>
<tr>
<td>Low</td>
<td>4.1954</td>
<td>2</td>
<td>0.1227</td>
</tr>
<tr>
<td>Mean</td>
<td>13.4066</td>
<td>2</td>
<td>0.001227</td>
</tr>
<tr>
<td>High</td>
<td>16.7482</td>
<td>2</td>
<td>0.0002308</td>
</tr>
<tr>
<td>Very high</td>
<td>5.2353</td>
<td>2</td>
<td>0.07298</td>
</tr>
</tbody>
</table>

Table 5.7: Robust Jarque Bera Test - Portfolio means based on Income/Sales ratios

There are five equally sized portfolios, formed on the basis of the Income/Sales ratio. The Jarque Bera statistic tests the probability that the returns of each portfolio is drawn from a Gaussian distribution.

At the 5% level of significance there is evidence that the returns of both the ‘Mean’ and ‘High’ portfolio are not drawn from a Gaussian distribution.

Source: Analysis of data by author.

It is therefore necessary to rely on non-parametric tests to gauge if the means return of each portfolio is different. The results of the Kruskal-Wallis rank sum test for the data is shown in Table 5.8. The test shows that at least one of the mean returns is statistically different from the others.
Figure 5.6: Returns for portfolios based on Income/Sales ratios

Firms are divided into 5 equally sized portfolios, based on the magnitude of the Income/Sales ratio.

Portfolio 1 contains firms with the lowest Income/Sales ratio (referred to as ‘very-low’ in the text),
Portfolio 2 contains the next lowest (‘low’),
Portfolio 3 contains firms that are centred around the mean (‘mean’),
Portfolio 4 contains firms with higher ratios (‘high’), and
Portfolio 5 those with the highest ratios (‘very-high’).

The mean return for each portfolio (left-hand axis) and the beta (right-hand axis) is shown in the graph. Returns are expressed in percentage points (e.g. 0.1 is equal to 0.1% pa)

The returns increase initially and then appear to flatten out. The risk of the portfolio (beta) does not appear to explain the differences in the portfolio returns.

Source: Analysis of data by author
Table 5.8: Kruskal-Wallis rank sum test - Portfolio means based on Income/Sales ratios

There are five equally sized portfolios, based on the Income/Sales ratio. The Kruskal-Wallis tests the probability that at least one of the portfolios has a return that is statistically different from the rest. This test is non-parametric and does not assume that the underlying distributions are either Gaussian or homoscedastic.

Source: Analysis of data by author.

In order to compare each of the portfolio returns in a pairwise fashion the Tukey HSD procedure was presented in Section 5.5.1. Figure 5.7 indicates that for these portfolios there are only two statistically different groups; the portfolio that represents the firms with the lowest values for Sales/Asset ratios (‘very-low’ portfolio) and the 4 remaining portfolios. The numeric values of the parameters for this procedure are contained in Table B.13, which is in Appendix B.

Inference of results for portfolios formed on the basis of Income/Sales ratios

Although there are only two statistically different groups of portfolios when portfolios are formed on the basis of the Income/Sales ratio the null hypothesis

\[ H_0^2: \text{The characteristic of the firm measured by the ratio of Net Income to Net Sales (i.e. the net profit margin) is not a determinant of the return of the firm’s equity.} \]

can still be rejected. There are a large number of firms (20% of the firms in the data set) in this ‘Very-low’ portfolio which have statistically lower returns than the remainder of firms. This is a useful result; if a firm in the lowest quintile can increase the value of the Income/Sales ratio by employing intangible assets (or by other means) it will be rewarded by an average 1.5% increase in the market return
Figure 5.7: Tukey HSD test of mean returns for portfolios based on Income/Sales ratios

Firms are divided into 5 equally sized portfolios, based on the magnitude of the Sales/Asset ratio.
Portfolio 1 contains firms with the lowest Income/Sales ratio (referred to as ‘very-low’),
Portfolio 2 contains the next lowest (‘low’),
Portfolio 3 contains firms that are centred around the mean (‘mean’),
Portfolio 4 contains firms with higher ratios (‘high’), and
Portfolio 5 those with the highest ratios (‘very-high’).
The Tukey honestly significant difference (HSD) test is used to test for differences in the mean of pairs of portfolios.
There are only two statistically different groups of portfolio; the portfolio that represents the firms with the lowest values for Income/Sales ratios (‘very-low’ portfolio) and the 4 remaining portfolios.
Source: Analysis of data by author
on its equity.

### 5.5.3 Portfolio returns and the Asset/Equity ratio

The ratio of Assets/Equity is referred to as ‘financial leverage’ and is a measure of the amount of debt employed by the firm. Return on equity can be increased by increasing borrowing, however this will increase the risk to the holders of equity. This ratio is not expected to be greatly influenced by the mixture of tangible and intangible assets that the firm employs.

In order to test the hypothesis:

\[ H_0^3: \text{The characteristic of the firm measured by the ratio of Total Assets to Equity (i.e. the financial leverage of the firm) is not a determinant of the return of the firm’s equity} \]

the same methods are used as those to test the previous hypothesis. As these methods were fully discussed in section 5.5.1 once again only the results of the analysis are discussed here.

Figure 5.8 depicts the relationship between the mean return on portfolios that are formed on the basis of the Asset/Equity ratio.

Firms with the lowest Asset/Equity ratios realized surprisingly good returns. These firms have very low leverage and risk. Except for the lowest quintile, the relationship between the Asset/Equity ratio is as expected; the higher the financial leverage the higher the realized return (although the relation to risk is unclear in these results). Except for the fact that intangible assets may mitigate against higher borrowing, this set of results does not indicate any significant effects for the use of intangible assets by the firm.
Portfolios based on Assets/Equity ratios

Firms are divided into 5 equally sized portfolios, based on the magnitude of the Asset/Equity ratio.

Portfolio 1 contains firms with the lowest Asset/Equity ratio (referred to as ‘very-low’ in the text),

Portfolio 2 contains the next lowest (‘low’),

Portfolio 3 contains firms that are centred around the mean (‘mean’),

Portfolio 4 contains firms with higher ratios (‘high’), and

Portfolio 5 those with the highest ratios (‘very-high’).

The mean return for each portfolio (left-hand axis) and the beta (right-hand axis) is shown in the graph. Returns are expressed in percentage points (e.g. 0.1 is equal to 0.1% pa)

The return initially declines and then rises steadily. The relationship between the risk of the portfolio (beta) and returns is not clear from this data set.

Source: Analysis of data by author
Chapter 5. Analysis and Empirical Results

Analysis of variance

Inspection of the distribution of the returns of each of the 5 portfolios indicates that they are fairly symmetrical and have similar variances (Figure B.3 in Appendix B). The Jarque Bera test statistics, as shown in Table 5.9, indicate that only the returns of the ‘Very high’ portfolio is unlikely to be drawn from a normal distribution.

<table>
<thead>
<tr>
<th>Portfolio</th>
<th>X-squared</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>2.1811</td>
<td>2</td>
<td>0.3360</td>
</tr>
<tr>
<td>Low</td>
<td>2.6497</td>
<td>2</td>
<td>0.2658</td>
</tr>
<tr>
<td>Mean</td>
<td>5.3087</td>
<td>2</td>
<td>0.07034</td>
</tr>
<tr>
<td>High</td>
<td>3.7347</td>
<td>2</td>
<td>0.1545</td>
</tr>
<tr>
<td>Very high</td>
<td>10.7277</td>
<td>2</td>
<td>0.004683</td>
</tr>
</tbody>
</table>

Table 5.9: Robust Jarque Bera Test - Portfolio means based on Asset/Equity ratios

There are five equally sized portfolios, formed on the basis of the Asset/Equity ratio. The Jarque Bera statistic tests the probability that the returns of each portfolio is drawn from a Gaussian distribution. At the 5% level of significance there is evidence that the returns of the ‘Very high’ portfolio are not drawn from a Gaussian distribution. Source: Analysis of data by author.

Both an analysis of variance procedure (Table B.14 in Appendix B) and the Kruskal-Wallis rank sum test (Table B.15 in Appendix B) indicate that at least one of the portfolios has a mean that is statistically different to the other portfolios. A pairwise comparison of the individual means is depicted in Figure 5.9, which shows that 4 of the 10 possible pairs are not statistically different at the 5% level of confidence. The numeric detail from which this figure is constructed can be found in Table B.16 in appendix B.

Inference of results for portfolios formed on the basis of Assets/Equity ratios

These results are somewhat unexpected. The portfolio containing firms with the lowest Asset/Equity ratios performed very well, and the return on equity of these
Firms are divided into 5 equally sized portfolios, based on the magnitude of the Assets/Equity ratio.

Portfolio 1 contains firms with the lowest Income/Sales ratio (referred to as ‘very-low’),
Portfolio 2 contains the next lowest (‘low’),
Portfolio 3 contains firms that are centred around the mean (‘mean’),
Portfolio 4 contains firms with higher ratios (‘high’), and
Portfolio 5 those with the highest ratios (‘very-high’).

The Tukey honestly significant difference (HSD) test is used to test for differences in the mean of pairs of portfolios.

The mean of four of the ten pairs of portfolios are not statistically different from each other.

Source: Analysis of data by author
firms was amongst the highest of all firms in the study. These firms have very low leverage ratios and very low beta’s.

The remaining four portfolios exhibited the expected relationship between the Asset/Equity ratio and returns. In these portfolios the relationship between risk (as measured by beta) and return is not clear.

The null hypothesis:

\[ H_0^3: \text{The characteristic of the firm measured by the ratio of Total Assets to Equity (i.e. the financial leverage of the firm) is not a determinant of the return of the firm’s equity} \]

can reasonably be rejected on the basis of the available evidence.

The ratio of Total Assets to Equity is closely aligned to the financial leverage of the firm. Miller & Modigliani (1958) have shown that when capital markets are complete and perfect, and where there are no taxes, the capital structure of a firm is irrelevant. This proposition was not meant to reflect the actual situation that firms find themselves in, but was rather a starting point for an examination of the determinants of the capital structure of firms. Miller (1988) states that:

‘The view that capital structure is literally irrelevant or that “nothing matters” in corporate finance, though still sometimes attributed to us,...is far from what we ever actually said about the real-world applications of our theoretical propositions.’

By removing the assumptions of the original model (Miller & Modigliani 1958, 1963) various possible explanations for the observed differences in capital structure emerge. The most popular explanations are:

**Trade-off theory:** which balances the tax benefits of borrowing against the cost
Chapter 5. Analysis and Empirical Results

of bankruptcy (Kraus & Litzenberger 1973),

**Pecking order theory:** where internal financing is preferred to debt which is preferred to equity (Myers 1984),

**Market timing hypothesis:** where capital structure is the result of past decisions by managers which were driven by the relative cost of capital in historical time (Graham & Harvey 2001).

There are also disputes in the empirical studies as to which factors affect the capital structure of firm; two important studies disagree over the characteristics that cause such differences (Harris & Raviv 1991, Titman & Wessels 1988). The detail of these issues are not relevant to the question at hand, and it is sufficient to point out that it is not surprising that any useful information of the effect of intangible assets on capital structure may be lost at this level of data aggregation.

### 5.6 Modelling the value of intangible assets

Once the relationship between the characteristics of the firm and the return to equity has been established to be statistically significant, it is possible to use this information to value intangible assets that give rise to these characteristics. This section of the study demonstrates how this can be accomplished.

The section begins by discussing the traditional method of deriving values from hedonic pricing models and the empirical problems that may arise. The methodology used to measure the effect of characteristics on firm performance in this thesis most closely follows the Fama and French tradition. This methodology effectively removes some of the empirical problems of estimating the parameters of the model, and the use of the parameters derived from this approach are discussed next. The extent to which this study differs from the Fama and French methods are then described as
well as the implication of this difference for the pricing of intangible assets. Finally an example is used to illustrate the proposed technique.

5.6.1 Traditional hedonic pricing models

The most general form of the hedonic pricing model for equities is given by Equations 4.3.7 and 4.3.8 which were discussed in Section 4.3.2 above. The equations are reproduced below for easy reference:

\[
E[R_i] = f(Risk_i, C_{1...m}) \tag{5.6.1}
\]

\[
Risk = g(C_{(n+1)...n}) \tag{5.6.2}
\]

where:

\(C_j\) represents the \(j\)’th characteristic.

The implicit price of each characteristic can be deduced from this set of equations (equations 5.6.1 and 5.6.2) by firstly estimating the parameters of the equations, and then taking the derivative of the return with respect to the characteristic in question. The problem is to estimate and interpret the parameters correctly; matters which are much disputed in the literature.

Since the model is specified in a reduce form, it is necessary to, a priori, specify sufficient structure so that the model being examined has a closed form solution (Rosen 1974, Epple 1987). Rosen (1974) argues that a non-linear form of the model (for example using log-log transformations) may be more appropriate. However Bartik (1987) has argued that because budget constraints are non-linear the problem is rather one of the endogeneity of both the prices of the characteristics and their quantity; an instrumental variables solution would therefore be appropriate.

These difficulties have not prevented a very large number of hedonic pricing models
from being estimated. Section 3.3.6 contains a survey of empirical studies and the extensive use of such models in public policy analysis is well documented in Boardman et al. (1996).

5.6.2 The Fama and French pricing models

Section 3.4.5 discussed the approach to the evaluation of the return to equities taken by Fama & French (1992, 1996, 2004). Equations 3.4.6 expresses the form of this relationship and is reproduced below:

\[ r_{ij} = \alpha_i + \beta_i M R_{Mt} + \beta_{iSMB} SM B_t + \beta_{iHML} H ML_t + e_u \]  

(5.6.3)

Each of the beta’s estimate the sensitivity of return to the characteristic in question. Thus, for example \( \beta_{SMB} \) is the premium that the market pays based on the size of the firm.

The purpose of these models is to estimate the value of the equity and the factors that are selected are those that have the strongest statistical relationship to the return on equities. As discussed in Section 3.4.5 there is no theoretical basis for the inclusion of this particular set of independent variables.

5.6.3 Application of the current model to value intangible assets

The hedonic model developed in this study is constructed specifically to be used to value intangible assets directly from the parameters of the reduced form of the model. Thus, unlike the Fama & French models, the selection of the firm characteristics are based on the theoretical model of how such assets are expected to affect the performance of the firm.
The model that is estimated is given by Equation 4.3.14, which is reproduced below for ease of reference:

\[ R_i = \beta_1 C_{1i} + \cdots + \beta_K C_{Ki} + u_i \]  

(5.6.4)

The characteristics, \( C_1 \cdots C_K \), are determined by an \textit{a priori} specification of the effect of intangible assets on firm performance. The allocation of equities to portfolios based only on the magnitude of the characteristic of interest results in each portfolio being highly heterogeneous except with respect to the single characteristic being investigated. The empirical results, even at the high level of granularity of the performance measures, are encouraging.

The relationship between the Sales to Asset ratio that was discussed in Section 5.5.1, and Figure 5.4 which depicts the relationship is replicated below. This relationship can be used to illustrate how an existing or yet to be acquired intangible asset can be valued.

\textbf{An illustrative example}

Consider a firm that wishes to invest in an intangible asset that would improve the Sales to Asset ratio of the firm. An improvement in this ratio implies that the firm is using the capital assets which are reported in its financial statement more efficiently. An extreme example of such an investment that would result in an intangible assets of this nature might take the form of improved staff training that results in a better customer experience and higher customer retention and referral rates.

If before the investment the firms Sales to Asset ratio placed it in the second quintile \textit{for its industry} in Figure 5.10, and the investment was expected to project the firm into the next quintile, then the firm would expect the return to shareholders to
Figure 5.10: Returns for portfolios based on Sales/Asset ratios

Firms are divided into 5 equally sized portfolios, based on the magnitude of the Sales/Asset ratio.

- **Portfolio 1** contains firms with the lowest Sales/Asset ratio (referred to as ‘very-low’ in the text),
- **Portfolio 2** contains the next lowest (‘low’),
- **Portfolio 3** contains firms that are centred around the mean (‘mean’),
- **Portfolio 4** contains firms with higher ratios (‘high’), and
- **Portfolio 5** those with the highest ratios (‘very-high’).

The mean return for each portfolio (left-hand axis) and the beta (right-hand axis) is shown in the graph. Returns are expressed in percentage points (e.g. 0.1 is equal to 0.1% pa).

The return increases monotonically. The risk of the portfolio (beta) does not explain the differences in the portfolio returns.

Source: Analysis of data by author

This figure was originally depicted as Figure 5.4 and is replicated here for ease of reference.
increase by approximately 0.25% p.a. (the difference between the mean of each of the portfolios, 0.1% p.a. and 0.35% p.a.). Assuming for simplicity that dividends remain unchanged, this implies that the value of the equity would need to increase by 0.25%. The value of the asset would thus equal 0.25% of the (pre-investment) capital value of the firm.

In contrast to an investment in an intangible asset, an investment in a tangible asset would result in an increase in both the numerator and denominator of the Sales to Asset ratio, and would result in a much smaller movement (or no movement) in the ratio. This is because the value of the asset is already in the financial statements of the firm, whereas the only evidence of the intangible asset is in the increased performance of the firm.

The acquisition of intangible assets which alter the other characteristics of the firm would be calculated in an analogous manner.

Although this method of valuation has not been suggested before in the literature, it is simply a variation on the other methods of valuation; which is to find a method of comparison between the asset of unknown value and assets with known values. In the present case the method of comparison is the effect of that asset on the productivity of the firm. The productivity of the firm is priced in the equity market and is used in the same manner that risk (as measured in CAPM) is used to price equities.

5.7 Conclusion

This chapter described the data that was used to test the null hypotheses that were developed in the previous chapter.

Corporate financial data for American firms for the years 2000 to 2006 was analysed,
and for each of the characteristics derived from the DuPont ratios (Income/Sales, Sales/Asset, and Asset/Equity ratios) five portfolios were formed. The return of each of these five portfolios was then examined to determine the possible effect of intangible assets on the returns of firms that possess such assets.

The results indicate that there seems to be a strong relationship between the Sales/Asset ratio (suitably adjusted for industry differences) and the realized return of the firm. This effect can be attributed to intangible assets that allow the firm to achieve greater efficiency in the use of its physical capital (for example: brand names, core competences, etc.)

The relationship between (adjusted) Income/Sales ratios and returns is less powerful when five portfolios are considered, but appears to hold if firms are split into only two portfolios. This relationship is also suggestive of the existence of intangible assets that are employed by the firm. The Asset/Equity ratio does not appear to be as influential in the problem at hand. The method by which these relationships can be used to value individual intangible assets was demonstrated.

The following chapter draws inferences based on the empirical results that have been discussed in this chapter.
Chapter 6

Conclusion

6.1 Introduction

The purpose of this thesis is to investigate if:

1. the value of intangible assets, embedded within firms whose equity is traded on stock markets, can be extracted from the market price of such firms via an hedonic pricing model, and

2. the values obtained from the hedonic pricing model can be used to value specific intangible assets of firms.

This is the first study to adopt this novel approach to the problem of valuing intangible assets.

In order to value intangible assets it is necessary to be able to define the nature and characteristics of assets of this type. Economics, accountancy, finance, and management theories emphasize different aspects of intangible assets. Each of these different approaches were discussed and a comprehensive description of intangible assets that are owned by firms was formulated. This is an important aspect of the thesis since the objective is to formulate a methodology to value intangible assets in
the generic sense, rather than to value only one particular type of intangible asset.

The magnitude of intangible assets in the modern economy was documented. Intangible assets were shown to be important in both the social capital of a society and as a component of most firms' capital structure. Studies have estimated that over one-third of the capital of American firms are intangible assets. In addition, the share of intangible assets in total corporate assets has grown rapidly over the last two decades.

Modern economic theory, as represented by the neoclassical school of economics, has generally failed to distinguish intangible assets from other forms of assets. Some important exceptions (notably the Austrian School and the American Institutionalists) have directly addressed the issue of intangible assets, but are often on the sidelines of contemporary mainstream economic theory.

Management theory has however recognized the importance of intangible assets. The resulting literature revealed that solutions to managerial concerns are however mostly ad hoc and specific to time and place. Never-the-less this literature has greatly increased our understanding of intangible assets.

Neoclassical economic theory was shown to form the basis for the valuation of all assets, including intangible assets. Financial assets are valued by comparing the asset to be valued with other similar assets for which a market value is already known. The use of ‘relative valuation’ models, discounted cash flow models, and contingent claims models are all based on this principal. Each of these valuation models was discussed in relation to intangible assets and the difficulty of applying each model in the context of intangible assets was examined. The nature of intangible assets are such that they render the use of the conventional neoclassic valuation model difficult.
A novel and exploratory method for comparing assets was then introduced; it was proposed that hedonic pricing models would be a more efficient technique for valuing intangible assets.

The hedonic pricing model is a generalization of the neoclassic model. It however has the advantage that the very characteristics of intangible assets that make the neoclassical model difficult to use for valuing these assets, are well suited to the hedonic approach.

In order to strengthen the case for using an hedonic pricing model for valuing intangible assets, the hedonic model was shown to be a super-set of the currently accepted valuation methods. Both the Capital Asset Pricing Model (CAPM) and the multi-factor models were shown to be consistent with, and are deducible from, the hedonic pricing model.

In the attempt to apply an hedonic pricing model to intangible assets an additional problem was encountered; the characteristics of intangible assets are not directly observable. It was suggested that the relevant characteristics can be estimated by the increase in the financial performance of the firm that employs such assets. A change in the firm’s performance is, in theory, both objective and quantifiable; which are both necessary if an hedonic model is to be used.

The quantification of the characteristics of intangible assets (the changes in the firm’s financial performance) introduced additional difficulties. In order to analyse the financial performance of firms the XBRL specification delivers great promise but there is, as yet, insufficient data available. The use of DuPont ratios was suggested as an interim method for measuring the characteristics of firm performance that are related to the presence of intangible assets.

In order to test this approach empirically a structural form of the hedonic model was
then proposed and a set of null hypotheses that can be used to test the efficacy of the model were developed. Corporate financial data for American firms for the years 2000 to 2006 was analysed. Each of the characteristics derived from the DuPont ratios (Income/Sales, Sales/Asset, and Asset/Equity ratios) were examined by splitting the entire set of equities into five equally sized portfolios based on the rank of the characteristic of interest. The return of each of these five portfolios was then examined to determine the possible effect of the characteristic on the returns of firms that possess such assets.

6.2 Findings

6.2.1 Empirical results

Three possible characteristics that are related to the presence of intangible assets were identified. In order to test if the equity market places any value on these characteristics the following hypotheses were tested:

1. \( H_0^1 \): The characteristic of the firm measured by the ratio of Net Sales to Total Assets (i.e. the asset turnover) is not a determinant of the return of the firm’s equity.

    The results indicate that there seems to be a strong and monotonic relationship between the Sales/Asset ratio (suitably adjusted for industry differences) and the realized return of the firm.

2. \( H_0^2 \): The characteristic of the firm measured by the ratio of Net Income to Net Sales (i.e. the net profit margin) is not a determinant of the return of the firm’s equity.

    The relationship between (adjusted) Income/Sales ratios and returns is less
powerful when five portfolios are considered, but appears to hold if firms are split into only two portfolios.

3. $H^3_0$. The characteristic of the firm measured by the ratio of Total Assets to Equity (i.e. the financial leverage of the firm) does not provide a clear relationship between return on equity and financial leverage.

There does not appear to be a usable relationship between the Asset/Equity ratio, the return on equity and the use of intangible assets (Section 5.5.3.2 discusses the reasoning behind this statement).

Given a relationship between a characteristic (such as the adjusted Sales/Asset ratio) it is possible to derive the ‘shadow price’ of this characteristic. The shadow price reflects the increase in return that the equity market pays for an additional unit of the characteristic.

### 6.2.2 Valuation of intangible assets

If the effect of an intangible asset on the financial performance of a firm can be estimated, and the shadow prices of the relevant characteristics are available, then the value of the intangible asset can be readily estimated. The estimation of the financial performance effects of intangible assets are likely to be far less onerous than estimating net cash flows and risks of such assets, although in a world of complete information both methods would yield the same valuation. This is because both methods of valuation derive from the same core theory; expected cash flows and risk are simply another set of characteristics.
6.3 Contribution to theory, practice and policy

The research conducted in this thesis has implications for both the theory and practice of asset valuation.

6.3.1 Implications for theory

The Law of One Price is a fundamental principle on which much of the theory of finance is built. All methods of financial valuation rely upon this condition. Each method of valuation compares the asset to be valued to a similar asset (or combination of assets) which has been priced in an efficient market. The most appropriate method for the valuation of a particular asset depends on the information available at the time of the valuation and the characteristics of the asset itself.

The characteristics of intangible assets owned by firms are such that the current set of valuation techniques are often not appropriate:

*Market valuations* require an active market in homogeneous assets.

*Relative valuation models* require an active market in assets which are largely similar and differ in only a few dimensions.

*Discounted cash flow models* require estimates of cash flows and risks, which are often very unclear for intangible assets.

*Contingent valuation models* require estimates of volatility and other characteristics which are often difficult to estimate even for physical assets.

This thesis has proposed an additional method of valuation that is more suited to the characteristics of intangible assets, but which is based on the same foundations of existing valuation techniques. All of the current valuation techniques are restricted forms of hedonic pricing models. The model that is proposed in this thesis is similarly
an hedonic pricing model, but with the difference that the characteristics are not directly observable. The implication of this formulation of model is that the shadow prices of the characteristics must be discovered before the model can be used to estimate the value of the asset.

In order to estimate the shadow prices of the characteristics, an approach that was previously used to value equities (Fama & French 1992, 1996, 2004) was employed. Equities are firstly ranked by the magnitude of the characteristic for which a shadow price is sought and then grouped into equally sized portfolios so that each portfolio is well diversified. This constitutes a novel use of this well known technique.

### 6.3.2 Implications for policy and practice

**Corporate finance**

Corporate finance aims to use the firms limited capital in the most efficient manner. There are a number of sub-tasks that require intangible assets to be valued:

*Capital allocation to projects.* The various projects that a firm can undertake are ranked, and capital is allocated to projects on the basis of their ability to increase the value of the firm as a whole. If any of the available projects involve the acquisition or creation of intangible assets then the capital allocation decision depends partly on the correct valuation of those assets.

*Mergers and acquisitions.* The purchase or sale of firms or divisions that contain substantial intangible assets require those assets to be correctly valued for optimal decisions to be made.

*Capital structure.* The capital structure of the firm and the subsequent weighted average cost of capital depend partly on the the ability of the firm to convince
lenders of the value of the firm’s assets; these assets can then be used as collateral for the loan. If intangible assets are an important percentage of the firm’s assets, the ability to demonstrate that they are fairly valued will affect the terms under which loans will be supplied to the firm.

In general, the ability to measure the value of a capital asset is important for efficient operation (profitability) and risk management of a firm. Intangible assets are no different to other capital assets in this regard.

**Investment analysis**

Firms which have their equity listed on a securities exchange have a vested interest in the price at which such equity trades. The price of the equity partly determines the average cost of capital for the firm and, as such, provides a hurdle rate for new investments that the firm wishes to undertake in the future.

The equity price will be affected by the quality of the information that is available to investment analysts. The valuation of intangible assets is often left to the assessment of equity analysts, who have far less information than internal management of the firm. An objective methodology and public disclosure of the model used to value intangible assets will be valuable to both parties, and can form the basis for resolving any disagreement over the value of important intangible assets.

**Financial reporting**

Equity holders have a right to up-to-date and accurate information of the past performance and future prospects of the firm. The value of intangible assets that the firm possess can be an important component of this information. An objective method of valuing the intangible assets would further shareholders interests.
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At times governmental agencies need to be able to assess economic phenomena in order to formulate policy. Competition policy and the stability of financial markets both fall under remits of this kind. Knowledge of the value of intangible assets will be useful to these agencies.

6.4 Limitations, future improvements and implications for future research

This study has examined intangible assets in the widest possible context. This approach has aided in the understanding of how such assets may be valued, and is especially useful where an asset is unique or very dissimilar to other intangible assets. Where there are groups of similar intangible assets it is reasonable to apply an hedonic model to the characteristics of the asset itself rather than to the characteristics of the firm that utilizes these assets. This approach has been successfully used in a limited number of cases (for example: Dehning & Stratopoulos (2002)) and with the increasing availability of data there will be many other opportunities. The conflict between having a greater number of observations (by casting the net over more assets) against the difficulty of finding methods of grouping disparate assets will however always remain. Both approaches are valid, and the optimal approach will differ with the circumstances of each case.

This study is exploratory in nature, since the hedonic pricing model has not previously been applied to valuing intangible assets. Consequently there are areas which can be expanded in future research.

Data quality and scope. The use of CRSP (CRSP n.d.) data will allow for access to quarterly financial statements, whereas in this study only annual statements are used. In addition this data source is used for many other studies in the
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characteristics of equities; using the same data will make the comparisons of results of earlier studies straightforward.

**Extend characteristics beyond DuPont ratios.** The Extensible Business Reporting Language (XBRL) has been developed in order to provide a mechanism that ensures that important information about how accounting quantities were derived is not lost in the reporting process. As mentioned in Section 4.3.3.2, there is not as yet sufficient data available in this format to undertake meaningful research into the characteristics of intangible assets, never the less, this promises to be a fruitful area for future research.

**Investigation of other markets.** All the data used to validate the proposed model is from financial markets in the United States. These markets were selected because they are the largest and most liquid of all equity markets. Unfortunately at the time of writing there was insufficient data available to undertake a study of Australian firms. It is hope that this situation will be remedied in the near future. Research using data from other markets would improve confidence in the use of the model.

**The effect of reporting intangible assets in financial statements.** As accounting practice changes it is likely that more firms will begin to report intangible assets on their balance sheets. The extent to which the equity market values such assets in comparison to tangible assets will become an interesting question once sufficient data becomes available i.e. does the book-to-price of firms with large reported intangibles differ from firms with more modest holdings of intangible assets?

**The relationship between intangible assets and capital structure.** It is probable that firms which employ mainly intangible assets will have different capital structures (less debt) than other firms. The extend to which this occurs and
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the effect on the measurement of firm productivity might be a profitable area of study.
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Appendices
Appendix A

Code Scripts

This appendix contains the code used to download and analyse the data.

The code scripts have been prepared to make the statistical procedures used in the study as clear as possible, and are thus not optimized for efficiency in machine utilisation.
A.1 Load Firm Data into R

# A01: Load Data from Damodaran’s website into R

# Preparation of data in Excel
# ----------------------------
# This script prepares the data from Damodaran’s website for processing in R.
# Separate files exist for each year of data.
# Naming convention for data: USyyFirms, where yy refers to the year.
# NOTE: Some of the variable names have been changed in Excel to prevent errors when translated into R code (especially "&"’s)
# All formatting has been removed from cells
# SIC code 6730 has different descriptors in the Excel spreadsheet, corrected by hand.
# In some cases the required data is not explicitly given in the spreadsheet. Where necessary the following variables are computed in the Excel spreadsheet before it is imported into R:
# BVofDebt = BookDebt.CapitalRatio *(InvestedCapital + Cash)
# BVofEquity = InvestedCapital + Cash - BVofDebt
# Sales = (EV.Sales)^-1 * EnterpriseValue
# Equity = InvestedCapital + Cash - BVofDebt
# Income = EBIT(1-t) as other froms of income are only reported spasmodically
# These calculations conform to the manner in which Damodaran defines the variables in the spreadsheets that he provides.
#
# Source of data: http://pages.stern.nyu.edu/~adamodar/
#
# Firm Data for 2005:
# ******************
# Import the Excel spreadsheet
# (which has been saved as a csv file):
US05Firms <- read.csv("Acompfirm05.csv",header=TRUE)
# Remove observation where there are no SIC codes
US05Firms <- US05Firms[!is.na(US05Firms$SIC),]
# Remove the financial sector
US05Firms <- US05Firms[!(which(US05Firms$SIC) >= 6000]
Appendix A. Code Scripts

& US05Firms$SIC <=6999) ),

# Remove ADR's and others
US05Firms <- US05Firms[-(which(US05Firms$SIC > 8800) ),
# These firms which do not report "sales"
US05Firms <- US05Firms[!is.na(US05Firms$Sales),
# Remove firms with reported SALES of less than $1 mill
US05Firms <- US05Firms[-(which(US05Firms$Sales <= 1) ),
# Remove firms with TOTAL ASSETS = NA
US05Firms <- US05Firms[!is.na(US05Firms$Assets),
# Remove firms with TOTAL ASSETS of less than $1 mill
US05Firms <- US05Firms[-(which(US05Firms$Assets <= 1) ),
# Remove firms with BOOK VALUE OF EQUITY < $1 million
US05Firms <- US05Firms[!is.na(US05Firms$Equity),
US05Firms <- US05Firms[-(which(US05Firms$Equity <= 1) ),

#*******************************************
# 2004 Repeat as for 2005
US04Firms <- read.csv("Acompfirm04.csv",header=TRUE)
US04Firms <- US04Firms[!is.na(US04Firms$SIC),
US04Firms <- US04Firms[-(which(US04Firms$SIC >= 6000
 & US04Firms$SIC <=6999) ),
US04Firms <- US04Firms[-(which(US04Firms$SIC > 8800) ),
US04Firms <- US04Firms[!is.na(US04Firms$Sales),
US04Firms <- US04Firms[-(which(US04Firms$Sales <= 1) ),
US04Firms <- US04Firms[!is.na(US04Firms$Assets),
US04Firms <- US04Firms[-(which(US04Firms$Assets <= 1) ),
US04Firms <- US04Firms[!is.na(US04Firms$Equity),
US04Firms <- US04Firms[-(which(US04Firms$Equity <= 1) ),

# 2003 Repeat as for 2005
US03Firms <- read.csv("Acompfirm03.csv",header=TRUE)
US03Firms <- US03Firms[!is.na(US03Firms$SIC),
US03Firms <- US03Firms[-(which(US03Firms$SIC >= 6000
 & US03Firms$SIC <=6999) ),
US03Firms <- US03Firms[-(which(US03Firms$SIC > 8800) ),
US03Firms <- US03Firms[!is.na(US03Firms$Sales),
US03Firms <- US03Firms[-(which(US03Firms$Sales <= 1) ),
US03Firms <- US03Firms[!is.na(US03Firms$Assets),
US03Firms <- US03Firms[-(which(US03Firms$Assets <= 1) ),
US03Firms <- US03Firms[!is.na(US03Firms$Equity),
US03Firms <- US03Firms[-(which(US03Firms$Equity <= 1) ),

# 2002 Repeat as for 2005
US02Firms <- read.csv("Acompfirm02.csv",header=TRUE)
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US02Firms <- US02Firms[!is.na(US02Firms$SIC),]
US02Firms <- US02Firms[-(which(US02Firms$SIC >= 6000 & US02Firms$SIC <= 6999)),]
US02Firms <- US02Firms[-(which(US02Firms$SIC > 8800)),]
US02Firms <- US02Firms[!is.na(US02Firms$Sales),]
US02Firms <- US02Firms[-(which(US02Firms$Sales <= 1)),]
US02Firms <- US02Firms[!is.na(US02Firms$Assets),]
US02Firms <- US02Firms[-(which(US02Firms$Assets <= 1)),]
US02Firms <- US02Firms[!is.na(US02Firms$Equity),]
US02Firms <- US02Firms[-(which(US02Firms$Equity <= 1)),]

# 2001 Repeat as for 2005
US01Firms <- read.csv("Acompfirm01.csv",header=TRUE)
US01Firms <- US01Firms[!is.na(US01Firms$SIC),]
US01Firms <- US01Firms[-(which(US01Firms$SIC >= 6000 & US01Firms$SIC <= 6999)),]
US01Firms <- US01Firms[-(which(US01Firms$SIC > 8800)),]
US01Firms <- US01Firms[!is.na(US01Firms$Sales),]
US01Firms <- US01Firms[-(which(US01Firms$Sales <= 1)),]
US01Firms <- US01Firms[!is.na(US01Firms$Assets),]
US01Firms <- US01Firms[-(which(US01Firms$Assets <= 1)),]
US01Firms <- US01Firms[!is.na(US01Firms$Equity),]
US01Firms <- US01Firms[-(which(US01Firms$Equity <= 1)),]

# 2000 Repeat as for 2005
US00Firms <- read.csv("Acompfirm00.csv",header=TRUE)
US00Firms <- US00Firms[!is.na(US00Firms$SIC),]
US00Firms <- US00Firms[-(which(US00Firms$SIC >= 6000 & US00Firms$SIC <= 6999)),]
US00Firms <- US00Firms[-(which(US00Firms$SIC > 8800)),]
US00Firms <- US00Firms[!is.na(US00Firms$Sales),]
US00Firms <- US00Firms[-(which(US00Firms$Sales <= 1)),]
US00Firms <- US00Firms[!is.na(US00Firms$Assets),]
US00Firms <- US00Firms[-(which(US00Firms$Assets <= 1)),]
US00Firms <- US00Firms[!is.na(US00Firms$Equity),]
US00Firms <- US00Firms[-(which(US00Firms$Equity <= 1)),]

#ends

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A.2 Construct data frame to hold the firm data

#############################################################
# A02: Construct dataframe to hold the firm data             #
# #
# Year <- 2005
names(Year) <- c("Year")
A05 <- data.frame(c(US05Firms["TickerSymbol"], Year,
                    US05Firms["SIC",
                    "BetaValueLine", "Income", "Sales", "Assets", "Equity",
                    "Dividends", "Firm", "IndustryName")])
Firms <- A05
Firms[(1:10),]
NamesDF <- names(Firms)           # Collect the names for the columns

Year <- 2004
names(Year) <- c("Year")
A04 <- data.frame(c(US04Firms["TickerSymbol"], Year,
                    US04Firms["SIC",
                    "BetaValueLine", "Income", "Sales", "Assets", "Equity",
                    "Dividends", "Firm", "Industry")])
names(A04) <- NamesDF
str(A04)
Firms <- rbind(Firms, A04)

Year <- 2003
names(Year) <- c("Year")
A03 <- data.frame(c(US03Firms["TickerSymbol"], Year,
                    US03Firms["SIC",
                    "BetaValueLine", "Income", "Sales", "Assets", "Equity",
                    "Dividends", "Firm", "IndustryName")])
names(A03) <- NamesDF
str(A03)
Firms <- rbind(Firms, A03)

# Exchange and Country variables are not available for y=2002
# to y=2000
Year <- 2002
names(Year) <- c("Year")
Exchange <- "NA"
Country <- "NA"
A02 <- as.data.frame(c(US02Firms["TickerSymbol"], Year,
US02Firms["SIC"],
  Exchange, Country, US02Firms[c( "MarketCap", "PBVRatio",
  "BetaValueLine", "Income", "Sales", "Assets", "Equity",
  "Dividends", "Firm", "IndustryName")]))
names(A02) <- NamesDF
str(A02)
Firms <- rbind(Firms, A02)

# Note: Value Line beta is not available for y=2001 & 2000
# replaced by the 3 year regression beta
Year <- 2001
names(Year) <- c("Year")
Exchange <- "NA"
Country <- "NA"
A01 <- as.data.frame(c(US01Firms["TickerSymbol"], Year,
US01Firms["SIC"],
  Exchange, Country, US01Firms[c( "MarketCap", "PBVRatio",
  "X.Beta3yearRegression", "Income", "Sales", "Assets",
  "Equity", "Dividends", "Firm", "IndustryName")]))
names(A01) <- NamesDF
str(A01)
Firms <- rbind(Firms, A01)

Year <- 2000
names(Year) <- c("Year")
Exchange <- "NA"
Country <- "NA"
A00 <- as.data.frame(c(US00Firms["TickerSymbol"], Year,
US00Firms["SIC"],
  Exchange, Country, US00Firms[c( "MarketCap", "PBVRatio",
  "X.Beta3yearRegression", "Income", "Sales", "Assets",
  "Equity", "Dividends", "Firm", "IndustryName")]))
names(A00) <- NamesDF
str(A00)
Firms <- rbind(Firms, A00)
str(Firms)

# Convert "Year" and "SIC" to factors:
# -----------------------------------
Firms$Year <- as.factor(Firms$Year)
Firms$SIC <- as.factor(Firms$SIC)
str(Firms)

# Save the file:
Appendix A. Code Scripts

# --------------
save(Firms, file="Firms1.Rdata")
#
# Clean up:  
# ---------
rm(A05, A04, A03, A02, A01, A00)
rm(Country, Exchange, Year, NamesDF)
rm(US05Firms, US04Firms, US03Firms, US02Firms, US01Firms, US00Firms)
ls()
# ends
A.3 Remove older firms that have the same Ticker as current firms

# A03: Remove older firms that have the same Ticker as current firms

# Removed the following firms (by Hand!):
# ---------------------------------------
# Sears Roebuck S 2004 - 2001
Firms <- Firms[-(which(as.character(Firms$TickerSymbol)=='S' &
    as.numeric(as.character(Firms$Year)==2004))),]
Firms <- Firms[-(which(as.character(Firms$TickerSymbol)=='S' &
    as.numeric(as.character(Firms$Year)==2003))),]
Firms <- Firms[-(which(as.character(Firms$TickerSymbol)=='S' &
    as.numeric(as.character(Firms$Year)==2002))),]
Firms <- Firms[-(which(as.character(Firms$TickerSymbol)=='S' &
    as.numeric(as.character(Firms$Year)==2001))),]
# Crosswalk.com Inc AMEN 2001
Firms <- Firms[-(which(as.character(Firms$TickerSymbol)=='AMEN' &
    as.numeric(as.character(Firms$Year)==2001))),]
# Biosepra Inc BSMD 2001
Firms <- Firms[-(which(as.character(Firms$TickerSymbol)=='BSMD' &
    as.numeric(as.character(Firms$Year)==2001))),]
# Medical Advisory Systems Inc DOC 2001
Firms <- Firms[-(which(as.character(Firms$TickerSymbol)=='DOC' &
    as.numeric(as.character(Firms$Year)==2001))),]
# ElPaso Corp. EPG 2001 - 2000
Firms <- Firms[-(which(as.character(Firms$TickerSymbol)=='EPG' &
    as.numeric(as.character(Firms$Year)==2001))),]
Firms <- Firms[-(which(as.character(Firms$TickerSymbol)=='EPG' &
    as.numeric(as.character(Firms$Year)==2000))),]
# Polymer Group PGI 2001 - 2000
Firms <- Firms[-(which(as.character(Firms$TickerSymbol)=='PGI' &
    as.numeric(as.character(Firms$Year)==2001))),]
Firms <- Firms[-(which(as.character(Firms$TickerSymbol)=='PGI' &
    as.numeric(as.character(Firms$Year)==2000))),]
# Prize Energy Group PRZ 2001

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Firms <- Firms[-(which(as.character(Firms$TickerSymbol) == "PRZ" & as.numeric(as.character(Firms$Year) == 2001))),]

# Sulzer Medica Ltd SM 2001
Firms <- Firms[-(which(as.character(Firms$TickerSymbol) == "SM" & as.numeric(as.character(Firms$Year) == 2001))),]

# Willamette Ind. WLL 2001 - 2000
Firms <- Firms[-(which(as.character(Firms$TickerSymbol) == "WLL" & as.numeric(as.character(Firms$Year) == 2001))),]
Firms <- Firms[-(which(as.character(Firms$TickerSymbol) == "WLL" & as.numeric(as.character(Firms$Year) == 2000))),]

# Alpine Group AGI 2000 - 2001
Firms <- Firms[-(which(as.character(Firms$TickerSymbol) == "AGI" & as.numeric(as.character(Firms$Year) == 2001))),]
Firms <- Firms[-(which(as.character(Firms$TickerSymbol) == "AGI" & as.numeric(as.character(Firms$Year) == 2000))),]

# Apache Medical Sys Inc AMSI 2000
Firms <- Firms[-(which(as.character(Firms$TickerSymbol) == "AMSI" & as.numeric(as.character(Firms$Year) == 2000))),]

# Armbro Enterprises Inc ARE.TO 2000
Firms <- Firms[-(which(as.character(Firms$TickerSymbol) == "ARE.TO" & as.numeric(as.character(Firms$Year) == 2000))),]

# Brindley Weston BDY 2000
Firms <- Firms[-(which(as.character(Firms$TickerSymbol) == "BDY" & as.numeric(as.character(Firms$Year) == 2000))),]

# Waterlink Inc. WLK 2000
Firms <- Firms[-(which(as.character(Firms$TickerSymbol) == "WLK" & as.numeric(as.character(Firms$Year) == 2000))),]

# NOTE:
# Where there was a name change, but the ticker was not changed
# no adjustments are necessary.
# ends
Appendix A. Code Scripts

A.4 Download share prices from Yahoo and calculate returns

# A04: Download share prices from Yahoo and calculate returns#
# Initialize the list of firms for which data is available:
# ----------------------------------------------
# Select only firms that are traded on the NYS, NDQ or AMS
DownloadFirms <- Firms[Firms$Exchange=="AMS" |
                     Firms$Exchange=="NDQ" |
                     Firms$Exchange=="NYS" ,]
DownloadList <- unique(sort(as.character(DownloadFirms$TickerSymbol)))
length(DownloadList)
rm(DownloadFirms)
# NOTE: "Exchange" is only available for firms from 2003 onwards
# Firms in 2000-2002 which DO NOT appear in later years have been
# dropped from the final data set

# Yahoo - Download daily prices for each equity:
# ----------------------------------------------
library(tseries)
# Initialize the "prices" dataframe
prices <- get.hist.quote("^dji", start = "1999-01-01", compress = "d", quote = "AdjClose")
# Use exception handling to overcome missing items on Yahoo
# Firstly define the function get.prices
get.prices <- function(v)
{
  p<-(get.hist.quote(v, start="1999-01-01", compress="d", quote="AdjClose"))
  return(p)
}
# Set up the download list to be max. 1000 names
# (This is to break the download into manageable chunks)
DownloadList <- TickerList[(1:1000),"TickerSymbol"]

# Next loop though all the firms in the list, "try" will
# trap exceptions and move to the next firm in the list if
# there is an exception condition
for (firm in DownloadList)
{

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```r
p <- try(get.prices(firm))
if ( !inherits( p, "try-error" ) ){
    colnames(p) <- firm
    prices <- merge(prices, p, all = TRUE)
}

# Store the interim list of prices in a MySQL database:
# -----------------------------------------------------
# "prices" is a dataframe of type "zoo" and needs to be
# transformed before it is stored in the SQL database
# Extract the data from the zoo object:
Date <- index(prices)
# Extract the data from the zoo object:
y <- coredata(prices)
# Combine into a dataframe:
z <- as.data.frame(cbind(Date,y))

# Write to db:
# -----------
library(DBI)
library(RMySQL)
m <- dbDriver("MySQL")
con <- dbConnect(m, username="root", password="",
                 dbname="equities", host="")
dbListTables(con)  # List tables in the database
names(dbGetInfo(con))  # DBIConnection info
dbWriteTable(con, "prices1", z)
#Writes the dataframe to the db

# Repeat, updating the download list, until all equity prices
# are captured
# -----------------------------------------------------------
# prices1, prices2, prices3, prices4, prices5

# Compute the MONTHLY return for each stock:
# ------------------------------------------
library(tseries)
# Read the prices from the db:
prices1 <- dbReadTable(con, "prices1")
prices2 <- dbReadTable(con, "prices2")
prices3 <- dbReadTable(con, "prices3")
prices4 <- dbReadTable(con, "prices4")
prices5 <- dbReadTable(con, "prices5")
# Transform back into objects of type "zoo"
```

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index.date <- as.Date(prices1[[1]])
p1 <- zoo(prices1[-1], index.date)

index.date <- as.Date(prices2[[1]])
p2 <- zoo(prices2[-1], index.date)

index.date <- as.Date(prices3[[1]])
p3 <- zoo(prices3[-1], index.date)

index.date <- as.Date(prices4[[1]])
p4 <- zoo(prices4[-1], index.date)

index.date <- as.Date(prices5[[1]])
p5 <- zoo(prices5[-1], index.date)

pdaily <- merge(p1, p2, p3, p4, p5)

# Define a function that converts from prices to returns
prices2returns <- function(x) 100 * diff(log(x))

# Replace NA's with the previous value, except where the
# NA is at the start of the series ie. if the share did
# not trade on any day then its price for that day is the
# price on the previous occasion that it traded
pdaily.locf <- na.locf(pdaily, na.rm=FALSE)

# Convert from daily to monthly returns
# (the daily prices are contained in the zoo object "pdaily")
returns.monthly <- prices2returns(aggregate(pdaily.locf,
as.yearmon, tail, 1))

# Store the results in the db:
# ----------------------------
# extract the data from the zoo object
Date <- index(returns.monthly)
# extract the data from the zoo object
y <- coredata(returns.monthly)
# transpose the column and rows and convert to a df
z <- as.data.frame(t(y))
# replace the column names with Date
colnames(z) <- Date
# Write to db:
dbWriteTable(con, "returns", z)

# Clean up:
Appendix A. Code Scripts

# ---------
rm(prices1, prices2, prices3, prices4, prices5)
rm(p1, p2, p3, p4, p5)
rm(pdaily.locf, pdaily, index.date)
#ends
A.5 Calculate the SIC averages

# A05: Calculate the SIC averages

# Add columns to the Firms dataframe to hold the SIC means:
SICMeanIncome <- as.numeric(rep(NA, length(Firms$TickerSymbol)))
SICMeanSales <- as.numeric(rep(NA, length(Firms$TickerSymbol)))
SICMeanAssets <- as.numeric(rep(NA, length(Firms$TickerSymbol)))
SICMeanEquity <- as.numeric(rep(NA, length(Firms$TickerSymbol)))
Firms <- cbind(Firms, SICMeanIncome, SICMeanSales, SICMeanAssets, SICMeanEquity)
str(Firms)

# Calculate the means for each year
# ---------------------------------
Y05 <- Firms[which((as.numeric(as.character(Firms$Year)))==2005),]
Y05 <- Y05[order(Y05$SIC),]
attach(Y05)
SICIncome <- by(Income, SIC, mean)
SICSales <- by(Sales, SIC, mean)
SICAssets <- by(Assets, SIC, mean)
SICEquity <- by(Equity, SIC, mean)
detach(Y05)
for (i in 1:length(Firms$TickerSymbol))
{
  if((as.numeric(as.character(Firms[i,"Year"])))==2005)
  {
    Firms[i,"SICMeanIncome"] <- as.numeric(SICIncome[Firms[i, "SIC"]])
    Firms[i,"SICMeanSales"] <- as.numeric(SICSales[Firms[i, "SIC"]])
    Firms[i,"SICMeanAssets"] <- as.numeric(SICAssets[Firms[i, "SIC"]])
    Firms[i,"SICMeanEquity"] <- as.numeric(SICEquity[Firms[i, "SIC"]])
  }
}

Y04 <- Firms[which((as.numeric(as.character(Firms$Year)))==2004),]
Y04 <- Y04[order(Y04$SIC),]
attach(Y04)
SICIncome <- by(Income, SIC, mean)
SICSales <- by(Sales, SIC, mean)
SICAssets <- by(Assets, SIC, mean)
SICEquity <- by(Equity, SIC, mean)
detach(Y04)
for (i in 1:length(Firms$TickerSymbol))
Appendix A. Code Scripts

```r
{  
if((as.numeric(as.character(Firms[i,"Year"])))==2004)  
{  
Firms[i,"SICMeanIncome"] <- as.numeric(SICIncome[Firms[i, "SIC"]])  
Firms[i,"SICMeanSales"] <- as.numeric(SICSales[Firms[i, "SIC"]])  
Firms[i,"SICMeanAssets"] <- as.numeric(SICAssets[Firms[i, "SIC"]])  
Firms[i,"SICMeanEquity"] <- as.numeric(SICEquity[Firms[i, "SIC"]])  
}  
}

Y03 <- Firms[which((as.numeric(as.character(Firms$Year)))==2003),]
Y03 <- Y03[order(Y03$SIC),]
attach(Y03)
SICIncome <- by(Income, SIC, mean)
SICSales <- by(Sales, SIC, mean)
SICAssets <- by(Assets, SIC, mean)
SICEquity <- by(Equity, SIC, mean)
detach(Y03)
for (i in 1:length(Firms$TickerSymbol))  
{  
if((as.numeric(as.character(Firms[i,"Year"])))==2003)  
{  
Firms[i,"SICMeanIncome"] <- as.numeric(SICIncome[Firms[i, "SIC"]])  
Firms[i,"SICMeanSales"] <- as.numeric(SICSales[Firms[i, "SIC"]])  
Firms[i,"SICMeanAssets"] <- as.numeric(SICAssets[Firms[i, "SIC"]])  
Firms[i,"SICMeanEquity"] <- as.numeric(SICEquity[Firms[i, "SIC"]])  
}  
}

Y02 <- Firms[which((as.numeric(as.character(Firms$Year)))==2002),]
Y02 <- Y02[order(Y02$SIC),]
attach(Y02)
SICIncome <- by(Income, SIC, mean)
SICSales <- by(Sales, SIC, mean)
SICAssets <- by(Assets, SIC, mean)
SICEquity <- by(Equity, SIC, mean)
detach(Y02)
for (i in 1:length(Firms$TickerSymbol))  
{  
if((as.numeric(as.character(Firms[i,"Year"])))==2002)  
{  
Firms[i,"SICMeanIncome"] <- as.numeric(SICIncome[Firms[i, "SIC"]])  
Firms[i,"SICMeanSales"] <- as.numeric(SICSales[Firms[i, "SIC"]])  
Firms[i,"SICMeanAssets"] <- as.numeric(SICAssets[Firms[i, "SIC"]])  
Firms[i,"SICMeanEquity"] <- as.numeric(SICEquity[Firms[i, "SIC"]])  
}  
}
```
Appendix A. Code Scripts

Y01 <- Firms[which((as.numeric(as.character(Firms$Year)))==2001),]
Y01 <- Y01[order(Y01$SIC),]
attach(Y01)
SICIncome <- by(Income, SIC, mean)
SICSales <- by(Sales, SIC, mean)
SICAssets <- by(Assets, SIC, mean)
SICEquity <- by(Equity, SIC, mean)
detach(Y01)
for (i in 1:length(Firms$TickerSymbol))
{
  if((as.numeric(as.character(Firms[i,"Year"])))==2001)
  {
    Firms[i,"SICMeanIncome"] <- as.numeric(SICIncome[Firms[i, "SIC"]])
    Firms[i,"SICMeanSales"] <- as.numeric(SICSales[Firms[i, "SIC"]])
    Firms[i,"SICMeanAssets"] <- as.numeric(SICAssets[Firms[i, "SIC"]])
    Firms[i,"SICMeanEquity"] <- as.numeric(SICEquity[Firms[i, "SIC"]])
  }
}

Y00 <- Firms[which((as.numeric(as.character(Firms$Year)))==2000),]
Y00 <- Y00[order(Y00$SIC),]
attach(Y00)
SICIncome <- by(Income, SIC, mean)
SICSales <- by(Sales, SIC, mean)
SICAssets <- by(Assets, SIC, mean)
SICEquity <- by(Equity, SIC, mean)
detach(Y00)
for (i in 1:length(Firms$TickerSymbol))
{
  if((as.numeric(as.character(Firms[i,"Year"])))==2000)
  {
    Firms[i,"SICMeanIncome"] <- as.numeric(SICIncome[Firms[i, "SIC"]])
    Firms[i,"SICMeanSales"] <- as.numeric(SICSales[Firms[i, "SIC"]])
    Firms[i,"SICMeanAssets"] <- as.numeric(SICAssets[Firms[i, "SIC"]])
    Firms[i,"SICMeanEquity"] <- as.numeric(SICEquity[Firms[i, "SIC"]])
  }
}

# Save the file
# ----------------
save(Firms, file="Firms2.Rdata")
# Export to Excel
# ---------------
write.csv(Firms, file = "Firms2.txt")

# Clean up
# --------
rm(i, SICAssets, SICEquity, SICIncome, SICSales)
rm(SICMeanAssets, SICMeanEquity, SICMeanIncome, SICMeanSales)
rm(Y00, Y01, Y02, Y03, Y04, Y05)
# ends
Appendix A. Code Scripts

A.6 Calculate the characteristics for the Portfolio

#############################################################
# A06: Calculate the characteristics for the Portfolio       #
#############################################################
#
# Calculate the Investment/Sales ratio (ISD = the difference #
of the firm ratio to that of the Industry)
#  ISfirm <- Firms[,"Income"]/Firms[,"Sales"]
#  ISindustry <- Firms[,"SICMeanIncome"]/Firms[,"SICMeanSales"]
#  ISD <- ISfirm - ISindustry
#  Firms <- cbind(Firms, ISfirm, ISindustry, ISD)
#  rm(ISfirm, ISindustry, ISD)

# Sales / Asset ratio (SAD = the difference of the firm ratio #
to that of the Industry)
#  SAfirm <- Firms[,"Sales"]/Firms[,"Assets"]
#  SAindustry <- Firms[,"SICMeanSales"]/Firms[,"SICMeanAssets"]
#  SAD <- SAfirm - SAindustry
#  Firms <- cbind(Firms, SAfirm, SAindustry, SAD)
#  rm(SAfirm, SAindustry, SAD)

# Assets / Equity ratio (AED = the difference of the firm ratio #
to that of the Industry)
#  AEfirm <- Firms[,"Assets"]/Firms[,"Equity"]
#  AEindustry <- Firms[,"SICMeanAssets"]/Firms[,"SICMeanEquity"]
#  AED <- AEfirm - AEindustry
#  Firms <- cbind(Firms, AEfirm, AEindustry, AED)
#  rm(AEfirm, AEindustry, AED)

# Save the output
save(Firms, file="Firms3.Rdata")
write.csv(Firms, file = "Firms3.txt")
#ends
A.7 Divide the firms into 5 equally sized portfolios

# A07: Divide the firms into 5 equally sized portfolios, for each of the characteristics

# Define a function that will divide the series into 5 sections of equal length
section <- function(x) cut(x, quantile(x, (0:5)/5), include.lowest=TRUE)

# Create portfolios for each portfolio characteristic
# 1 = lowest, 5 = highest presence of that factor
ISportfolio <- section(Firms\$ISD)
SAportfolio <- section(Firms\$SAD)
AEportfolio <- section(Firms\$AED)
# These are ordered factors
Firms <- cbind(Firms, ISportfolio, SAportfolio, AEportfolio)

save(Firms, file="Firms4.Rdata")
write.csv(Firms, file = "Firms4.txt")
# Clean up:
# ---------
rm(ISportfolio, SAportfolio, AEportfolio, section)
# ends
Appendix A. Code Scripts

**A.8 Merge the returns into each portfolio**

```r
# A08: Merge the returns into each portfolio
#
# Connect to the MySQL database:
library(DBI)
library(RMySQL)
m <- dbDriver("MySQL")
con <- dbConnect(m, username="root", password="",
    dbname="equities", host="")
dbListTables(con)
names(dbGetInfo(con))

# Fetch the Returns dataframe from the database:
returns <- dbReadTable(con, "returns")
# Add the row.names as a column to the dataframe
# (i.e. the ticker symbols)
TickerSymbol <- row.names(returns)
returns <- cbind(TickerSymbol, returns)

# Split the "returns" into YEARS before merging into dataframe
# Each year starts in May and ends in April of following year
R00 <- returns[,c(1, 18:29)]
R01 <- returns[,c(1, 30:41)]
R02 <- returns[,c(1, 42:53)]
R03 <- returns[,c(1, 54:65)]
R04 <- returns[,c(1, 66:77)]
R05 <- returns[,c(1, 78:89)]

# Merge the return into the ANNUAL portfolios
# PRnn = Portfolio of all shares for year = 19nn
PR00 <- merge(Firms[which(as.numeric(as.character(Firms$Year))) ==2000],, R00)
PR01 <- merge(Firms[which(as.numeric(as.character(Firms$Year))) ==2001],, R01)
PR02 <- merge(Firms[which(as.numeric(as.character(Firms$Year))) ==2002],, R02)
PR03 <- merge(Firms[which(as.numeric(as.character(Firms$Year))) ==2003],, R03)
PR04 <- merge(Firms[which(as.numeric(as.character(Firms$Year))) ==2004],, R04)
PR05 <- merge(Firms[which(as.numeric(as.character(Firms$Year))) ==2005],, R05)

# Extract the data for analysis
```
# treat each month as a separate record - iterate through the annual portfolios and extract the return for each month
Character <- c(1:5)
names(Character) <- c("Return", "Beta", "ISratio", "SAratio", "AEratio")

# Year = 2000:
for(i in 32:43)
{
  C0 <- PR00[, c("BetaValueLine", "ISportfolio", "SAportfolio", "AEportfolio")]
  C0 <- cbind(PR00[i], C0) # 1=May, etc.
  names(C0) <- c("Return", "Beta", "ISratio", "SAratio", "AEratio")
  Character <- rbind(Character, C0)
}

# Year = 2001:
for(i in 32:43)
{
  C1 <- PR01[, c("BetaValueLine", "ISportfolio", "SAportfolio", "AEportfolio")]
  C1 <- cbind(PR01[i], C1) # 1=May, etc.
  names(C1) <- c("Return", "Beta", "ISratio", "SAratio", "AEratio")
  Character <- rbind(Character, C1)
}

# Year = 2002:
for(i in 32:43)
{
  C2 <- PR02[, c("BetaValueLine", "ISportfolio", "SAportfolio", "AEportfolio")]
  C2 <- cbind(PR02[i], C2) # 1=May, etc.
  names(C2) <- c("Return", "Beta", "ISratio", "SAratio", "AEratio")
  Character <- rbind(Character, C2)
}

# Year = 2003:
for(i in 32:43)
{
  C3 <- PR03[, c("BetaValueLine", "ISportfolio", "SAportfolio", "AEportfolio")]
  C3 <- cbind(PR03[i], C3) # 1=May, etc.
  names(C3) <- c("Return", "Beta", "ISratio", "SAratio", "AEratio")
  Character <- rbind(Character, C3)
}  
# Year = 2004:
for(i in 32:43)
{
  C4 <- PR04[, c("BetaValueLine","ISportfolio", "SAportfolio",
                "AEportfolio")]
  C4 <- cbind(PR04[i], C4)  # 1=May, etc.
  names(C4) <- c("Return", "Beta", "ISratio", "SAratio",
                "AEratio")
  Character <- rbind(Character, C4)
}
# Year = 2005:
for(i in 32:43)
{
  C5 <- PR05[, c("BetaValueLine","ISportfolio", "SAportfolio",
                "AEportfolio")]
  C5 <- cbind(PR05[i], C5)  # 1=May, etc.
  names(C5) <- c("Return", "Beta", "ISratio", "SAratio",
                "AEratio")
  Character <- rbind(Character, C5)
}

save(Character, file="Character.Rdata")
write.csv(Character, file = "Character.txt")
# Clean up
# ----------
rm(C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12)
rmdir("PR00", "PR01", "PR02", "PR03", "PR04", "PR05")
rmdir("R00", "R01", "R02", "R03", "R04", "R05")
# ends
A.9 Divide the firms into 5 equally sized portfolios

# A09: Divide the firms into 5 equally sized portfolios, for each of the characteristics
# Define a function that will divide the series into 5 sections of equal length
section <- function(x) cut(x, quantile(x, (0:5)/5), include.lowest = TRUE)
# Create portfolios for each portfolio characteristic
# 1 = lowest, 5 = highest presence of that factor
ISportfolio <- section(Firms$ISD)
SAportfolio <- section(Firms$SAD)
AEportfolio <- section(Firms$AED)
# These are ordered factors
Firms <- cbind(Firms, ISportfolio, SAportfolio, AEportfolio)
save(Firms, file="Firms4.Rdata")
write.csv(Firms, file = "Firms4.txt")
# Clean up:
# -------
rm(ISportfolio, SAportfolio, AEportfolio, section)
# ends
A.10 Calculate the monthly return for each portfolio

```r
# Establish connections with the db:
library(DBI)
library(RMySQL)
m <- dbDriver("MySQL")
con <- dbConnect(m, username="root", password="",
dbname="equities", host="")
dbListTables(con)
names(dbGetInfo(con))

# Fetch the Returns dataframe from the db:
returns <- dbReadTable(con, "returns")

# Add the row.names as a column to the df -
# these are the ticker symbols
TickerSymbol <- row.names(returns)
returns <- cbind(TickerSymbol, returns)

# Split the "returns" into YEARS before merging into dataframe
# Each year starts in May and ends in April of following year
R00 <- returns[,c(1, 18:29)]
R01 <- returns[,c(1, 30:41)]
R02 <- returns[,c(1, 42:53)]
R03 <- returns[,c(1, 54:65)]
R04 <- returns[,c(1, 66:77)]
R05 <- returns[,c(1, 78:89)]

# Merge the return into the ANNUAL portfolios
# PRnn = Portfolio of all shares for year = 19nn
PR00 <- merge(Firms[which((as.numeric(as.character(Firms$Year)))
==2000),], R00)
PR01 <- merge(Firms[which((as.numeric(as.character(Firms$Year)))
==2001),], R01)
PR02 <- merge(Firms[which((as.numeric(as.character(Firms$Year)))
==2002),], R02)
PR03 <- merge(Firms[which((as.numeric(as.character(Firms$Year)))
==2003),], R03)
PR04 <- merge(Firms[which((as.numeric(as.character(Firms$Year)))
==2004),], R04)
PR05 <- merge(Firms[which((as.numeric(as.character(Firms$Year)))
==2005),], R05)

# Extract the data for analysis
# C = characteristics
# Treat each month as a separate record - iterate through the
# annual portfolios and extract the return for each month
```
# Initialize the dataframe to hold the results:
Character <- c(1:5)
names(Character) <- c("Return", "Beta", "ISratio", 
     "SAratio", "AEratio")

# Year = 2000:
for(i in 32:43)
{
    C0 <- PR00[, c("BetaValueLine", "ISportfolio", "SAportfolio", 
    "AEportfolio")]
    C0 <- cbind(PR00[i], C0) # 1=May, etc.
    names(C0) <- c("Return", "Beta", "ISratio", "SAratio", "AEratio")
    Character <- rbind(Character, C0)
}

# Year = 2001:
for(i in 32:43)
{
    C1 <- PR01[, c("BetaValueLine", "ISportfolio", "SAportfolio", 
    "AEportfolio")]
    C1 <- cbind(PR01[i], C1) # 1=May, etc.
    names(C1) <- c("Return", "Beta", "ISratio", "SAratio", "AEratio")
    Character <- rbind(Character, C1)
}

# Year = 2002:
for(i in 32:43)
{
    C2 <- PR02[, c("BetaValueLine", "ISportfolio", "SAportfolio", 
    "AEportfolio")]
    C2 <- cbind(PR02[i], C2) # 1=May, etc.
    names(C2) <- c("Return", "Beta", "ISratio", "SAratio", "AEratio")
    Character <- rbind(Character, C2)
}

# Year = 2003:
for(i in 32:43)
{
    C3 <- PR03[, c("BetaValueLine", "ISportfolio", "SAportfolio", 
    "AEportfolio")]
    C3 <- cbind(PR03[i], C3) # 1=May, etc.
    names(C3) <- c("Return", "Beta", "ISratio", "SAratio", "AEratio")
    Character <- rbind(Character, C3)
}

# Year = 2004:
for(i in 32:43)
{
    C4 <- PR04[, c("BetaValueLine", "ISportfolio", "SAportfolio", 
    "AEportfolio")]
}
Appendix A. Code Scripts

C4 <- cbind(PR04[i], C4) # 1=May, etc.
names(C4) <- c("Return", "Beta", "ISratio", "SAratio", "AEratio")
Character <- rbind(Character, C4)
}
# Year = 2005:
for(i in 32:43)
{
  C5 <- PR05[, c("BetaValueLine","ISportfolio", "SAportfolio",
               "AEportfolio")]
  C5 <- cbind(PR05[i], C5) # 1=May, etc.
  names(C5) <- c("Return", "Beta", "ISratio", "SAratio", "AEratio")
  Character <- rbind(Character, C5)
}
#Save the working files:
save(Character, file="Character.Rdata")
write.csv(Character, file = "Character.txt")
# Clean up
# -------
rm(C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12)
rm(PR00, PR01, PR02, PR03, PR04, PR05)
rm(R00, R01, R02, R03, R04, R05)
#ends.
A.11 Descriptive statistics - portfolios

# A11: Descriptive statistics - portfolios
#................................................................................
C <- Character
# Remove the observation if the return = NA (Shares are
# not yet traded in the month being observed)
C <- C[!is.na(C$Return),]
# Remove the observation if the monthly return is > 1000%
# or less than 1000, to excluded cases were there are
# discrete jumps REMOVES 2 OBSERVATIONS ONLY
C <- C[-(which(C$Return > 1000))]
C <- C[-(which(C$Return < -1000))]
summary(C)
str(C)

# Place the characteristics in order
levels(C$ISratio) <- c("very_low", "low", "mean", "high",
"very_high")
levels(C$SAratio) <- c("very_low", "low", "mean", "high",
"very_high")
levels(C$AEratio) <- c("very_low", "low", "mean", "high",
"very_high")
str(C)

library(lattice)
# Compare return of each portfolio (over entire sample period)
g1 <- by(C[,"Return"], C$ISratio, mean, trim=0.0, na.rm=TRUE)
g2 <- by(C[,"BetaValue"], C$ISratio, mean, trim=0.0, na.rm=TRUE)
op <- par(mar = c(5, 4, 4, 4) + 0.3) # Leave space for z axis
plot(g1, ylim=c(-1.0, 1.3), type="b", lwd="2", col="red",
xlab="Portfolios based on Income/Sales ratio",
ylab="Returns")
par(new = TRUE)
plot(g2, type="p", pch=5, lwd="2", axes = FALSE, bty = "n",
xlab = "", ylab = "")
axis(4, at = pretty(range(g2)))
legend(x="topright", bty="o",
lty=1, pch=5,
col=c("red", "black"),
legend=c("return", "beta"))
par(op)
Appendix A. Code Scripts

```r
# Appendix A. Code Scripts

# Code for Sales/Assets ratio (SAratio)
g1 <- by(C[, "Return"], C$SAratio, mean, trim=0.0, na.rm=TRUE)
g2 <- by(C[, "BetaValue"], C$SAratio, mean, trim=0.0, na.rm=TRUE)
op <- par(mar = c(5, 4, 4, 4) + 0.3)  # Leave space for z axis
plot(g1, ylim=c(-0.5, 0.9), type="b", lwd="2", col="red",
     xlab="Portfolios based on Sales/Assets ratio",
ylab="Returns")
par(new = TRUE)
plot(g2, type="p", pch=5, lwd="2", axes = FALSE, bty = "n",
     xlab = "", ylab = "")
axis(4, at = pretty(range(g2)))
legend(x="topright", bty="o",
       lty=1, pch=5,
       col=c("red", "black"),
       legend=c("return", "beta"))
par(op)

# Code for Assets/Equity ratio (AEratio)
g1 <- by(C[, "Return"], C$AEratio, mean, trim=0.0, na.rm=TRUE)
g2 <- by(C[, "BetaValue"], C$AEratio, mean, trim=0.0, na.rm=TRUE)
op <- par(mar = c(5, 4, 4, 4) + 0.3)  # Leave space for z axis
plot(g1, ylim=c(-0.7, 1.3), type="b", lwd="2", col="red",
     xlab="Portfolios based on Assets/Equity ratio",
ylab="Returns")
par(new = TRUE)
plot(g2, type="p", pch=5, lwd="2", axes = FALSE, bty = "n",
     xlab = "", ylab = "")
axis(4, at = pretty(range(g2)))
legend(x="topright", bty="o",
       lty=1, pch=5,
       col=c("red", "black"),
       legend=c("return", "beta"))
par(op)

# AoV
library(xtable)
IS.aov <- aov(Return ~ ISratio, data=C)
summary(IS.aov)
print(xtable(IS.aov))

SA.aov <- aov(Return ~ SAratio, data=C)
summary(SA.aov)
print(xtable(SA.aov))

AE.aov <- aov(Return ~ AEratio, data=C)
summary(AE.aov)
print(xtable(AE.aov))
```

---

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# Testing for Normality:
# Visual of the distribution each factor
# by IS (mean monthly return for each portfolio):
library(lawstat)
g1 <- by(C[,1], list(C$ISratio, C$Month), mean, trim=0.0,
na.rm=TRUE)
k0 <- density(g1[1,])
k1 <- density(g1[2,])
k2 <- density(g1[3,])
k3 <- density(g1[4,])
k4 <- density(g1[5,])
xrange <- range(k0$x)
plot(k0$x, k0$y, xlim=xrange, ylim=c(0, 0.09), type="l", lwd="2",
col="purple",
  xlab="Returns for portfolios based on Income/Sales ratios"
  , ylab="Density")
grid()
lines(k1$x, k1$y,lwd="2", col="red")
lines(k2$x, k2$y, lwd="2", col="green")
lines(k3$x, k3$y, lwd="2", col="blue")
lines(k4$x, k4$y, lwd="2", col="yellow")
legend(x="topright", bty="o",
  lty=1, pch=5,
  col=c("purple", "red", "green", "blue", "yellow"),
  legend=c("very low", "low", "mean", "high", "very high"))

# x = rnorm(1000)
# rjb.test(x)
rjb.test(g1[1,])
rjb.test(g1[2,])
rjb.test(g1[3,])
rjb.test(g1[4,])
rjb.test(g1[5,])

# To make a panel of pictures.
op <- par(mfrow=c(3,2)) # 3 rows, 2 columns.
qqnorm(g1[1,], sub="Portfolio of very-low ratios"); qqline(g1[1,])
qqnorm(g1[2,], sub="Portfolio of low ratios"); qqline(g1[2,])
qqnorm(g1[3,], sub="Portfolio of mean ratios"); qqline(g1[3,])
qqnorm(g1[4,], sub="Portfolio of high ratios"); qqline(g1[4,])
qqnorm(g1[5,], sub="Portfolio of very-high ratios"); qqline(g1[5,])
par(op) # restore graphical parameters

# by SA:
g1 <- by(C[,1], list(C$SAratio, C$Month), mean, trim=0.0,
Appendix A. Code Scripts

na.rm=TRUE)
k0 <- density(g1[1,])
k1 <- density(g1[2,])
k2 <- density(g1[3,])
k3 <- density(g1[4,])
k4 <- density(g1[5,])

xrange <- range(k0$x)
plot(k0$x, k0$y, xlim=xrange, ylim=c(0, 0.09), type="l", lwd="2",
     col="purple",
     xlab="Returns for portfolios based on Sales/Asset ratios",
     ylab="Density")
grid()
lines(k1$x, k1$y,lwd="2", col="red")
lines(k2$x, k2$y, lwd="2", col="green")
lines(k3$x, k3$y, lwd="2", col="blue")
lines(k4$x, k4$y, lwd="2", col="yellow")
legend(x="topright", bty="o",
       lty=1, pch=5,
       col=c("purple", "red", "green", "blue", "yellow"),
       legend=c("very low", "low", "mean", "high", "very high"))
rjb.test(g1[1,])
rjb.test(g1[2,])
rjb.test(g1[3,])
rjb.test(g1[4,])
rjb.test(g1[5,])

# To make a panel of pictures.
op <- par(mfrow=c(3,2)) # 3 rows, 2 columns.
qqnorm(g1[1,], sub="Portfolio of very-low ratios"); qqline(g1[1,])
qqnorm(g1[2,], sub="Portfolio of low ratios"); qqline(g1[2,])
qqnorm(g1[3,], sub="Portfolio of mean ratios"); qqline(g1[3,])
qqnorm(g1[4,], sub="Portfolio of high ratios"); qqline(g1[4,])
qqnorm(g1[5,], sub="Portfolio of very-high ratios"); qqline(g1[5,])
par(op) # restore graphical parameters

# AE:
g1 <- by(C[,1], list(C$AEratio, C$Month), mean, trim=0.0,
na.rm=TRUE)
k0 <- density(g1[1,])
k1 <- density(g1[2,])
k2 <- density(g1[3,])
k3 <- density(g1[4,])
k4 <- density(g1[5,])

xrange <- range(k0$x)
Appendix A. Code Scripts

```r
plot(k0$x, k0$y, xlim=xrange, ylim=c(0, 0.09), type="l", lwd="2", 
     col="purple",
     xlab="Returns for portfolios based on Asset/Equity ratios",
     ylab="Density")
grid()
lines(k1$x, k1$y,lwd="2", col="red")
lines(k2$x, k2$y, lwd="2", col="green")
lines(k3$x, k3$y, lwd="2", col="blue")
lines(k4$x, k4$y, lwd="2", col="yellow")
legend(x="topright", bty="o",
     lty=1, pch=5,
     col=c("purple", "red", "green", "blue", "yellow"),
     legend=c("very low", "low", "mean", "high", "very high"))

rjb.test(g1[1,])
rjb.test(g1[2,])
rjb.test(g1[3,])
rjb.test(g1[4,])
rjb.test(g1[5,])

# To make a panel of pictures.
op <- par(mfrow=c(3,2)) # 3 rows, 2 columns.
qqnorm(g1[1,], sub="Portfolio of very-low ratios"); qqline(g1[1,])
qqnorm(g1[2,], sub="Portfolio of low ratios"); qqline(g1[2,])
qqnorm(g1[3,], sub="Portfolio of mean ratios"); qqline(g1[3,])
qqnorm(g1[4,], sub="Portfolio of high ratios"); qqline(g1[4,])
qqnorm(g1[5,], sub="Portfolio of very-high ratios"); qqline(g1[5,])
par(op) # restore graphical parameters

# Kruskal-Wallis:
IS.Kruskal <- kruskal.test(Return ~ ISratio, data=C)
IS.Kruskal

SA.Kruskal <- kruskal.test(Return ~ SAratio, data=C)
SA.Kruskal

AE.Kruskal <- kruskal.test(Return ~ AEratio, data=C)
AE.Kruskal

# Using lm
IS.lm <- lm(Return ~ factor(ISratio), data=C)
summary(IS.lm)
print(xtable(IS.lm))

SA.lm <- lm(Return ~ factor(SAratio), data=C)
summary(SA.lm)
print(xtable(SA.lm))
```
Appendix A. Code Scripts

```R
AE.lm <- lm(Return ~ factor(AEratio), data=C)
summary(AE.lm)
print(xtable(AE.lm))

# Tukey's "honest significant difference test"
library(stats)
op <- par(mar = c(5, 10, 4, 4) + 0.3)
IS.Tukey <- TukeyHSD(IS.aov, ordered = TRUE)
IS.Tukey
plot(IS.Tukey, las=2)

SA.Tukey <- TukeyHSD(SA.aov, ordered = TRUE)
SA.Tukey
plot(SA.Tukey, las=2)

AE.Tukey <- TukeyHSD(AE.aov, ordered = TRUE)
AE.Tukey
plot(AE.Tukey, las=2)
par(op)
```
Appendix B

Supporting statistics, tables and figures

This appendix contains statistical analysis, table and figures that support the arguments in the main body of text.
## B.1 Distribution of firm size

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Table B.1: **Distribution of firm size - log(Market Cap)**

*The distribution of firms by size. Size is measured by the log of market capitalisation.*

*The pattern is similar for each year for which data is available.*

Source: Analysis of data by author
### B.2 Number of firms by SIC code and year

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Continued on next page
Table B.2: Number of firms by SIC code

The number of firms in each 4-digit SIC code, for each year.

Source: Analysis of data by author.

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### B.3 SIC code description

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Table B.3 – continued from previous page

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Table B.3 – continued from previous page

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Table B.3: **SIC code description**

*Description of the sector that each SIC code represents.*

Source: US Securities and Exchange Commission

www.sec.gov/info/edgar/siccodes.htm
Appendix B. Supporting statistics, tables and figures

### B.4 Distribution of equity returns, by month

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Table B.4: Distribution of equity returns, by month

The distribution of returns for each month of the study.

There is considerable variation in the monthly returns to equity.

Source: Analysis of data by author.

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### B.5 Outliers - Income/Sales ratios, smallest values

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Table B.5: **Extreme observations for Income/Sales ratios**

The Income/Sales ratio of each firm is subtracted from the relevant SIC mean. The 20 smallest values are listed in this table.

Source: Analysis of data by author
### B.6 Outliers - Income/Sales ratios, largest values

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Table B.6: Extreme observations for Income/Sales ratios

The Income/Sales ratio of each firm is subtracted from the relevant SIC mean. The 20 largest values are listed in this table.

Source: Analysis of data by author
# B.7 Outliers - Sales/Asset ratios, smallest values

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<td>Abrams Ind</td>
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Table B.7: Extreme observations for Sales/Asset ratios
The Sales/Asset ratio of each firm is subtracted from the relevant SIC mean. The 20 smallest values are listed in this table.

Source: Analysis of data by author
Table B.8: Extreme observations for Sales/Asset ratios

The Sales/Asset ratio of each firm is subtracted from the relevant SIC mean. The 20 largest values are listed in this table.

Source: Analysis of data by author
### Appendix B. Supporting statistics, tables and figures

#### B.9 Outliers - Asset/Equity ratios, smallest values

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Table B.9: **Extreme observations for Asset/Equity ratios**

The Asset/Equity ratio of each firm is subtracted from the relevant SIC mean. The most extreme left-hand side value are listed in this table.

Source: Analysis of data by author
### B.10 Outliers - Asset/Equity ratios, largest values

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<td>UST Inc.</td>
<td>2005</td>
<td>1659.50</td>
<td>9.60</td>
<td>169.50</td>
</tr>
<tr>
<td>CKEC</td>
<td>Carmike Cinemas Inc</td>
<td>2002</td>
<td>617.80</td>
<td>3.77</td>
<td>162.50</td>
</tr>
<tr>
<td>MXM</td>
<td>MAXXAM Inc.</td>
<td>2000</td>
<td>4393.10</td>
<td>27.80</td>
<td>155.57</td>
</tr>
<tr>
<td>MCLL</td>
<td>Metoicall Inc.</td>
<td>2000</td>
<td>1025.60</td>
<td>6.60</td>
<td>153.48</td>
</tr>
<tr>
<td>AGCCQ</td>
<td>Anchor Glass Container Corp</td>
<td>2005</td>
<td>657.20</td>
<td>4.30</td>
<td>149.25</td>
</tr>
<tr>
<td>ELN</td>
<td>Elan Corp. ADR</td>
<td>2006</td>
<td>2340.90</td>
<td>16.90</td>
<td>136.51</td>
</tr>
<tr>
<td>MYG</td>
<td>Maytag Corp.</td>
<td>2002</td>
<td>3156.20</td>
<td>23.57</td>
<td>130.02</td>
</tr>
<tr>
<td>MTNT</td>
<td>Motient Corp.</td>
<td>2001</td>
<td>1571.70</td>
<td>12.90</td>
<td>119.79</td>
</tr>
<tr>
<td>MYG</td>
<td>Maytag Corp.</td>
<td>2001</td>
<td>2688.90</td>
<td>21.70</td>
<td>119.35</td>
</tr>
<tr>
<td>JQH</td>
<td>Hammons John Q Hotels Inc</td>
<td>2002</td>
<td>881.70</td>
<td>7.21</td>
<td>119.04</td>
</tr>
</tbody>
</table>

Table B.10: **Extreme observations for Asset/Equity ratios**

*The Asset/Equity ratio of each firm is subtracted from the relevant SIC mean. The most extreme right-hand side value are listed in this table.*

Source: Analysis of data by author
Appendix B. Supporting statistics, tables and figures

B.11 Analysis of variance - Portfolio means based on Sales/Asset ratios

<table>
<thead>
<tr>
<th>Source</th>
<th>Df</th>
<th>Sum Sq</th>
<th>Mean Sq</th>
<th>F value</th>
<th>Pr(&gt;F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAratio</td>
<td>4</td>
<td>26566.72</td>
<td>6641.68</td>
<td>22.48</td>
<td>0.0000</td>
</tr>
<tr>
<td>Residuals</td>
<td>255338</td>
<td>75426603.14</td>
<td>295.40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table B.11: Analysis of variance - Portfolio means based on Sales/Asset ratios

There are five equally sized portfolios, based on the Sales/Asset ratio. The ANOVA procedure measures the probability that the differences in the returns of the portfolios is due only to chance.

Source: Analysis of data by author
B.12 Distribution of returns: Sales/Asset ratios

Figure B.1: Distribution of returns for portfolios based on Sales/Asset ratios

Firms are divided into 5 equally sized portfolios, based on the magnitude of the Sales/Asset ratio. Portfolio 1 contains firms with the lowest Sales/Asset ratio, and Portfolio 5 those with the highest. The distribution of the return for each portfolio is shown in the graph.
Source: Analysis of data by author
## B.13 Tukey multiple comparisons of means - Portfolio means based on Sales/Asset ratios

<table>
<thead>
<tr>
<th>SAratio</th>
<th>diff</th>
<th>lwr</th>
<th>upr</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>low-very low</td>
<td>0.3996832</td>
<td>0.10567498</td>
<td>0.6936914</td>
<td>0.0019494</td>
</tr>
<tr>
<td>mean-very low</td>
<td>0.6510620</td>
<td>0.35952374</td>
<td>0.9426002</td>
<td>0.0000000</td>
</tr>
<tr>
<td>high-very low</td>
<td>0.7647804</td>
<td>0.47070900</td>
<td>1.0588518</td>
<td>0.0000000</td>
</tr>
<tr>
<td>very high-very low</td>
<td>0.9298495</td>
<td>0.63410049</td>
<td>1.2255918</td>
<td>0.0000000</td>
</tr>
<tr>
<td>mean-low</td>
<td>0.2513788</td>
<td>-0.03965176</td>
<td>0.5424094</td>
<td>0.1275664</td>
</tr>
<tr>
<td>high-low</td>
<td>0.3650972</td>
<td>0.07152912</td>
<td>0.6586653</td>
<td>0.0062331</td>
</tr>
<tr>
<td>very high-low</td>
<td>0.5301663</td>
<td>0.23491774</td>
<td>0.8254149</td>
<td>0.000096</td>
</tr>
<tr>
<td>high-mean</td>
<td>0.1137184</td>
<td>-0.17737600</td>
<td>0.4048128</td>
<td>0.8241912</td>
</tr>
<tr>
<td>very high-mean</td>
<td>0.2787875</td>
<td>-0.01400158</td>
<td>0.5715766</td>
<td>0.0708125</td>
</tr>
<tr>
<td>very high-high</td>
<td>0.1650691</td>
<td>-0.13024243</td>
<td>0.4603806</td>
<td>0.5462696</td>
</tr>
</tbody>
</table>

Table B.12: Tukey multiple comparisons of means: Portfolio means based on Sales/Asset ratios; 95% family-wise confidence level, factor levels have been ordered.

There are five equally sized portfolios, based on the Sales/Asset ratio. The Tukey multiple comparison of means test, also called the ‘Tukey honestly significant difference (HSD) test’ (Yandell 1997) allows each pair of means to be tested for statistical difference.

Source: Analysis of data by author.
B.14 Distribution of returns: Income/Sales ratios

Figure B.2: Distribution of returns for portfolios based on Income/Sales ratios

Firms are divided into 5 equally sized portfolios, based on the magnitude of the Income/Sales ratio. Portfolio 1 contains firms with the lowest Income/Sales ratio, and Portfolio 5 those with the highest. The distribution of the return for each portfolio is shown in this graph.

Source: Analysis of data by author
### Tukey multiple comparisons of means - Portfolio means based on Income/Sales ratios

<table>
<thead>
<tr>
<th>ISratio</th>
<th>diff</th>
<th>lwr</th>
<th>upr</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>low-very low</td>
<td>1.410656</td>
<td>1.105542</td>
<td>1.715770</td>
<td>0.000000</td>
</tr>
<tr>
<td>very high-very low</td>
<td>1.426805</td>
<td>1.126172</td>
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</tr>
<tr>
<td>high-very low</td>
<td>1.500243</td>
<td>1.203438</td>
<td>1.797048</td>
<td>0.000000</td>
</tr>
<tr>
<td>mean-very low</td>
<td>1.713903</td>
<td>1.413732</td>
<td>2.014074</td>
<td>0.000000</td>
</tr>
<tr>
<td>very high-low</td>
<td>0.016148</td>
<td>-0.277822</td>
<td>0.310118</td>
<td>0.999887</td>
</tr>
<tr>
<td>high-low</td>
<td>0.089586</td>
<td>-0.200468</td>
<td>0.379641</td>
<td>0.917329</td>
</tr>
<tr>
<td>mean-low</td>
<td>0.303246</td>
<td>0.009748</td>
<td>0.596744</td>
<td>0.038796</td>
</tr>
<tr>
<td>high-very high</td>
<td>0.073438</td>
<td>-0.211899</td>
<td>0.358775</td>
<td>0.956088</td>
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<tr>
<td>mean-very high</td>
<td>0.287098</td>
<td>-0.001739</td>
<td>0.575934</td>
<td>0.052299</td>
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<tr>
<td>mean-high</td>
<td>0.213659</td>
<td>-0.071191</td>
<td>0.498510</td>
<td>0.244052</td>
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</table>

Table B.13: Tukey multiple comparisons of means - Portfolio means based on Income/Sales ratios; 95% family-wise confidence level, factor levels have been ordered.

There are five equally sized portfolios, based on the Income/Sales ratio. The Tukey multiple comparison of means test, also called the ‘Tukey honestly significant difference (HSD) test’ (Yandell 1997) allows each pair of means to be tested for statistical difference.

Source: Analysis of data by author.
Appendix B. Supporting statistics, tables and figures

B.16 Distribution of returns: Assets/Equity ratios

Firms are divided into 5 equally sized portfolios, based on the magnitude of the Assets/Equity ratio. Portfolio 1 contains firms with the lowest Assets/Equity ratio, and Portfolio 5 those with the highest. The distribution of the return for each portfolio is shown in this graph.

Source: Analysis of data by author
B.17 Analysis of variance - Portfolio means based on Asset/Equity ratios

<table>
<thead>
<tr>
<th></th>
<th>Df</th>
<th>Sum Sq</th>
<th>Mean Sq</th>
<th>F value</th>
<th>Pr(&gt;F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE ratio</td>
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<td>18805.24</td>
<td>4701.31</td>
<td>15.91</td>
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<tr>
<td>Residuals</td>
<td>255338</td>
<td>75434364.62</td>
<td>295.43</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table B.14: Analysis of variance - Portfolio means based on Asset/Equity ratios

Analysis of variance - Portfolio means based on Asset/Equity ratios

There are five equally sized portfolios, based on the Asset/Equity ratio. The ANOVA procedure measures the probability that the differences in the returns of the portfolios is due only to chance.

Source: Analysis of data by author
B.18 Kruskal-Wallis rank sum test - Portfolio means based on Asset/Equity ratios

<table>
<thead>
<tr>
<th>Kruskal-Wallis chi-squared</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEratio</td>
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</tr>
</tbody>
</table>

Table B.15: Kruskal-Wallis rank sum test - Portfolio means based on Asset/Equity ratios

There are five equally sized portfolios, based on the Asset/Equity ratio. The Kruskal-Wallis tests the probability that at least one of the portfolios has a return that is statistically different from the rest. This test is non-parametric and does not assume that the underlying distributions are either Normal or homoscedastic.

Source: Analysis of data by author.
B.19 Tukey multiple comparisons of means - Portfolio means based on Assets/Equity ratios

<table>
<thead>
<tr>
<th>AEratio</th>
<th>diff</th>
<th>lwr</th>
<th>upr</th>
<th>p-value</th>
<th></th>
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</thead>
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<tr>
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<tr>
<td>high-low</td>
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<td>0.13938164</td>
<td>0.7169958</td>
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</tr>
<tr>
<td>very low-low</td>
<td>0.6241684</td>
<td>0.33530347</td>
<td>0.9130333</td>
<td>0.0000000</td>
<td></td>
</tr>
<tr>
<td>very high-low</td>
<td>0.7405100</td>
<td>0.44163742</td>
<td>1.0393825</td>
<td>0.0000000</td>
<td></td>
</tr>
<tr>
<td>high-mean</td>
<td>0.2409275</td>
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<td>0.5311842</td>
<td>0.1566213</td>
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<td>very low-mean</td>
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<td>0.14659302</td>
<td>0.7272215</td>
<td>0.0003890</td>
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</tr>
<tr>
<td>very high-mean</td>
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<td>0.8535224</td>
<td>0.0000050</td>
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</tr>
<tr>
<td>very low-high</td>
<td>0.1959797</td>
<td>-0.09500662</td>
<td>0.4869660</td>
<td>0.3520435</td>
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</tr>
<tr>
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<td>0.01139788</td>
<td>0.6132447</td>
<td>0.0374090</td>
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</tr>
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<td>-0.18463736</td>
<td>0.4173205</td>
<td>0.8297554</td>
<td></td>
</tr>
</tbody>
</table>

Table B.16: Tukey multiple comparisons of means - Portfolio means based on Asset/Equity ratios; 95% family-wise confidence level, factor levels have been ordered.

There are five equally sized portfolios, based on the Sales/Asset ratio. The Tukey multiple comparison of means test, also called the ‘Tukey honestly significant difference (HSD) test’ (Yandell 1997) allows each pair of means to be tested for statistical difference.

Source: Analysis of data by author.